THE ROYAL AUSTRALIAN CHEMICAL INSTITUTE

FUTURE OF CHEMISTRY STUDY: Supply and Demand of Chemists

Interim Report

March 2005

Foreword

In many ways the timing for the Future of Chemistry Study could not be more opportune given the discussions about skills shortages, education and industry changes. It seems our community is already talking about many of the broader themes that have emerged through our research and we are well placed to expand these discussions to include chemists. It appears chemistry is at a crossroad, and we are seeking to explore the state of chemistry and its future.

Science literacy is essential to society. Therefore, we must provide through our education system, the means for people to understand the role and impact that science can have in our lives. This means that we must educate potential science high achievers in a way which lets them be among the world leaders as well as provide all students with the knowledge needed for them to comment (that is vote) on matters of the environment, genetic manipulation and stem cells to name a few.

I believe that the teaching of chemistry must meet the needs of society and of industry and that now is the appropriate time to review that match. This is why the 'Future of Chemistry' project is so important to the RACI and to the community. We have reached the stage in this project where we have received comments from bodies representing over 4000 working chemists. We are releasing this Interim Report for comment. It is important we listen to the responses we are receiving and frame future action based on real opportunities rather than traditional views of the way the world should be. I urge you to give considered thought to the Interim Report as you see it. It is a time for change.

Please send your comments to future@raci.org.au by Friday April 29, 2005. Let me know what you think – agree or disagree – and be part of the change!

Greg Simpson
President
The Royal Australian Chemical Institute

Executive Summary

Chemistry underpins many industries within the Australian economy and is seen as vital to the emergence of new industries like biotechnology and nanotechnology- industries that State and Federal Governments alike are keen to see generating wealth within Australia's borders. However, there has been concern raised that Australia may not be able to meet the demand for chemists especially considering the decline in the numbers of chemistry graduates over the last decade.

This Interim Report was undertaken by The Royal Australian Chemical Institute (RACI) to investigate the supply and demand of chemists. The report focuses on secondary schools and the tertiary sector as largely responsible for the supply of high quality chemists; the chemical, pharmaceutical, biotechnology and nanotechnology industry sectors responsible for creating much of the current and future demand for chemists; and an international overview.

The purpose of the Interim Report was to collect information pertaining to the status of chemistry in Australia. Findings from this research include:

- Australia's current investment in Research and Development (R&D) intensity is 1.62% of GDP which needs to increase to keep in line with world trends in R&D intensity by industry. (See Chapter 1)

- The Chemical, Pharmaceutical and Biotechnology industries need continuing access to high quality research and development to ensure viability and growth (see Chapter 5).

- Respondents from both the University (42%) and Employer surveys (62%) believe the status of chemistry in Australia is falling. Comments from both groups suggested that chemistry has a poor public profile. A view that is not exclusive to Australia (see Chapters 4 & 5).

- Data published by the Federal Department of Education, Science and Training over a 15 year period (1989 – 2004) reveals a declining number of students studying chemistry as a proportion of total students from 2.3% to 1.7% (see Chapter 4)

- The RACI Survey of universities provides insights into reasons for the decline in student numbers. It also raises the issue of the difficulties that chemistry departments are facing in providing chemical education services as a result of cuts to Commonwealth and intra university funding. University concerns include; that students see a correlation between the score and the course prestige, falling quality of students entering Bachelor courses particularly in relation to their chemistry knowledge, attracting and retaining students, job prospects, competition from other disciplines like business based courses and the rise of specialist science courses for example 'forensic science'. However, there were also positive findings, such as the fact that universities find their links with industry to be very beneficial, especially in relation to their students and industry. Universities also reported a high proportion of completions amongst PhD students. Section 4 details the findings on the university sector.

- The Employer Survey provides insight into the state of chemistry within 132 organisations around Australia (73.8 % from industry). Just over 40% of respondents planned to increase the number of chemists they employ in the next ten years, mostly at a rate of 10%. A significant proportion of organisations had experienced recruiting problems, with 60% of all respondents having strategies in place to ensure an ongoing supply of chemists for their organisation. Over half of the respondents believed there to be a current shortage of qualified chemists. Issues raised amongst the respondents were concern about student preparedness for work within business environments and the general public's perception of the industry (see Chapter 5).

Further research and analysis will be undertaken in relation to each of the sectors identified and detailed in the Final Report due for release in mid 2005. It is the intention of the RACI to canvas the results of this interim report widely amongst many different stakeholders. Your comments will assist in building a strong a strong and healthy future of chemistry.

Please respond to future@raci.org.au by 29 April 2005 with your comments.

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Acknowledgements

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Finally we wish to thank all of the people that responded to the on-line employer survey and the university survey. We thank them for their time and also for the enthusiasm they showed for contributing to the future of chemistry in this country.

Felicity Jensz
Samantha Carroll
Elizabeth Gibson (Project Director)
Future of Chemistry Project Team

Royal Australian Chemical Institute

The Royal Australian Chemical Institute (RACI) was founded in January 1917, as both the qualifying body in Australia for professional chemists and a learned society promoting the science and practice of chemistry in all its branches. The Institute has almost 8,000 members. More information regarding the RACI can be found on the website www.raci.org.au

Steering Committee Members

Dr Graeme L Blackman (Chairman, Institute of Drug Technology Australia Ltd) PhD, BSc(Hons), FTSE, FRACI, FAICD. Dr Graeme Blackman is the Chairman and Managing Director of Institute of Drug Technology Australia Ltd (IDT). He is a member of the Board and Vice Chairman of the peak pharmaceutical industry body Medicines Australia and has been a director and board member of a number of companies and advisory boards. Dr Blackman is also the Chairman of the Australian Government's Action Agenda for the Pharmaceuticals Industry. He graduated BSc(Hons I) and PhD from Monash University and was a Postdoctoral Fellow at the University of California Berkeley and a member of faculty of Monash University and the Victorian College of Pharmacy, where he held the position of Professor of Pharmaceutical Chemistry from 1982 to 1986.

Professor Allan Canty (University of Tasmania; Chair, National Committee for Chemistry of Australian Academy of Science)
Professor Allan Canty has been Head of the School of Chemistry at the University of Tasmania since 1993. He is a Fellow of the RACI and of the Australian Academy of Science, and is Chair of the Academy's National Committee for Chemistry. His research interests, encompassing inorganic and organometallic chemistry, have been funded continuously by the Australian Research Council since 1980

Ms Deborah Crossing (Executive Director, Australian Science Teachers Association)
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Mr David Edmonds (Peptech Pty Ltd, Past President of RACI)
David is an Applied Chemistry graduate from UNSW and professional analyst by training, and has worked in therapeutic goods manufacture and QA for over 30 years. He has been the Manager, Quality Assurance and Regulatory Affairs at Peptech Limited since 1987. Former positions include Quality Assurance and Production Management variously at Eli Lilly, Crystal Products Pty Ltd (London) and Sterling Pharmaceuticals Pty Ltd. David is the past president of the RACI and was the NSW Branch President from 199 to 2001.

Dr Elizabeth Gibson Elizabeth is the National Coordinator for the Royal Australian Chemical Institute - the professional association for chemists. Previously she worked for Executive Impact (risk management services) after working as the State Manager AGAL VIC - a Commonwealth Government Analytical laboratory. From 1993 she worked in a variety of senior managerial roles at the Environment Protection Authority (State) including Principal Environmental Auditor and Secretary to EPA where she took lead roles in the development of state and national environmental policy. Elizabeth has an MBA and spent six years in post-doctoral industrial research conducted in Australia and in the UK.

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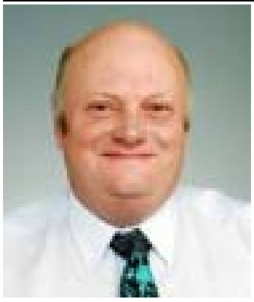

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Professor Tom Spurling, Dean of the Faculty of Engineering and Industrial Sciences at Swinburne University of Technology, was the Chief of CSIRO Molecular Science from 1989 to 1998 and Manager of a World Bank project in Jakarta from 1999 to 2001. The aim of that project was to modernise the planning and management systems of the CSIRO sister organisation, LIPI. His research interests are in computational chemistry applied to drug design and the properties of materials. He is also interested in policy and management issues around the effective interaction of publicly funded research institutes with the private sector.

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Glossary of Abbreviations

ACC	American Chemical Council
AllChemE	Alliance for Chemical Sciences and Technologies in Europe
AAS	Australia Academy of Science
ACSPA	Australian Consumer and Specialty Products Association
AIG	Australian Industry Group
AIRG	Australian Industrial Research Group
ANZSIC	Australian & New Zealand Standard Industrial Classification
APMF	Australian Paint Manufacturers Federation
APPEA	Australian Petroleum Production and Exploration Association Ltd
ASEAN	Association of South East Asian Nations
ASTA	Australian Science Teachers Association
ATSE	Australian Academy of Technological Sciences and Engineering
CRC	Cooperative Research Centre
CommAust	Commonwealth of Australia
CSIRO	Commonwealth Scientific & Industrial Research Organisation
DEST	Department of Education, Science and Training
DIIRD	Department of Innovation, Industry and Regional Development
ELIG	Environmental Laboratories Industry Group
FECS	Federation of European Chemical Societies
GDCh	Gesellschaft Deutscher Chemiker [Society of German Chemists]
MCA	Minerals Council of Australia
OECD	Organisation for Economic Co-operation and Development
PISA	Programme for International Student Assessment
PACIA	Plastics and Chemicals Industry Association
PHODS	Professors and Heads of Departments
RACI	Royal Australian Chemical Institute
RSC	Royal Society of Chemistry
STAWA	Science Teachers' Association of Western Australia
TAFE	Technical And Further Education
VICS	Victorian Institute for Chemical Sciences

Definitions

In this document the following definitions are used:

Accreditation: First-degree tertiary programmes in chemistry/chemistry based discipline that meet the minimum academic qualifications as defined by the RACI for recruitment to the profession of chemists as a member of the RACI

Chemistry department: a department, school or section within a university that teaches chemistry

Enabling Sciences: the science disciplines of Chemistry, Physics and Mathematics

Secondary School: a secondary or high school within the Australian school system

Status: Perceived societal standing of profession

Traditional Chemistry: Including, but not limited, to the following areas of chemistry: Analytical Chemistry, Cereal Chemistry, Celloid and Surface Science, Electrochemistry, Environment, Industrial Chemistry, Inorganic Chemistry, Organic Chemistry, Physical Chemistry, Polymer, Solid State, Engineering , Geochemistry, Regulatory, Policy Development, and Quality Control.

Emerging Chemistry: these are primarily the areas of nanotechnology and biotechnology

Chapter 1: Introduction

The Royal Australian Chemical Institute (RACI) undertook the following study into the *Future of Chemistry* as part of its leadership role for the chemistry profession.

Chemistry supports a broad range of existing industry sectors including pharmaceuticals, automotive, mining, chemicals and plastics, petroleum, energy, food and agriculture. It is also crucial in the development of the new industries of biotechnology and nanotechnology. If Australia wishes to support this vibrant scientific community, then an understanding of the current and future needs of industry is needed, so as to best able to prepare future generations of chemists. The *Future of Chemistry* study aims to deliver this information.

The study investigated the perception by some stakeholders that there was a 'disconnect' between the strengthening demand for quality graduate chemists by employers and a decline in their quality and supply within Australia. The investigation explored the pathway to a graduate chemist by analysing the areas of secondary school teaching, universities and also industry. The project also undertook a desktop scan of chemistry internationally, in order to contextualise the state of chemistry within Australia.

1.1 Purpose of study

This project arose from the 2004 Professors and Heads of Chemistry Departments (PHODS) annual forum, where concern was raised as to the future of chemistry and chemists in Australia. Presentations were made that suggested a decline had occurred in the quality of chemistry being taught at secondary schools and also at tertiary level. Furthermore, it was suggested that there was a decline in the number of chemistry graduates and postgraduates being produced.

In addition to the presentations at the PHODS 2004 meeting, there have been other Australian reports that suggest that the number of graduates and postgraduates will not be sufficient for teaching, research, government and industry needs in the future. The emerging areas of nanotechnology and biotechnology have been tagged as areas where growth is expected (Tegart, 2002), and in which Australia currently lags behind other industrialized nations (Warris, 2004). Although difficult to predict exact numbers needed for these new areas, the Victorian Government, for example, estimates that by 2010 there will be a need for 12,000 more skilled graduates and workers in the area of micro- and nano-enabling sciences, many of whom will need to have a strong grounding in chemistry. The report also identified 'significant graduate shortages …in the nano-enabling specializations' including chemistry (DIIRD, 2003: 12).

Other sources, including the chief scientist of Queensland, Peter Andrews, suggest that if Australia wishes to be competitive in an international market in relation to a knowledge-based economy, then 75,000 more scientists are needed by 2010 (Wood, 2004). One way in which this may be achieved is through increased expenditure on Research and Development from the Business sector. Currently R&D spending in this sector lies well below that of the OECD mean (DEST, 2004).

In light of the information tabled at the PHODS meeting and other similar reports, the review intends to gather information on the state of chemistry in Australia and especially explore the reasoning behind the current view that there is a "disconnect" between the strengthening demand for quality graduate chemists and a decline in numbers and their quality within Australia. It does this through a desktop review of the Australian secondary school sector, collating information from a university survey and analysing data collected from survey of people employing chemists (employer survey) designed by the RACI. Where applicable, international benchmarks are used and discussed.

1.2 Terms of Reference

The project aims to collect information with a broad range of stakeholders in mind, focusing on Australia's ability to produce chemists to meet the needs of current and emerging industries.

The project concentrated on four areas – international trends, secondary education, tertiary education and industry. The major points of research for the four areas were as follows:

For the International Context

- Information pertaining to the status and state of chemistry in an international context;
- Trends in student numbers;
- International best-practice for encouraging students into the area, and
- International linkages through chemistry.

For the Secondary Education Sector

- Supply and qualification of secondary teachers in chemistry;
- Practical environment in which Chemistry is taught;
- Ability of courses to inspire and interest students; and
- Careers advice.

For the Tertiary Education Sector

- Factors influencing numbers and quality of chemistry undergraduates;
- Changes in the number and quality of chemistry graduates and postgraduate chemists;
- Changes in postgraduate education;
- Staff changes, and
- Interaction with Secondary Schools and Industry.

For industry

- Current trends in the chemical industry in Australia;
- A profile of the type of organisations employing chemists;
- Current requirements of employers in the chemical industry in relation to supply;
- Quality and types of qualification for traditional and expanding areas of chemistry, including nanotechnology and biotechnology;
- Strategies undertaken by employers to secure a supply of highly skilled chemists, and
- Determination of future requirements indicating numbers, levels of qualification and identification of issues impacting the industry.

1.3 Methodology

The methodologies for each of the four sectors varied, and are as follows:

1.3.1 Desktop review of the international state of chemistry

A desktop review was undertaken as to the international trends in student numbers in chemistry, predicted future needs of industry and international best practice with relation to encouraging students to study chemistry. There was a specific focus on the Federal Republic of Germany, the United Kingdom and the United States of America, as each of these countries has a large chemical industry and/or strong historical links to their chemical industry. Results of the review are found in Chapter 2.

1.3.2 Desktop review of the state of chemistry within the Australian secondary school environment

A preliminary desktop review was undertaken as to the state of chemistry within the Australian Secondary School environment. Results of the review are found in Chapter 3.

1.3.3 The University Sector

Information for the university sector was obtained through analysis of Department of Education Science and Training (DEST) data as well as a university survey designed by the RACI. The DEST data was analysed to ascertain the overall numbers of students studying chemistry over the last 15 years, and also as the percentage of science students from the whole number of tertiary students.

The University Survey was prepared in collaboration with the Steering Committee members. It comprised of 36 questions in four sections focusing on:

- Undergraduate students;
- Postgraduate students;
- Staff, and
- An overview of the state of Chemistry.

The questionnaire required qualitative and quantitative responses. The survey instrument can be found in Appendix 1. Results of this survey are found in Chapter 4. For the undergraduate student section, which was the first section, the questions asked pertained to:

- Entry scores and their ten-year trend;
- Department capacity;
- Quality of students;
- Interaction with Secondary Schools;
- Industry interaction;
- Chemistry curriculum;
- Course coverage, and
- Issues affecting students.

Section Two, which focused on graduates, contained questions on:

- Department capacity;
- Issues effecting students;
- Course coverage, and
- Amount of Industry interaction.

In Section Three, which pertained to staffing of the chemistry department, question on the following areas were asked:

- Growth of department;
- Capacity of department;
- Number of staff;
- Type of support offered to staff from within the university;
- Interaction between department/school and industry;
- Departmental links to professional associations;
- Timing of Course Reviews;
- Comments on RACI accreditation processes, and
- Departmental staffs' view on industry.

The final section, Section Four, was broader in its reach as it asked for general comments on:

- Chemistry within the Australian context;
- Perceived contemporary value of a Chemistry degree within Australia;
- Marketing activities undertaken by the department to encourage more people to study chemistry;
- The status of Chemistry;
- The state of Chemistry in Australia in general;
- The state of Chemistry in secondary schools;
- The state of Chemistry in universities, and
- The state of Chemistry within Australia

All 32 Australian universities that taught Chemistry were emailed copies of the questionnaire (see Appendix 2). Only seventeen universities responded to the questionnaire.

1.3.4 The Industry Sector

A brief literature review of the state of the Australian chemical industry was conducted as well as number of interviews with people involved in the chemical industry. These results form the first part of Chapter 5.

In order to access the views and concerns of industry an on-line survey for employers of chemists was prepared by the RACI and the Steering Committee. The survey was accessible through a link on the RACI web-site. Results of the survey are discussed in the second section of Chapter 5.The survey was advertised to industry through 12 industry associations, all of which were deemed to have access to large data bases of chemists. The names of these industry contacts appear in Appendix 4. An email advertising the on-line questionnaire was sent to all RACI branches, groups and committees as well as all individual RACI members - all of whom were asked to disseminate the survey and information as widely as possible.

Through the Australian Associated Press a media release was issued to all metropolitan newspapers and to all talk-back radio stations, which directed people to the on-line survey on the RACI web-page. Federal Government was targeted through emailing Australian Government Councils, Committees, Boards, Departments and Agencies. State Governments were targeted by sending emails directly to ministers. An email was sent to the Australian Local Government Association (see Appendix 5 for a list of government organisations contacted).

The questionnaire consisted of 51 questions in three sections:

- Who employs chemists?
- Are our requirements for chemists changing?
- Is there a shortage of chemists, and if so why?

In Section One, respondents were asked to provide background information on their organisation, including:

- the name of the organisation they represented;
- how they received notice of the questionnaire;
- the Australian and New Zealand Standard Industrial Classification (ANZSIC), the classification that best described the organisation's core business;
- the size and classification of the business (Private, Public or Government);
- the position of the respondent within the organisation;
- number of chemists employed within the organisation;
- percentage of total staff that the chemists represented;
- to categorise chemists into thirteen discrete categories and state if the chemists were university or TAFE trained, and
- if the respondent expected the need for the number of chemists to change in the next 10 years, and if so, by what percentage.

The purpose of Section Two was to gauge if the employers' requirements for chemists were changing. The respondent was asked:

- what level of chemistry qualification did new staff within the organisation typically require ten years ago, currently and a predication of ten years time;
- whether the organisation had difficulties in recruiting people with chemistry qualifications in six different categories (from chemistry at secondary school level to chemistry at a PhD level) and if so, what were the nature of these difficulties;
- of twenty discrete areas of chemistry, what one did staff within the organisation require ten years ago, currently and a prediction of these areas for ten years time;
- whether the organisation had experienced difficulties in recruiting people in any of the twenty discrete areas;
- if the organisation preferred to employ non-university trained chemists, recently trained university graduates, chemists with some experience, or very experienced chemists;
- whether the respondent had any suggestion as to how new graduates can gain experience in the field;
- whether the respondent's organisation had any problems in recruiting people in specific geographical locations;
- whether the organisation undertook any strategies to attract and retain chemists, and if so, from 16 strategies presented, what importance the employer placed on them from a scale of 1 to 5, and
- if the organisation undertook strategies to ensure that there will be an ongoing supply of chemists for Australia, and if so, what they were.

Section 3 enquired into the state of chemistry in Australia. The respondents were asked:

- if they believed there was a shortage of chemists, and if so, why;
- what they saw as the prime cause of any shortage,
- if they had any suggestions to help address the causes;

- their perception on the status of chemistry within Australia;
- if they had any comments pertaining to chemistry within secondary schools, universities and/or TAFE, and industry, and
- if they were interested in further collaboration with the RACI.

The survey was on-line from 15 November 2004 until 13 January 2005 and received 136 responses. See Appendix 6 for the survey instrument.

Chapter 2: Chemistry in the international context

The state of chemistry in Australia is affected by global trends and international markets, especially since many chemical industries are multinational entities. The aim of this chapter is to present and compare information on the international state of chemistry in schools, universities and in industry internationally with a focus on different strategies that have been employed by a selection of comparable countries to ensure the health of the discipline.

The chapter focuses on information from the United States, the United Kingdom and Germany as all three countries have a strong tradition of chemistry in universities and industry. Together these countries produce a large proportion of the world's chemicals. The final report will extend the scope to cover Ireland, the Netherlands, India, Japan and Singapore. Ireland and the Netherlands were selected as two countries similar in population size to Australia. India has been chosen as it produces many chemists, Japan has been chosen as representing a large industrial nation in the Asia Pacific region, and Singapore as Australia's largest trading partner in ASEAN. The final report will also provide information on the current state of chemistry in a former Eastern Bloc country, as it has been suggested that there is a strong tradition in chemical training and good chemistry within this geographical area.

Table 1, below, presents an overview of some human capital and economic figures in relation to the chemical industry on an international scale.

Table 1: Comparative data on the chemical industry in Australia, USA, UK and Germany

Country	**Population**	**People employed in the chemical industry**	**Annual turnover of industry**
Australia^	20 million	90,000	$US 22 billion
USA#	290 million	1 million	$US 419 billion
UK+	51 million	400,000	$US 79.5 billion
Germany$	82.4 million	467,000	$US175 billion

^ Information from Upstill, Spurling and Simpson (draft)
# Information from www.chemistryamerica.com
$ Information from www.ahkmena.com/New_Editorial/Details.asp?News=446 (2001 data)
+ Information from www.dti.gov.uk

2.1 OECD activities

The global state of science, as well as chemistry specifically, is a concern that has been flagged by the Organisation for Economic Co-operation and Development (OECD, 2004a). In their Policy Brief for Science and Innovation Policy, the OECD suggests that while there is a downturn in interest in studying science in OECD countries there is also a global demand for scientific advances and technological innovations. They also predict that there will be a long-term demand for tertiary level graduates and science and technology workers in many of the OECD countries, especially since many of the current workers in these fields are retiring.

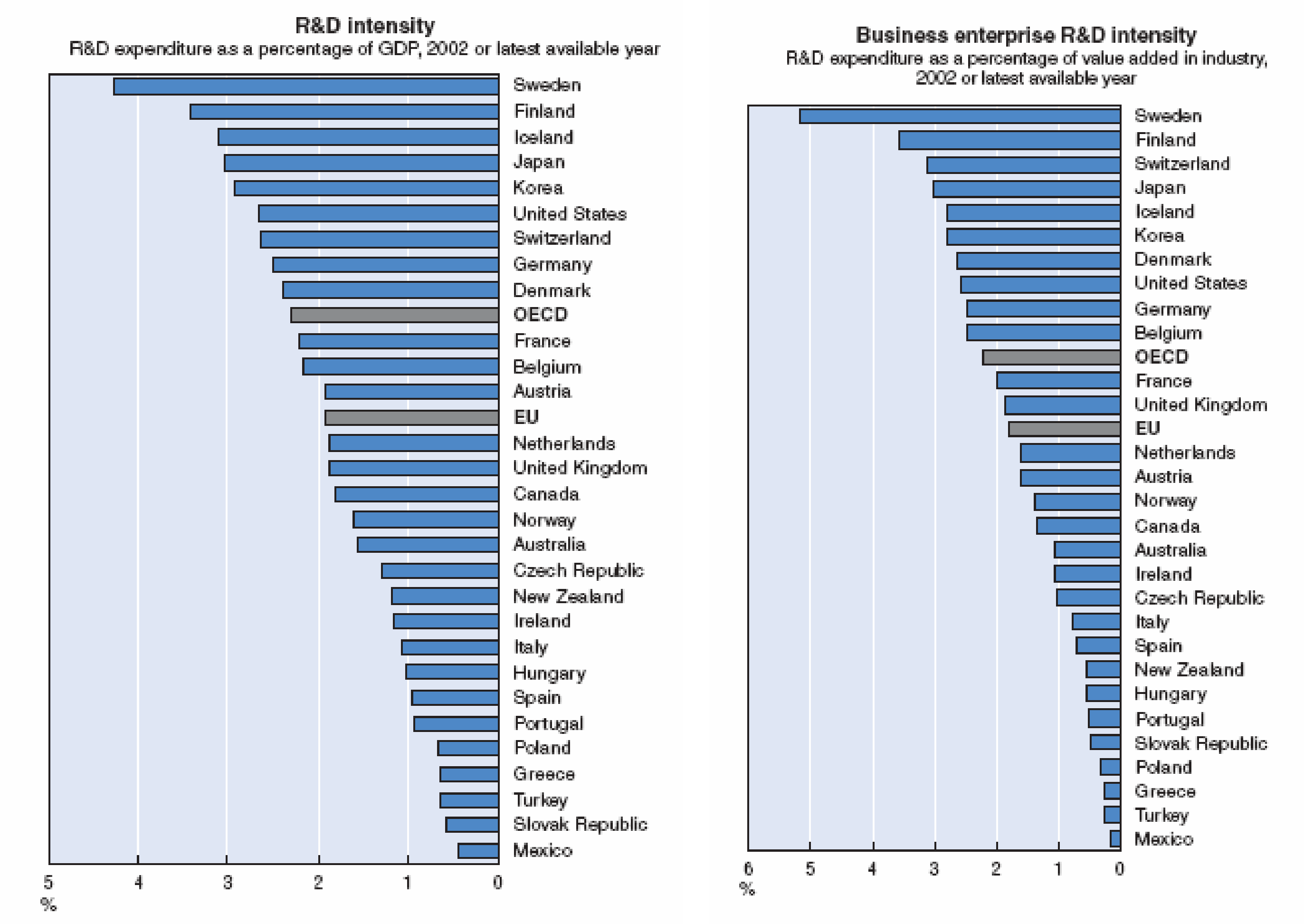
Although the global market for scientists is deemed to be healthy, there may not be enough suitably skilled people to fill future positions. In order to obtain a comprehensive picture of the state of science, the OECD, through the Global Science Forum (GSF), has formed committees to collect information pertaining to the perceived downturn in the numbers of students wishing to study science. Australia's representative, William Thorn from the Department of Foreign Affairs and Trade (DFAT), is part of the working group looking at the causes of this decline and suggestions to improve this situation. The OECD reports that in some of their member countries there has been a decline in the number of chemists and physicists, with low salaries and poor career prospects cited as main reasons for people not wishing to pursue studies in these areas. As the results of the international research project will be first presented at a conference in the Netherlands in November 2005, and the workshop on this material is to take place in Paris in April 2005, they do not feature in our Interim Report. The future of science, and also chemistry, is seen to be an important focus by many other organizations, such as The Federation of European Chemical Societies (ENC, 1997) and the European Union (EC, 2004).

In 2002 the European Union determined that in order for it to be competitive and ensure long term innovation, growth and employment potential it needed to increase the average research and development investment level to 3% of Gross Domestic Product (research intensity) by 2010 from a base in 2002 of 1.9%. Further the 3% target should be comprised 2/3 by private sector expenditure with the remainder from the public sector. They further postulated that if this target is to be reached, then by 2010 there will be a need for 700,000 new researchers (OECD, 2004b). The benefits of reaching this target would include a further 4000,000 new jobs per annum as well as an estimated 0.5% of supplementary output (CEC, 2003).

The United States is also following a path of R&D. Reporting on the Science and Engineering Indicators 2004, the National Science Board suggested that:, "US strength in science and technology reflects many decades of government support for the conduct of research and development, the development and maintenance of the necessary infrastructure and the education and training of scientists and engineers". Currently the US leads the world in research and development expenditure with approximately 2/3 or $177 billion of the total $276 billion expended by the private sector as "an engine for continuing competitive strength and profit growth" (NSB, 2004).

Currently Australia does not have targets for research intensity, with recent performance of total research intensity of 1.62%. However, the research intensity component for the private sector is only 0.79%. Australia has a non business research intensity of 0.83% and is above the average for the EU and the OECD (see Figure 1, below). If Australia decided to adopt the 3% target there would need to be an increased science and engineering workforce. As stated in the introducation, Professor Peter Andrews, Chief Scientist in Queensland, has suggested that an increase in the order of 75,000 new scientists and engineers would be required (Wood, 2004).

Figure 1: R&D intensity for OECD countries in 2002



Source: *Science and Technology Statistical Compendium, 2004*

From an industrial point of view, the American journal *Chemical and Engineering News* predicts that the chemical industry will continue their economic expansion within the U.S.A, Canada, Latin America and Asia, with Europe's chemical industry lagging behind the rest of the world (C&E News, 2005).

2.2 The situation in the United States of America

Of the approximately 290 million people living in the United States of America, around one million are employed in the chemical industry. The USA Chemical industry is worth $US419 billion dollars a year and is the country's largest exporter accounting for 10 cents of every export dollar (www.americanchemistry.com).

Although the industry may be viable in US and in the export of chemicals and resultant goods, the industry has a public image problem (Mehta, 2003). This lacklustre public image has been raised in

Chemical and Engineering News, with a suggestion that a 'Center for the Public Image of Chemistry' is needed to raise the positive profile of chemistry and chemicals in the United States (Pavlath, 2002). The profile may need to be raised to encourage more students to enter the profession.

2.2.1 The teaching of Chemistry in the USA

There is some concern in the USA that although the industry may be healthy, the number of students undertaking science at secondary and tertiary levels may be falling. The American Chemical Society suggests that there is a crisis in science education affecting all levels from Kindergarten to Year 12 (K-12). They suggest that there is a need for teachers to be better skilled in teaching science from K-12 (ACS, 2005). Up to a third of current chemistry teachers with American high schools are expected to retire in the next ten years (Smith, 2002). Consequently, it is not surprising that the demand for well-qualified chemistry teachers is expected to soar (Raber, 2003).

Within the university context the number of science graduates as a proportion of all graduates in the USA is low compared with other OECD countries. In 2000, for example, only about one sixth of the total number of university degrees conferred was in science compared with one quarter of all degrees in the EU and in Japan (OECD, 2004b).

From data posted on the National Center for Education Statistics (NCES) website, it can been seen that the largest percentage of graduates of Bachelor degrees in 2001/02 were Business students (21.4 per cent), followed by Social Sciences and History (10.3 per cent), then by Education (8.5 per cent). Within the sciences, the highest ranking subject was Biological sciences, which was seventh of 33 categories (DES, 2004). Table 2, below, presents the ten fields in which the most number of people graduated in 2001/02, plus the sciences.

Table 2: Ranking, number and percentage of US Bachelor graduates for 2001/02

Rank	Bachelor Degree	Number of Graduates	Percentage of total
1	Business	265,746	21.4
2	Social sciences and history	128,036	10.3
3	Education	105,566	8.5
4	Psychology	73,534	5.9
5	Health professions and related sciences	73,490	5.9
6	Visual and performing arts	61,148	4.9
7	Biological sciences/life sciences	60,553	4.9
8	Engineering	58,098	4.7
9	Communications	58,013	4.7
10	English language and literature/letters	51,419	4.1
11	Computer and information sciences	41,954	3.4
12	Liberal arts and sciences, general studies, and humanities	37,962	3.0
18	Physical sciences and science technologies	17,979	1.4

22	Mathematics	11,674	0.9
	Other	198,999	16

*Data obtained from Digest of Educational Statistics. http://nces.ed.gov/programs/digest/d02/ch_3.asp#3

Due to the different taxonomy utilised by the US, the figures cannot be directly compared with Australian data (as presented in Chapter 4). However, what is clear from the NCES data is that the numbers of physical science and science technologies graduates are much lower that of biological sciences/life sciences. When all science students are grouped together, the proportion of science graduates to all graduates fluctuates between six and seven percent of the total.

According to *Chemical and Engineering News* 'Employment Outlook for 2004', the number of BSc, MS and PhD graduates in Chemistry has remained relatively constant over the last 10 years, with there being less than a six per cent change from any one year to the next. When looking specifically at chemistry graduates for the period between 1994 and 2001, the number of graduates from a Bachelor degree in Chemistry remained around 10,000, with Masters and Doctorates in Chemistry remaining around 2,000.

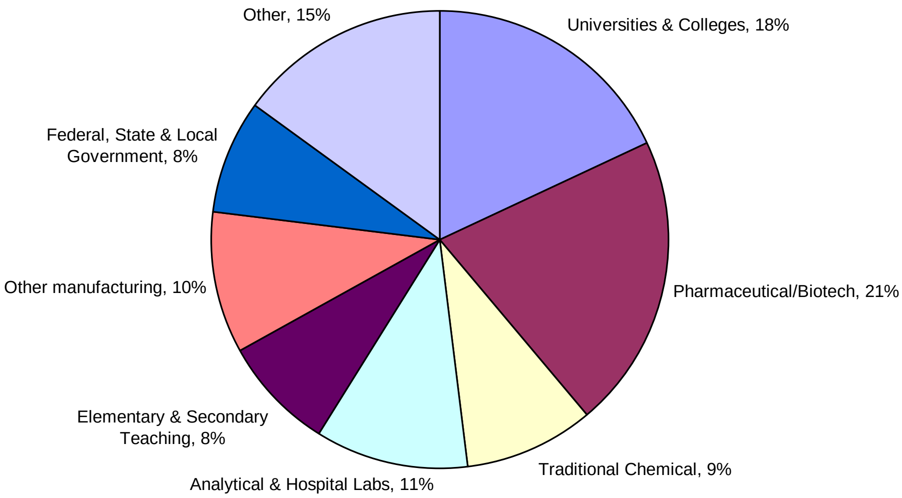
Combining the total numbers of graduates of Bachelor degrees from 1994-2001 with the data from *Chemical and Engineering News,* the number of people graduating with Bachelor degrees in Chemistry as a percentage of the whole cohort of Bachelor graduates remained between 0.76 and 0.90 per cent of the 1.2 million people graduating with Bachelor Degrees each year.

Overall, within the US university system, the number of students graduating in chemistry has remained relatively consistent over the last seven-years.

2.2.2 Graduate Destinations

In 2002, the largest percentage of new chemistry graduates were employed by the pharmaceutical/ biotech sector, accounting for over one fifth of all new graduate positions. The second largest sector in the USA which employed chemists was the higher education sector (universities and colleges) at 18 per cent of the cohort. Figure 2 presents this data, as adapted from *Chemistry and Engineering News* (Mehta, 2003).

Figure 2: Sectors employing newly graduated Chemists, 2002 (USA)



2.2.3 The employment market for Chemists in the US

According to the OECD, 'the US National Science Foundation estimates that employment within the fields of science and engineering will increase at three times the rate of the overall rate of employment between 2000 and 2010' (OECD, 2004a, p7)). As a consequence, if the number of graduates does not increase, then there will be a shortfall in the number of scientists produced.

A number of American organisations have predicted a shortage of qualified chemists. In 2003, *Nature Reviews Drug Discovery* (a *Nature* publication) suggested that there was a shortage of qualified chemists to take up combinatorial chemistry positions. Their information was received from 'talk[ing] to the large companies' (*Nature Reviews*, 2003, p163), but exactly who and where these companies were, was not stated. This *Nature Review* article is by no means the only article that suggests a shortfall of chemists without any quantitative data. Indeed, predicting the numbers of chemists needed in newer and emerging fields of chemistry is difficult. There are conflicting reports as to the need for chemists withIn 2005, the on-line *Chemical & Engineering News* stated that the outlook for the employment market in the US was not bright (Storck, 2005). However, other commentators, including Donald Kennedy, editor of *Science*, see no imminent shortage (Greenberg, 2004). Predicting supply and demand is also complicated by the different needs in geographical areas, for example in 2002 around Boston there was a shortage of people in the areas of organic and medicinal chemists (Connolly, 2002). These reports indicate that supply and demand is affected by three distinct factors: skills shortage, skills gap and recruitment difficulty.

Within the Research and Development sector, the chemical industry is one of the eight industries that contributes to more than 70% of all of the industrial R&D spending in the U.S. The predicted total spending in 2005 on R&D in the chemistry industry is $US13.49 billion up 1.6% from 2004, although there is a predicted decrease in the numbers of staff in R&D in the chemical industry of 1.5% from the 2004. Observers suggest that the relative decline in federal funding of basic research will mean that there will be a focus on short-term applied R&D to the detriment of long-term research (Duga & Studt, 2005).

Overall, there is no overall consensus as to the future industry needs for chemists, however, there are more commentators and experts predicting a future need for chemists, rather than an oversupply of chemists.

2.2.4 The American Chemical Society survey

Every year the American Chemists Society (ACS) conducts a survey of the employment status and salaries of its 90,000 members. In the 2003 report, the profile of the working chemists included the fact that a quarter of all members were women, with the median age of all chemists being 45 years old and about 85 per cent of working ACS chemists being white. These statements confirm the general perception of the industry as an older, white male dominated arena. Also the areas in which chemists are employed have changed since 1990, with fewer chemists working in chemical manufacturing, dropping from 23% to 15%, but with more chemists working within the pharmaceutical industry, rising from 12% to 21% (Heylin, 2003).

2.2.5 State of Chemistry in the USA

Overall, the number of chemistry graduates has remained relatively constant since 1998. More jobs are expected to be created in chemistry but as many chemists are expected to retire in the next 15 years, there may well be a shortage of skilled chemists if graduate numbers do not increase in the near future.

2.3 Chemistry in the UK

The chemical industry is the largest manufacturing sector in the UK, employing over 400,000 people, and selling more than £42 billion worth of products annually. There are many international chemical companies operating in the UK, however, the vast majority of companies (more then 80 per cent) employ less than 50 people with almost 70 per cent of the chemicals produced being used within other industries (DTI, 2005).

Although the industry itself remains fiscally viable, the image of chemistry is not healthy amongst the general population. According to *BBC News Magazine*, academics in the UK suggest that chemistry has 'unwittingly become a whipping horse for public skepticism about science' (Duffy, 2004). According to Stephen Breuer in his article *Does Chemistry have a future?* The general public has a negative attitude towards chemistry, as the public perceive an association with 'toxicity, flammability or some adverse effects on the environment' (Breuer, 2002). The lack of public status, combined with the fact that many students are abandoning chemistry in favour of 'soft' subjects, has resulted in many university chemistry departments closing and, as a consequence, industry is concerned about a long-term effect on recruitment of chemistry graduates.

2.3.1 Science teaching in UK schools

In an article written for the *BBC News* on the state of chemistry, a secondary school teacher was quoted as saying: 'It is not difficult getting children interested in chemistry as long as there are plenty of flashes and bangs, but it is far harder to maintain their interest beyond that' (Duffy, 2004). Within many secondary school curricula students have little interaction with hands-on experiments due to costs of equipment, crowded curricula or concerns over safety. This leaves students believing that chemistry is a dry and theoretical subject (Breuer, 2002).

The pressure on students to get good grades in their A-levels in order to get into university, has meant that many students 'tend to opt for subjects which offer a better chance of high grades', with many students taking chemistry only if it is a pre-requisite for entry into courses such as veterinary science, medical degrees, forensic science or dentistry (Duffy, 2004). However, there has been an overall downturn in the number of students undertaking A levels in Chemistry, with there being a 23% decrease in the number of students taking A level chemistry from 1993 to 2003 (DES, 2004).

In 2004, The Royal Society of Chemistry (RSC) released a report into qualifications of chemistry teachers in British schools, which reported that 44% of chemistry teachers do not have a degree in chemistry. This was seen to be a cause as to why students do not continue with chemistry at higher levels of secondary school. This, in turn, had a carry-over effect into the number of students undertaking chemistry studies at university level. The UK government has noted this shortfall of suitably qualified teachers and has increased funding to ensure that teachers are trained in chemistry (Harries-Rees, 2004). It will, however, take some years before these teachers are available for the workforce.

2.3.2 Chemistry in UK universities

The higher education system in the UK is currently undergoing reforms, many of which have placed more emphasis on the universities themselves to raise revenue for their departments. According to the *Sunday Times* of December 5, 2004, the outlook for Chemistry in the near future is dire. Currently, there are 40 chemistry departments in the UK, however, the Royal Society of Chemistry is concerned that only six will remain by 2010. Already many chemistry departments have been forced to close, with twenty-eight chemistry departments closing since the mid-1990s (Hackett, 2004).

It is not only Chemistry Departments that are closing, but also other 'Enabling Sciences'. For example, 30 per cent of Physics Department within UK universities have closed since 1997. The closure of enabling science departments is seen partly due to lack of student demand and partly due to funding cuts to universities. In 1997, the National Institute of Economic and Social Research predicted a closure of chemistry departments as a means of restoring the quality of higher education in chemistry (Manson, 1997). However, according to Director of Education at the Institute of Physics, Professor Peter Martin, another reason for the declining student numbers is that 'people are choosing courses that are not much use to them or to the country. Sciences, engineering and languages have suffered' (Hackett, 2004).

According to *Nature*, the total number of students entering chemistry degrees fell by 16 per cent between 1995 and 2000, although the total number of students beginning study at tertiary level rose 12 per cent (Adam, 2002). Other sources quote that total student numbers have also fallen from 7,490 in 1997 to 5,735 in 2004 (Cassidy, 2004), with the RSC suggesting that over the last five to six years undergraduate numbers have fallen 25 per cent (Davies, 2004). The Department for Education and Skills states that there was a 37.3% negative change in the number of undergraduate chemistry students from 1994/95 to 2000/01 (DES, 2004).

Although the situation is seen to be dire by many within the institutions, there is also a train of thought that suggests that the closure of some chemistry departments is inevitable. The President of Universities UK, Ivor Crewe, who is also the Vice-Chancellor of Essex University, believes that chemistry should be concentrated in fewer universities. He is quoted in the *Sunday Times* as saying:

> I don't think the government should subsidise departments that are not attracting students. To compete globally, it may be necessary to have larger and better equipped departments. We can't have 100 universities all with separate science departments (Hackett, 2004).

Other voices, such as Simon Jenkins of *The Times*, in response to closing down of Chemistry Departments, reiterated the need for universities to act more like private institutions and to cut courses which are not financially viable. He uses Exeter's Chemistry Department as an example, which had its last intake of students in 2005 due to the fact that it was losing £3 million a year (Jenkins, 2004). However, in some instances the closure of chemistry departments impacts on other research institutes associated with the university, which in turn impacts on funding and staffing levels. The closure of the chemistry department at Kings College London (KCL), for example, weakened the KCL's proposal to host the new location of the National Institutes of Medical Research (NIMR). A statement from the NIMR suggested that the KCL proposal was 'less strong in relation to underpinning chemistry and physics and the maturity of its clinical research' compared to University College London, which was the successful bidder. The choice to relocate the NIMR to a university that still teaches chemistry was seen by Simon Campbell, President of the Royal Society of Chemistry, as an indication that an understanding of chemistry was vital in the understanding of biological processes and necessary for 'the development of innovative new medicines' (Murphy, 2005).

With the advent of television shows which focus on the excitement and intrigue of forensics, chemistry at university level seems to be losing out as a subject in its own right to 'specialist degrees', such as forensic science, even though the basis of such degrees include chemistry (See Box 1, below, for a German example). Professor Keith Smith, of the soon-to-be closed chemistry department at Swansea University, is not alone when he suggests that the word 'chemistry' itself may be a problem the image does not allure people to the subject (Duffy, 2004).

Breuer in his 2002 article, indicated that the number of students taking Chemistry at university had not only dropped as total numbers, but also as a percentage of student studying at university level. He suggests that since 1997 the number of students undertaking chemistry at university level has continued to decrease. From 1989 until 2001, the percentage of students undertaking chemistry at university level dropped from around 2.7 per cent of all subjects to around 1.0 per cent of all subjects undertaken at university level.

A 1999 study published in *University Chemistry Education* investigated the key skills that chemistry graduates received from a university education compared to the skills that they need within their workplace. From an analysis of a graduate questionnaire, they suggested that 'in almost all cases […] provision within the course could be usefully improved in order to prepare graduates better for work' (Duckett et al, 1999, p4). They did, however, suggest that they were interested in generic work skills and not necessarily those associated exclusively with the science of chemistry. This study demonstrates that university curricula may be informed by industry needs.

2.3.3 Chemistry in Industry

The chemical industry in the UK is the sixth largest in the world and worth £42 billion per annum. The industry represents 7% of the added value in manufacturing, with the vast majority (76 %) of chemicals products being exported each year. Imports supply the domestic market with 75% of chemical products (DTI, 2005). According to the *Chemistry and Engineering News* forecast the outlook for the UK chemical industry in 2005 is not as bright as that for the US, Canadian or Asian markets, with production expected to be down from 2004 (Short, 2005).

2.3.4 The Royal Society of Chemistry

The Royal Society of Chemistry [RSC] is the largest chemical professional society in Europe, with over 45,000 members. It has a large publishing sector, and is particularly strong in lobbying government to 'ensure that the chemical community can exert influence and guide government policy' (RSC, 2004a). For example, during the latter part of 2004, when many UK universities were indicating the imminent closure of many chemistry departments, the RSC lobbied the government to provide universities with more funding. They also plan to increase their influence within the EU institutions (RSC, 2004a).

The RSC is also pro-active in obtaining funding to enhance the profile of chemistry. For example, in 2004, the RSC was successful in a bid to receive funding for the *Chemistry: the next generation* project. With the £1 million in funding, links will be created between industry and universities, as well as opportunities for school students to actively engage in chemistry by using equipment at universities.

As well as collaborating with government initiatives, the RSC also commissions its own reports into the state of chemistry. For example in 2004 it commissioned the report *Laboratories, Resources and Budgets*, a report to ascertain how much money would be needed to raise secondary school chemistry departments to suitable standards of occupational health and safety as well as technical levels (RSC, 2004b).

The RSC jointly with the Institute of Physics recently commission Pricewaterhouse Coopers to produce a report entitled, *The economic benefits of higher education qualifications* (PWC, 2005). One of the major findings of the report was that chemistry and physics graduates 'will earn on average over 30% more during their working lifetimes than 'A' level holders', which is higher than between 13-16% average of psychology, biological sciences, linguistics and history holders (PWC, 2005, p1). This study debunks some claims that the chemistry profession is not well remunerated.

2.3.5 Government initiatives

There are a number of initiatives that the UK government has undertaken to ascertain the state of science. For example the 2004 *STEM Mapping* review (DES, 2004) mentioned above. Other initiative of the government include the 2004 *Chemistry: the next generation* project and the established the Chemistry Leadership Council (CLC). The CLC was established in 2003 in fulfillment of a recommendation that came out of the Chemicals Innovation and Growth Team (CIGT) Report of December 2002. The terms of reference for the GIGT are:

- To evaluate the key factors that will impact on the chemicals industry globally and identify the opportunities and challenges for the UK over the next 15 - 20 years;

- To formulate a vision of what the future chemicals industry might look like and how to get there, and
- To make recommendations to industry, Government and others for specific actions. (DTI, 2004)

The government funded council and the corresponding team established specifically to further chemistry can be seen as evidence of the importance of the chemical industry to the UK government.

The concern 'that the supply of high quality scientists and engineers should not constrain UK's future research and development and innovation performance' was one of the factors which lead to the government undertaking a review of the science, technology, engineering and mathematic skills (Science, Engineering and Technology, SET). Amongst some of the findings of the Sir Gareth Robert's *SET for success* review were; that there was a decrease in the number of students studying chemistry at university from 1995 to 2000; that there was a disconnect between the demand for high quality graduates in the enabling sciences and the supply of such students; and that there was a shortage of teachers of physical sciences and mathematics. The recommendations that the report made are aimed at encouraging more people to study and work in the areas of science, technology, engineering and mathematics (Roberts, 2002). These recommendations were addressed in part by the strategy paper 'Investing in Innovation: A strategy for Science, Engineering and Technology' review (UKTreasury, 2002).

2.3.6 State of Chemistry in the UK

Overall, the number of students studying chemistry in the UK has fallen over the last decade. Funding shortages in secondary schools, along with under-qualified teachers has meant that the number of students at secondary level has dropped, and subsequently less students are studying chemistry at the tertiary level. As a consequence of funding shortages in the tertiary sector, many universities have been forced to close their chemistry departments, citing falling student numbers and the expense of running chemistry laboratories. In order to counter the falling student numbers the RSC has successfully lobbied government for funding to encourage students into chemistry and the government has established committees and councils to undertake research into how the UK chemical industry can best capitalise on the opportunities presented to it.

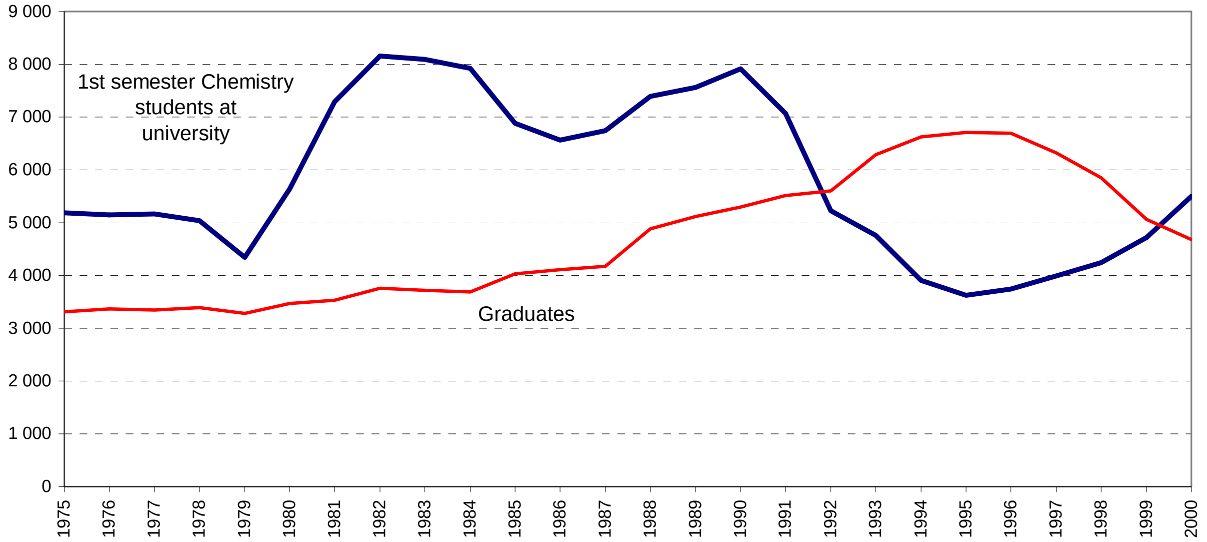
2.4 Chemistry in Germany

The German chemical industry is a major world supplier of chemicals and goods. In light of this, it is not surprising that within Germany 60% of the public support the German chemical industry (Allen, 2004). The industry is worth more than $US79.5 billion a year and employs almost half a million people.

2.4.1 Chemistry in German universities

Since 1992, university student numbers in Germany remained relatively constant, however, the number of people studying chemistry has fluctuated greatly (Jackson, 2000). Between the years 1994 and 1999 the number of students starting a chemistry degree oscillated between 2,000 and 3,500 people a year. In 2001 the number was 4,924, which increased in 2002 to 5,322 (uniMagazin, 2004). As Figure 3, below, indicates, numbers for students starting a chemistry degree were the highest in the early 1980s and have dropped considerably since that time.

Figure 3:
1st semester students and graduates of Chemistry in Germany Universities from 1975 until 2000*)



*) Until 1992 the earlier GDR states, from 1993 Germany. Adapted from Statisches Bundesamt Deutschland, 'Rückgang der Absolventenzahlen in den Naturwissenschaften',

As Figure 3 indicates, the numbers of students entering into a chemistry degree in the mid-1990s decreased by some 60 per cent from the early 1990s. These numbers have, however, recovered according to Kurt Begitt, the director for education and employment with the Gesellschaft Deutscher Chemiker (GDCh) [Society of German Chemists], due to efforts by institutions and also improvements in job opportunities for chemistry graduates (Adam, 2002).

In 2004, Woldfram Koch, the CEO of the GDCh, suggested that the rise in the number of students wishing to study chemistry may have been due to a general improvement in the public attitude towards chemistry in the last few years and also to the publicity chemistry as a discipline received in the 'Year of Chemistry' in Germany in 2003. The initiative was run by the German Federal Ministry of Education and Research along with the GDCh and other chemical organisations (Davies, 2004).

Although the campaign significantly increased the numbers of undergraduate students at university, there is some concern that in seven to eight years time there will be an oversupply of PhD graduates, as currently ninety per cent of German undergraduate chemistry students continue on to doctoral levels. This contrasts with the current situation, where there are too few PhD students (Davies, 2004). In the 1990s, more than 2000 German students graduated each year with Doctorates in Chemistry. Since 2000, however, the numbers of doctoral graduates have dropped to between 1700 and 1500 per annum (uniMagazin, 2004). The retention rate may, however, change as the German higher educational system changes from the *Diplom* to the Bachelor/Masters degree structure and may well reduce the amount of time that students spend at university from currently around six years for an undergraduate degree to around four years for a Bachelor degree.

Overall, the number of first semester German chemistry students has risen from the low levels of the mid-1990s. With the increasing popularity of the discipline there may be an oversupply of PhD graduates by 2012.

BOX 1. Case study- The trend towards offering Specialist Degrees: A German mathematical example.
The growing trend to offer 'specialist degrees', where before there was only one major area of study, is found not only within Chemistry departments, but also in other 'hard' sciences, such as mathematics. This trend is due to dropping student numbers in 'hard' sciences. In Mathematics for example, between 1992 and 1999 there was a drop of 20 per cent for students enrolling in courses at German universities. Other subjects, such as Computer Science, rose more than 50 per cent in the same period. In order to entice more students back to mathematics, a subject area which is seen as being difficult - and also seen to offer less lucrative positions once graduated. Some universities started to create sub-discipline specialisations, such mathematical finance. To some extent this obtained the goal of attracting more students back to mathematics. At the Universität Konstanz, for example, the number of beginners in the specialised course was four times the number as that of the regular mathematics program. However, such specialised courses have received criticism, for many people believe that these specialisations create students who are too narrowly educated. This defeats the purpose, according to some German academics, as their view is that the German job market is so good for mathematicians *because* of their broad education. Mathematics departments are reqiored to be creative to in order to retain student numbers needed to maintain a department and staffing levels, and as a result are implementing courses which are popular amongst students. In the longer term, this survival technique may in the long run damage the reputation of the subject area, for students who become too highly specialised may reduce their chances of finding employment in broader areas.
Information from: Allyn Jackson 'Declining Student Numbers Worry German Mathematics Departments' *Notices of the AMS*, 2000, **47**, 3, 364-368.

2.4.2 Employment opportunities for Chemists in Germany

The number of German Chemists who are unemployed has decreased significantly since 1997 (STD, 2004). However, as stated above, there may well be an oversupply in the number of chemists in 2006 and also in 2012. The constant fluctuation in the numbers of students who enroll in chemistry degrees affects the employment market. According to German employment statistics supplied by the *Zentralstelle für Arbeitsvermittlung*, the percentage of qualified Chemists who were unemployed in 2003 was 10.2 per cent. This is a lower unemployment rate than for other professionals, which, for the same period was 13.5 per cent. As the German chemical industry is expected to grow by at least 2 per cent in 2005, there may well be more jobs for chemists (Short, 2005).

2.4.3 View of the Gesellschaft Deutscher Chemiker

The peak body of chemists in Germany is the Gesellschaft Deutscher Chemiker (GDCh), or Society of German Chemists, which is the largest chemical society in continental Europe, with members from universities, industries, government agencies and consultants. In order to combat the decline in numbers of students studying at university level the Society has been pro-active in trying to entice more students into the subject area. One method undertaken to attract students to chemistry was the creation of a 134-page colour brochure, which advertises the benefits of a chemical degree. The fourth edition, published in 2004, combined information on where one can study chemistry, employment opportunities and case studies of employment histories. The publication also contained advertisements for chemical companies and this functioned as both an indicator of where students may find employment as well as advertising positive aspects of the industry.

2.4.4 Overview of the state of Chemistry in Germany

Overall, the health of chemistry education within Germany has improved over the last decade, with an expected over production of chemists in 2006/07 and also 2012/13, due to large intakes of first year students six years previously. Job opportunities for gradates is improving and with a predicted 2 per cent increase in the output of the chemical sector in 2005, employment prospects may continue to be positive for chemists.

2.5 International State of Chemistry

Internationally there seems to be a down-turn in the number of students willing to study chemistry, with teacher shortages looming in the USA, and departments closing at universities in the UK. In contrast, the state of chemistry within Germany is healthy. However, this has been achieved over the last few years through a concerted effort by universities, government and industry alike to raise the profile of chemistry and to encourage more students to undertake this subject at university level. In summary, there are differing opinions as to if there will be a shortage of chemists in the next few years and the outcome is likely to vary from country to country.

Chapter 3: The state of Chemistry in Australian Schools

The next generation of Chemists is currently being educated in the primary and secondary school systems across Australia. This is a fact that is clear to many Federal and State government bodies as seen by the many programs and initiatives in place all over the country to promote the sciences. In primary and secondary schools science is a key learning area. However, chemistry is not usually a separate subject until later in secondary education. By exposing students to a range of science areas students develop scientific literacy, which is seen as one of the main purposes of science education. Australia students, according to the 2000 PISA results, preformed significantly higher then the OECD average in scientific literacy (Lokan, 2001). However there is a growing concern that there results do not translated to higher level student participation in science education. This chapter will examine a small selection of reports, literature and some science education programs conducted within the primary and secondary schooling system of Australia in regard to how chemistry is taught and perceived by educators and students. The final report will provide a more detailed picture of the state of chemistry teaching in primary and secondary school systems than the brief overview presented here.

3.1 Chemistry within Primary schools

In 1998, Donald Watts produced a report for The Australian Academy of Technological Sciences and Engineering (ATSE) that examined the readiness of Australian schools to meet the demands of teaching the curriculum areas of science and technology in the compulsory years of schooling. In an abridged version of the report Watts suggested that 'by their own assessment, the great majority of primary teachers are ill-prepared to teach the content of the new science and technology curricula' (Watts, 1998, p 10). He suggests that as most primary schools 'lack the facilities for science and technology that will allow teachers to gain the hands-on experience enabling confident demonstration to a critical audience of pupils' (Watts, 1998, p 10) one of the best ways to combat this would be to equip primary schools with a Science and technology Resource Centre. The concerns that Watts raised in the 1998 report were reiterated in a 2002 report by ATSE. Entitled *The Teaching of Science and Technology in Australian Primary Schools. A Cause for Concern'*, the report indicates that the situation had not improved significantly since the 1998 report (ATSE, 2002).

3.2 Chemistry within Secondary schools

In the 1998 report by Watts citied above, in reference to secondary school teachers he stated that 'all the evidence suggest that a further decline in the general quality of the intake into teacher training will lead to a sharper decline in the readiness in the science and technology areas' (Watts, 1998, p9). He also suggested that there were a number of states in which supply is far short of demand and that there was a prospect of a 'decline in the quality of teachers entering the profession in the next few years' (Watts, 1998, p 14).

This concern about the decline in the supply of people entering the science teaching profession was also raised in a 2000 report by the Science Teachers' Association of Western Australia. From a census of all science secondary teachers in the state that concluded that there was a shortage of qualified science teachers. They also found that 15.0 per cent of senior school chemistry teachers not being qualified to teach in the area, where qualified is defined as having successfully completed a second year subject at university level in the discipline. The report predicted that there were not enough qualified physical science (chemistry and physics) teachers to replace the unqualified teachers and that the lack of new physical science teachers entering the profession was a concern (STAWA, 2000). Although this report only comments on the situation in Western Australia, anecdotal evidence suggests that there is a shortage of qualified science teachers nationally. In order to address this issue of a lack of quantitative data, the Australian Council of Deans of Science has undertaken a study into the qualifications and aspirations of science teachers on a national level. This report is due for release in 2005 and will add significantly to the current understanding of the qualifications of secondary school teachers nationally.

One organization that is concerned about this shortage is the Australian Science Teachers Association (ASTA). They are concerned that there is a declining uptake of science teaching as a career - including chemistry teaching. ASTA notes that many graduates do not stay in science teaching beyond five years. They believe that graduates are not adequately supported and mentored, and there is no obvious career path for them except into administration within schools. Support and mentoring is part of the professional development process towards accomplishment and recognition against standards. One suggestion put forth by ASTA to raise the profile of science teaching is to implement a national assessment, accreditation and reward system for teachers of science.

The DIIRD report cited in Chapter 1, suggested four likely causes for students not wanting to study chemistry, or not continuing with it. They were; the poor public image of chemistry, the perception that chemistry research is not cutting edge, the lack of clear information on career options and remuneration, and the 'non-engaging or exciting teaching and/or curriculum in both secondary schools and university' (DIIRD, 2003, p 14). Terry Lyons, in his international study of students' experiences of school science, postulates that it is the experiences of learning science at secondary school that students obtains that will influence their choices as to whether to continue studying the discipline, and that 'negative experiences have a significant, and in some cases, decisive, influence on students' enrolment deliberations' (Lyons, in press). Lyons further suggests many students who had a personal interest in science were deterred from continuing with science in senior school levels because they felt 'estranged by school science'. It can be suggested that science at secondary school level is failing to engage students. One method to make science more attractive to students is to make it applicable to real world learning. For example, the DIIRD report suggested that nanotechnology be taught as part of the chemistry curricula of the Victorian Certificate of Education (VCE). The associated concern with this method is that teachers need to be made aware of the relevance of the area to the tertiary aspirations of the students (DIIRD, 2003).

Other commentators, such as that of Price and Hill in their RSC article 'Raising the status of chemistry education', have concluded that the chemistry is declining international, with Australia being no exception to this. They especially comment on the status of the discipline within in the secondary school and tertiary sectors, suggest that the essence of the solution is to enhance the public perception of chemistry so that people understand the importance of the enabling sciences in their daily lives (Price & Hill, 2004).

3.3 General initiatives and programs to promote science in general and chemistry in particular

The Federal Government is aware of the low standing of science and has given support to raise the profile of science through initiatives such as *Backing Australia's Ability* (BAA), which delivered an additional $143.5 million over a period of four years to enhance the science, mathematics and technology skills and innovation in State and Territory government schools (CommAust, 2001). One of the many programs to benefit from this funding was the *National Science Week* (NScWk) program. Through *Backing Australia's Ability*, the NScWk received funds in excess of $2 million per year through DEST. This program had doubled its media coverage between the years 2003-2004, indicating that the program was seen by the general public to be of interest. Other programs, which are funded through Federal agencies, and which aim to increase student's awareness of science included the CSRIO funded Double-Helix science projects, aimed at middle primary school students and the National Chemistry Quiz, run through the RACI aimed at high school students.

In order to promote chemistry amongst primary and secondary school students, as well as the general public, the RACI runs the annual Australian National Chemistry week, which incorporates the National Chemistry Quiz and approximately 100,000 school students take part in. Other programmes offered during ANC have include displays in Shopping Malls, visits by chemists to primary schools, a programme of Youth Lectures, national radio and television interviews, Newspaper Feature Articles , Public Lectures and Debates , Functions to Welcome New Graduates , Crystal Growing Competitions , Chemistry Week Dinners , and a special feature in the CSIRO 'Double Helix'.

Another initiative to come out of the Federal Government's *Backing Australia's Ability*, was the report *Australia's Teachers: Australia's Future*. The purpose of this report was to identify strategies that will increase the number of quality people embarking on a career in teaching. The report pointed to the areas of science, technology and mathematics education as a priority, with concern being raised at the decline in students undertaking these subjects, the lack of qualified teachers engaged in these teaching areas as well as the low scientific literacy and interest of many primary school teachers. The report also provided an agenda for action that comprised of 54 actions and aimed to raise the scientific, mathematical and technological literacy amongst school students (DEST, 2003). The *Clever Teacher*, *Clever Sciences* report published by DEST in 2003 also provided some insight into how teachers were trained in science, mathematics and technology, with a view to 'providing guidance for meeting the challenges of teaching in these fields' (Lawrance & Palmer, 2003). Federal reports such as these demonstrate the government's concern as to the quality and supply of teachers in the sciences and how this will affect current and future students of science.

State governments have also seen the need to promote science, and chemistry, at the primary and secondary school level. The Queensland government, for example, suggests that there is a brain-loss, by which they mean that there are fewer students undertaking 'hard sciences', such as chemistry, currently occurring within the state's schools. This brain-loss needs to be curbed if Australia wishes to have a competitive knowledge based economy (DSDI, 2004).

In Victoria, a program is currently in place to encourage students to study chemistry at higher levels. The state government provided funding to advance the chemical sciences in Victoria through the *Victorian Institute for Chemical Science* (VICS). The program, which is a collaboration between the University of Melbourne, Monash University and the Department of Applied Chemistry at RMIT University, is organsied around four themes; Drug Discovery and Chemical Synthesis, Environmental Solutions, Molecular Analysis and Dynamics, and Chemistry Education and Outreach (VICS, 2003). According to some of the participants in VICS the last area, Chemistry Education and Outreach, has been the most successful part of the program and the participating universities have seen an increase in the number of students applying for places within a chemistry program.

There are many other initiatives that state governments have established in order to encourage more students to not only undertake science and chemistry at higher levels, but also to increase the scientific literacy of the schooled population. Details of further initiatives will be presented in the final report.

3.4 Chemistry within Australian schools

The state of chemistry in Australian schools is not healthy. It is, however, been noted as a concern by Federal and State governments, which have researched into the reasons as to why there is a downward trend in the number of students undertaking chemistry, and have also offered some suggestions as to how to improve this.

Chapter 4: The State of Chemistry in Australian Universities as seen by the Universities

> '*A university without a chemistry department should be stripped of the title and redesignated a liberal arts college, which is all it is.* Harry Kroto, Nobel laureate and co-discoverer of buckyballs, lamenting the closure of chemistry departments of many UK universities. The Sunday Times, London, 28 November, 2004' (as citied in *New Scientist* No. 2476, 4 December 2004, p 9)

As Chapter 2 demonstrated, there has been a decrease in the proportion of students studying chemistry compared with all students undertaking higher education. This has prompted some tertiary sectors to close down chemistry departments, for example in the UK there is a predicted decrease in the number of chemistry departments at universities from 40 to 6 by 2010 (*Sunday Times*, 2004). Australian universities are not immune from such global developments.

The aim of this chapter is to create a picture of how Australian universities view the state of Chemistry within Australia, building on information presented in Chapter 2. It uses data from DEST and also from a survey of university chemistry departments.

The quantitative DEST data shows a drop in chemistry student numbers over the last decade, which follows international trends. These numbers, however, do not present the whole picture. In order to gain a deeper understanding of the state of chemistry education within universities we surveyed chemistry departments themselves to gain an understanding of their views on why and how student numbers were changing. The survey instrument was a questionnaire designed by the RACI and sent to 33 tertiary institutions within Australia (see Appendix 4). The instrument contained questions of both a quantitative and a qualitative nature. The questionnaires were sent to either the Heads of Departments or Schools, or those people nominated by the Faculty/Division as being people well placed to answer questions on the changing nature of chemistry within the university environment.

Seventeen questionnaires are analysed in this preliminary report. All states and territories, except for one were represented in the responses, with responses received from regional, metropolitan, older and newer institutions.

4.1 Student numbers at tertiary levels

Global indicators suggest that the number of students undertaking study in the sciences has decreased over the last decade. Data from the OECD, the German Federal Government, the governments of the United Kingdom and of the United States of America all suggest a down-turn in the number of science students, with chemistry being particularly affected.

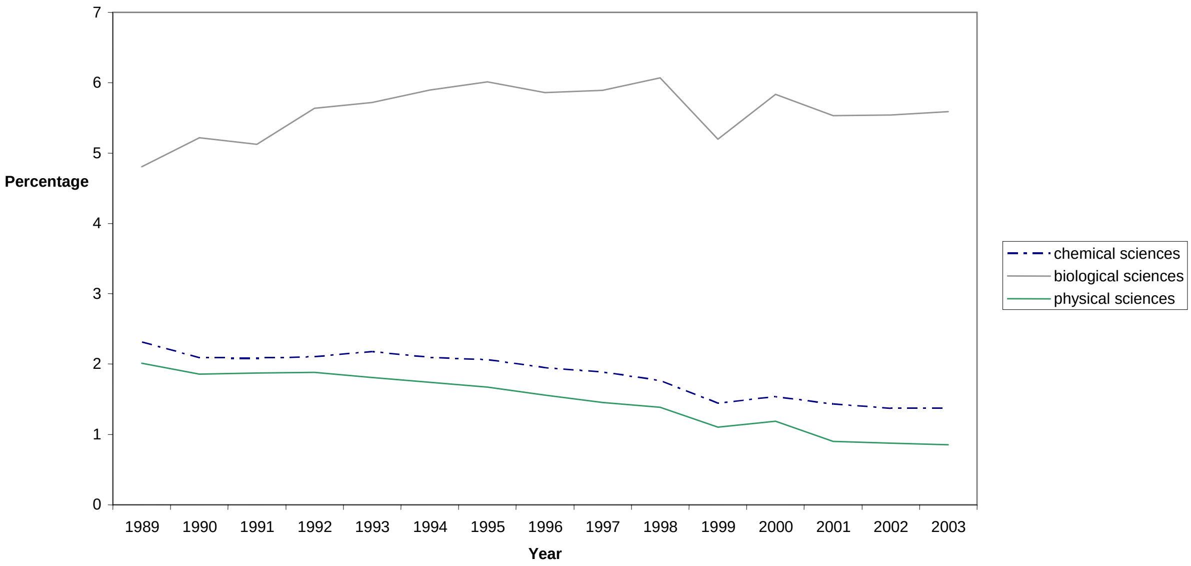
In Australia, data is collected annually by the Federal Government from universities through the Department of Education, Science and Training (DEST). Data from DEST for the last 15 years demonstrates a decrease in the number of students undertaking science related degrees. DEST collection methods of DEST have not remained constant over the last ten years. Classifications were constant across the following periods, 1989-94, 1995-98, 2001-2004, with there being classification changes between all periods and also in 1999 and 2000. The dip in 1999 may be due to radical changes in the categories of collection in this year, which largely reverted in the following period.

Over this time frame chemistry as a discipline has continued to decrease as a percentage of the whole student population as well as losing actual student numbers over the last ten years.

4.1.1 Science students as a percentage of the whole student population

Analysis of student load statistics reveals a decline in chemistry students compared with the growth in overall student numbers over the period 1989 - 2003 as shown in Figure 4, below. Originally at over 2.3 per cent of the total student population in 1989 by 2003 the percentage of students studying chemistry had fallen to 1.7 per cent of the total student population.

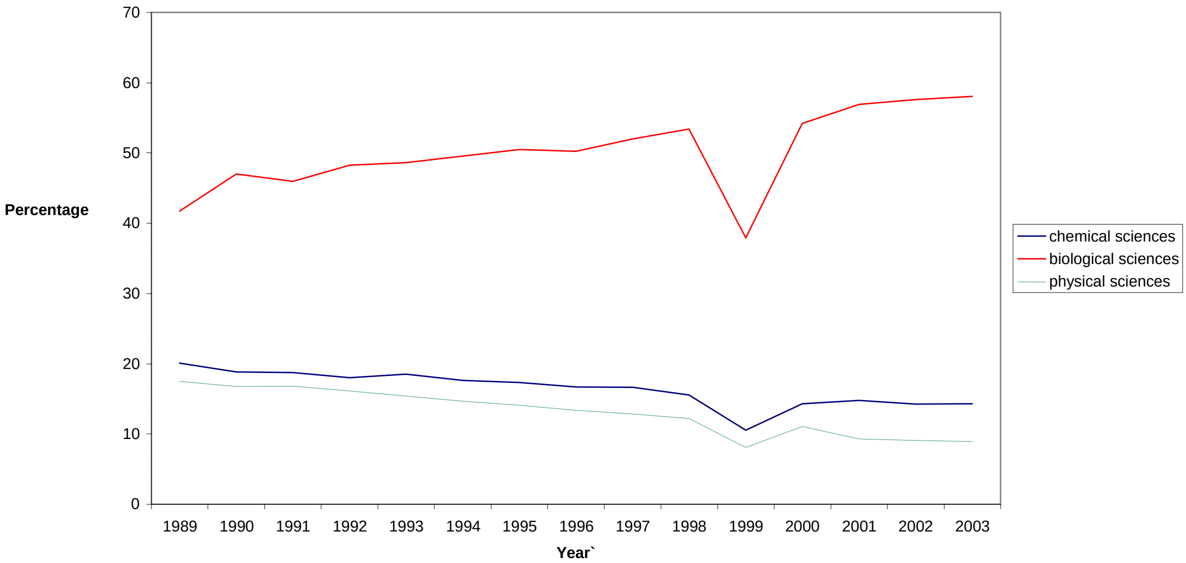
Figure 4: Percentage of Chemistry, Biology and Physical Science University students as a percentage of all University students



4.1.2. Chemistry students as a percentage of the science student population

Within the cohort of science students, the numbers of those studying chemistry has also fallen as a percentage of the whole. Figure 5, below, presents the trend over the last fifteen years.

Figure 5: Chemistry, Biology and Physical Sciences as a proportion of total higher education science student numbers



Along with Physical sciences, the number of students undertaking chemical sciences has continued to decrease and is now below twenty per cent of all science students.

4.2 Overview of Chemistry within Australian Universities

In Australia, there are 44 self-accrediting higher education institutions, of which 33 have courses accredited by the Royal Australian Chemical Institute (See Appendix 4). According to the web-sites of the 33 universities that were surveyed for this chapter, only a third of them had a discrete Department or School of Chemistry. For the majority of universities Chemistry was part of a multi-discipline school of science. For many universities, amalgamations of chemistry with other discipline areas are of a purely administrative nature and do not effect the internal structure of the chemistry section and some amalgamations have been positive for the discipline. However, for other universities amalgamations herald funding cuts to the department. Although the situation in Australia is not as dire as in the UK it still warrants close attention.

For this review, a survey was sent out to 33 universities (see Appendix 2) in mid-November 2004, for completion by end of 2004. Of the 33 universities, 17 universities responded by 28 January 2005. Of these 17, all states and territories, except for the one were represented. There were respondents from regional, metropolitan, sandstone and newer institutions.

4.2.1 Undergraduate students

As indicated above, the aim of this section on undergraduates was to determine the change in quality and quantity of undergraduate students in the Australian tertiary sector, with a focus on recruitment and industry connections.

From the seventeen responding universities the results from sixteen universities are presented here, one of the respondents to the questionnaire did not have undergraduate teaching duties.

4.2.1.1 Entrance scores

Universities were asked to indicate what the numerical value was for the entry requirements to their chemistry courses. Many universities provided a Tertiary Entry Requirement (TER) score or scores equivalent to a TER. Henceforth the term TER will be used to indicate a TER or a TER equivalent . The mean ±std.dev. across 13 universities that provided a TER was 76.5 ± 7.7.

When asked to provide comments on this, eight of the eleven respondents indicated that they would like the TER to be higher in order to attract a higher quality of student, with low TER scores indicating a low demand for the course. TER scores were seen by universities as being inextricably linked to prestige, with a higher score equating to higher prestige.

4.2.1.2 Trend in entry scores

The trend for TER scores over the last 10 years varied from university to university. Seven of the fourteen respondents to this question said that the TER scores had remained relatively constant, four suggested that they had risen, two suggested that it varied, one indicated that the TER scores had fallen and another did not know.

From the eight universities that supplied information on TER scores over the last ten-years the mean ± std.dev. rise in TER scores from 2001 to 2004 was 5.2 ± 4.2 %. There was greater variation in the ratio of TER scores over the last 10 years compared with that of the TER of 2004. Five of the eight universities fluctuated above and below the 2004 score, two rose constantly and only one remained constant. The largest difference between the lowest and highest TER score was 17.6 per cent at one university.

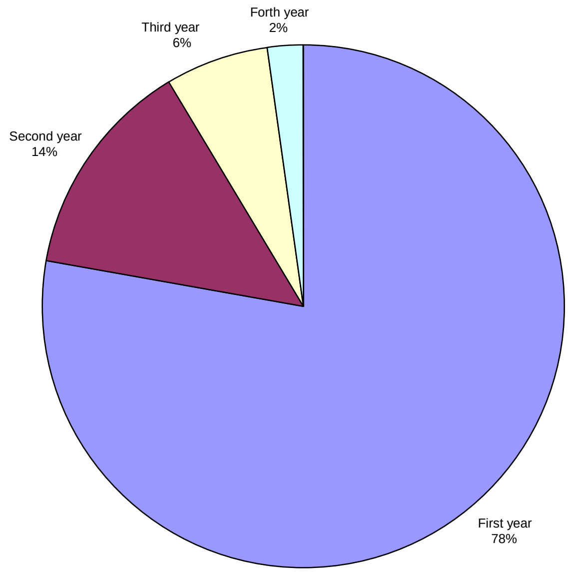
When asked to comment about the trend in TER scores, half of the respondents (n=5/10) suggested that a high TER score reflected a high quality student cohort, with one university considering raising the entry score. One of these respondents further added that a high TER score correlated with higher retention rates.

From the trends in entrance scores, it can be surmised that the majority of the respondents would like to see a high(er) TER as it corresponds with a higher quality student.

4.2.1.3 Department capacity

Universities were asked to indicate what the capacity of the department was. The capacity varied greatly across the responding universities. The mean ± std. dev. number of undergraduate students was 5589 ± 414, with first year students consisting of 78 ± 7.1% of the total undergraduate chemistry student number, second year students 14 ± 4.6%, third year students 6.4 ±3.8% and fourth year students only 2.2 ± 1.9%. Figure 6, below, presents this data in a pie chart.

Figure 6: Average per cent of Chemistry students per year level



Data on the distribution of undergraduate students across other science disciplines taught at university was not collected for this paper, and therefore no comparisons can be made. However, within the Australian system it is usual for there to be a large reduction between first and second year subjects. As one of the major disciplines in undergraduate science degrees, chemistry is often taken by students who hope to use it as an entry point into more specific courses, such as veterinary science. Chemistry is often a compulsory first year subject in many degree programs (such as Pharmacy, Engineering, Health Science, Biomedical Science, Environmental Science), enhancing numbers at first year. On an anecdotal level at the 2005 PHODs meeting, it was suggested that the attrition rates were often connected to the quality of teaching at first year level, with the implication that first year students need to be actively engaged in learning at this level.

On a broader institutional level, the mean± std.dev percentage of undergraduate chemistry students was 19 $\pm$ 22.4% of the total science student number and 2.5 $\pm$1.6% of the total university student population.

The questionnaire required responded to state whether the numbers of chemistry students had risen, remained constant or fallen over the last 10 years. When asked to mark one of the three options (risen, remained constant or had fallen), there was an equal distribution of responses, indicating that there is great variance amongst chemistry departments with regard to undergraduate places. As only seven universities were able to provide a ten-year history of the numbers of students this data is not presented.

4.2.1.4 Quality of undergraduate students

There was no clear trend in the responses on the quality of students over the last 10 years. When asked to mark one of four choices (risen, constant, fallen or don't know) indicating the change in quality of undergraduate students, five respondents indicated that student quality had remained constant, four believed the quality of students had risen with four more believing that it had fallen. One respondent each suggested that the quality had fluctuated or they did not know.

In the open-ended section of the question various reasons were postulated for the changing nature of students. Five of the fifteen respondents focused on the changing knowledge base of secondary school students, with four of these respondents suggesting that this knowledge base had decreased over the last ten years. Comments on this factor included:

> Fall in quality undoubtedly reflects declining standards and requirements in secondary science education. We find now that we need to teach in first year material that was previously assumed knowledge from high school.

And,

> An increasing cohort of students has not done chemistry at school. Many now do combined degrees (BE/BSc, BA/BSc) so do less chemistry.

Three respondents indicated that the rise in popularity of 'specialist' degrees resulted in students with higher TER scores opting for such courses. Students with lower TER scores were seen as applying for straight science degrees. The following comment typifies these responses:

> Niche degrees like the Bachelor of Technology in Forensic & Analytical Chemistry attract a greater percentage of better students than the BSc. The overwhelming majority of students doing chemistry are in niche degrees.

The results from the open-ended comments were coded and tabulated along with the results from the fixed choice answers on student quality. Although the numbers of responses are too small for statistical analysis, there is a noticeable trend with respondents who believed that student quality was falling also suggesting that it was due to the changing knowledge base of students and the trend towards specialist degrees.

Overall, there was no consensus when it came to the quality of undergraduate students over the last ten years.

4.2.1.5 Breakdown of curriculum

Respondents were asked to provide a breakdown of the time that students at that university spent in the laboratory, classroom, computer lab, on field trips or other forms of education. According to the information provided, the mean ± std.dev percentage of time a chemistry undergraduate student spends in the laboratory is 48.8 ±7.6%, 44.4 ±6.3% in the classroom, 5.4 ± 3.2% in computer labs and a very small proportion of time is allocated to field trips 1.4 ± 2.1%. (The total means added up to 102.4, as the responses were independent of knowing what the other stated. The results have been scaled accordingly.)

The majority of the respondents suggested that this was an appropriate breakdown of curriculum (n=13/15). Of the two respondents who disagreed with this statement, one was dissatisfied in the reduction of laboratory time instigated a couple of years ago at the university where he/she taught. This reduction in laboratory time was an issue raised by four other respondents, all of whom commented on the expense of running and maintaining the laboratories. Two respondents suggested that the curriculum for chemistry students could be diversified to include more emphasis on generic skills and computer skills. Another respondent suggested that an honours year was becoming increasing important to ensure that students graduated with adequate laboratory experience, thus indicating a lack of laboratory training within a pass degree.

One of the functions of the RACI is to accredit university chemistry degrees. As part of the RACI's brief an expert committee audits chemistry departments and their curriculum at regular intervals. This data, once available, will be utilised to ascertain the ten-year trend in laboratory times and will be presented in the final report.

Overall, respondents thought the proportion of time allocation among (chemistry) laboratory, classroom and computer lab was appropriate. However, there were concerns raised about the viability of maintaining these proportions considering the major costs associated with running and equipping laboratories.

4.2.1.6 Chemistry curriculum

The questionnaire required chemistry departments to indicate if the curriculum had changed over the last ten years to ascertain how and why courses change. The majority of respondents (n=14/16) indicated that courses had undergone significant changes to the chemistry curriculum in this period.

Asked to comment on these changes many universities suggested that they were constantly revising curricula in order to improve courses. Some respondents, however, were constrained in their curriculum due to university structures, for example funding cuts, staff changes, directions from university administration. Other universities changed their curricula in order to respond to outside influences such as the perceived need for more vocational training, changing curricula at the secondary school level and tapping into other tertiary areas, eg:

> we have introduced courses in drug discovery to tap into the Biomed student market.

When asked to rate the changes on a level from 1, least beneficial, to 5, most beneficial, the mean ± std. dev was 3.9 ±1.0, indicating that generally the universities were quite satisfied with these changes.

Of the two universities that had not undergone significant changes in the curriculum, one university indicated that this was due to recently re-instating the course and another respondent suggested that the changes made were only to refine the course.

Overall, universities were constantly changing their chemistry courses to reflect both internal and external factors. Although the decreased breadth of course was a worry for some universities, generally the respondents were quite satisfied with the changes made to their curricula.

4.2.1.7 Course coverage

In order to ascertain what skills students obtained in an undergraduate chemistry major, respondents were asked to rate on a five point scale (1 being least, 5 being most) how skilled their undergraduate chemistry students were in eight different areas. Table 3, following, presents this data.

Table 3: Mean (± std dev) Skill levels of undergraduate students

Area of Chemistry	**Rating ± std.dev**
Fundamental Chemistry	4.00 ± .076
Analytical Chemistry	3.57 ± 0.73
Applied Chemistry	3.13 ±0.52
Teaching	1.92 ± 0.76
Intellectual property	1.57 ± 0.68
Commercialisation areas	1.30 ± 0.53
Operational areas	1.30 ± 0.48
Business areas	1.07 ±0.27

There was a significant variance between groups (ANOVA, $p<.05$, df=7). With the three chemistry specific areas (fundamental, analytical and applied chemistry) being more highly ranked than more industry or general skills.

When asked to comment on the course coverage, four of the twelve respondents suggested that reduced funding impacted on the current design of the course and the breadth of curricula that were available. The following comment exemplifies this concern:

> With economic-driven increasing pressures on staffing levels, it is becoming increasingly difficult for many smaller departments to cover the discipline adequately. There is a critical mass of staff that is necessary for discipline coverage, and many institutions are falling below that. The alternative strategy is for specialisation and selectivity, and while this provides good training within these constraints, it does not result in a well-rounded chemistry graduate and limits their options and competitiveness in future employment.

Two respondents suggested that their course was designed with industry in mind, so that their graduates would be well placed to obtain positions within industry. To another respondent being aware of the potential to interact with industry to cater for their needs was of limited help as his/her colleagues were reluctant to change the curriculum with these industry needs in mind.

Overall, the respondents were quite satisfied with the skills that their undergraduate students obtained in fundamental, applied and analytical chemistry. The open-ended comments provided an insight into the reason that chemistry departments may not wish to change curricula, with many respondents suggesting that the economic pressures did (and do) not allow for courses to be designed as wished by the departments. These comments concur with the comments from the previous section, which suggested that the changes in curricula were often a reflection of internal or external factors.

4.2.1.8 Interaction between secondary schools and chemistry sectors

The questionnaire required responded to state if their university had any connections in place between themselves and secondary schools, and what these programs were, and if any programs of significant benefit could be developed on a national level. Universities were asked to state what programs they had in place and to rank the perceived benefit of these programs (although the questionnaire was deliberately designed so that the benefactor was ambiguous) on a scale from one (least benefit) to five (most benefit).

The majority of respondents (n=15/16) had programs in place to formalise interaction between departments and local secondary schools and their students. Below is a table of programs undertaken, their ranking and the mean for their category. As some respondents did not rank all of these programs there are some programs without a score. Responses were placed in categories depending on their formality (informal/formal), geographical location (off-campus/on-campus), and if the programs were administered by the university or initiated or administered by another organisation (internal/external). The mean number of programs offered by each of the 15 universities was 2.2. Table 4, below, presents this information.

Table 4 Programs undertaken by universities to enhance interaction between secondary schools and chemistry departments/sections

Type of program	**Description of Program**	**Rating (1=lest benefit, 5=most)**
Informal off-campus internal programs	Visits to colleges by staff and postgraduates	4
	Visits by staff to schools to promote chemistry	4
	Ad hoc visits to selected school groups	3
	Meetings with local Chemistry teachers during teachers pupil free days.	3
	Staff visit schools	2
	Giving advice on assessment and pracs	2
	Lecturers go out and demonstrate some chemistry experiments	
	Visits by secondary schools are arranged on an ad hoc basis.	
	Lecturers go out and set up activities that students complete with the help of the lecturer	
	Mean	3
Formal off-campus internal programs	Chemistry enhancement program and other outreach programs.	5
	School Outreach officer appointment	5
	Mean	5
Formal off-campus external programs	Senior teacher on External Advisory Committee	4
	‘Extreme Science Van’ takes hands-on science pracs to primary/middle schools	4
	Working with several high schools on providing assistance with writing new Senior Syllabus modules under the new [State] Syllabus.	3
	Chemists in Schools	3
	State] workshop involvement	2

	Mean	3.2
Informal on-campus internal programs	Visits by groups of students to [university] for lectures and to conduct experiments/use instruments. Year 11 and year 12 experiments. About 2000 secondary students visit the department each year. Ad hoc visits from and to selected school groups. School visits to dept > 50% of Chem students in state come through our labs during the year	4 4 3 2
	Mean	3.25
Formal on-campus internal programs	Transition Teaching Fellow Open Day and related activities Schools on-campus activities Discovery Day Chemistry Certificate programs (Faculty of Science)	5 4 3 3 2
	Mean	3.4
Formal on-campus external programs	Chemical Mystery program. VCE analysis workshops. Host Chemistry Education Association (CEA) supported HSC Booster Day for secondary Schools [Company] Science Experience for selected students Science in the Bush activity RACI titration competition, RACI Youth Lecture CSIRO Student Research Project. Schools Murder Mystery Day RACI Chemical Education group activities [Company] Secondary Science Experience	5 5 5 3 3 3 3 3 3 3 2
	Mean	3.4
	Overall Mean	3.3

The average rank±std.dev given to a program was 3.3 ±0.98, which indicates a fair response to the programs. The highest mean ranking programs (mean= 5) were formal off-campus internal programs, ie structured programs that the university administered off the main campus. The lowest mean ranking programs (3.0) were informal off-campus internal programs, ie. non-structured programs conducted by the university off-campus for example ad hoc visits to local schools.

When asked to comment on the programs run, one respondent suggested that the schools program run by the university was appreciated by the schools and therefore was beneficial from a community-service perspective, but it was difficult to determine if the program attracted students to science. The fact that tangible outcomes are hard to observe within school out-reach programs may influence the mean ranking of the programs as programs which connected industry to undergraduate students ranked higher (see below).

4.2.1.9 Interaction with industry

As for the university-school interaction, respondents were also asked to describe the connections there were between undergraduate students and industry. Universities were asked to state the programs and rank their benefit on a scale from 1-5. (1=least to 5=most). The majority of the respondents (n=12/16) had programs in place for interaction between industry and the department.

As with the programs for the secondary schools, a table indicating the programs undertaken, their ranking and the average for their category was created and is presented below (Table 5). Responses were placed in categories depending on their formality (informal/formal), geographical location (off-campus/on-campus), and if the programs were administered by the university or initiated or administered by another organisation (internal/external). The universities were asked to describe the nature of the activities. Of the 10 universities that provided information the mean number ± std.dev. of programs offered was 1.8 ±1.0. Some respondents, however, did not provide a ranking for their programs.

Table 5: Programs undertaken by universities to enhance interaction between industry and chemistry departments/sections for the benefit of undergraduate students

Type of program	Program	Rating (1 least benefit, 5 most)
Informal off-site internal programs	Work placements prior to graduating	5
	Site visits for 3rd year Industrial and Analytical Chemistry students	5
	Field visits	5
	Mean	5.0
Formal off-site internal programs	Industry Projects	5
	Considerable interaction with [State] Forensic Services	5
	'Year-in-industry' program	
	'Year-in-industry-program' for students between 2nd and 3rd year	
	Cadetship program	
	Mean	5.0
Formal off-site external programs	Membership of External Advisory C'ttee	5
	Industrial Chemistry Partnership/Club	4
	University Industry Linkages in Chemistry	4
	Mean	4.3
	Some interaction with local industries in the form of guest lectures and visits	5
	Interface meetings between	5

	companies and students	
Informal on-site internal programs	Provision of 3rd year lectures by industry staff	5
	Visiting Lecturers from other universities	5
	Visiting lecturers	5
	3rd year units in Industrial Chemistry and Analytical Chemistry include guest lectures from local industry	5
	Mean	5.0
Formal on-site internal programs	Financial support for Visiting Lecturers from other universities	5
	Mean	5
Formal on-site external programs	Industrial representation on School Advisory Board	5
	Mean	5.0
	Overall Mean	4.9

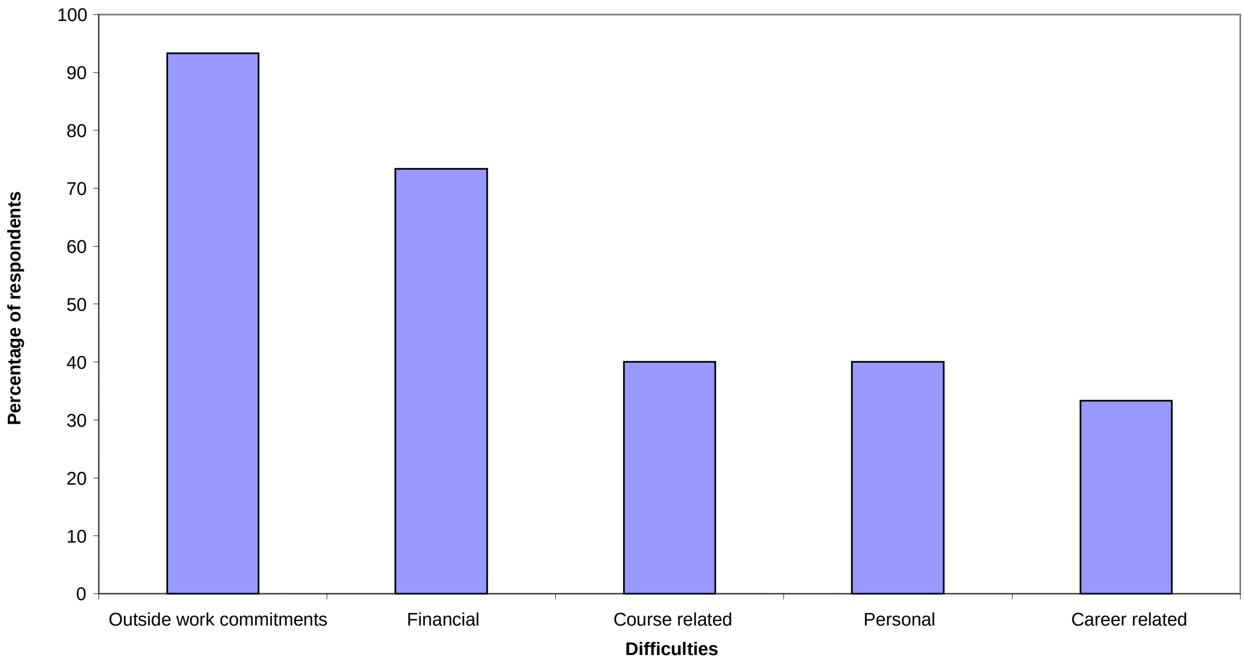
The overall mean± std.dev of 4.9± 0.3 demonstrates a high level of satisfaction amongst the chemistry departments/sections with the interaction that they currently enjoy with industry. Respondents suggested that the programs were very beneficial to the students, especially in regard to obtaining graduate positions. One respondent suggested that students, who participated in the industry programs, were often lost to the department, perhaps indicating that the programs were too successful!

Universities are significantly more satisfied with their interaction with industry than with secondary schools (t-test, assuming equal variance, $p<.001$, df=45). This may be due to the fact that there are definite outcomes from many of the industry programs (for example students obtain employment), whereas for the schools programs the benefits are often harder to quantify.

4.2.1.10 Student issues

Respondents were asked to rate on a five-point scale (1=least to 5= most) what they saw as the main difficulties that undergraduate chemistry students faced. They were asked to tick as many of the five issues offered as applicable. In total there were 42 responses to this question, which was on average 2.8 responses per university. These results are presented in Figure 7.

Figure 7: Percentage of universities indicating difficulties faced by students



The majority of respondents (n=14/15) indicated that *outside work commitments* was the major difficulty that their students faced (see Figure 7). The following comment is typical of the responses:

> Outside work commitments for students are increasing related to financial concerns affecting progress. Students are facing more complex decisions relating to course and career choices.

Other comments included personal student issues, for example:

> These difficulties are especially apparent for distance education (off-campus) students who generally have family, work and career commitments, with related financial implications.

Issues that were *career related* were not seen by the majority of universities as the most pressing issue for undergraduate chemistry students, however, a number of respondents pointed out that students need access to detailed information about careers in chemistry and related disciplines to alleviate student concerns as to career-related prospects.

4.2.1.11 Assistance offered to students by the department and university to overcome difficulties associated with studying

There were a number of responses as to how the department helped students in overcoming the difficulties associated with studying. Besides from expected responses eg. scholarships, pastoral care, academic support, career advice, flexibility in assessment, scheduling evening practicals and generous special consideration, other, more innovative responses such as the following were presented:

> We try to be as flexible as possible with assessment deadlines. Prior to semester we map all assessments across all units in first year to check that staff are not all asking for an assignment in the same week – we then try to spread out assignments over the whole semester.

One university tried to alleviate financial pressure by offering students jobs. For example:

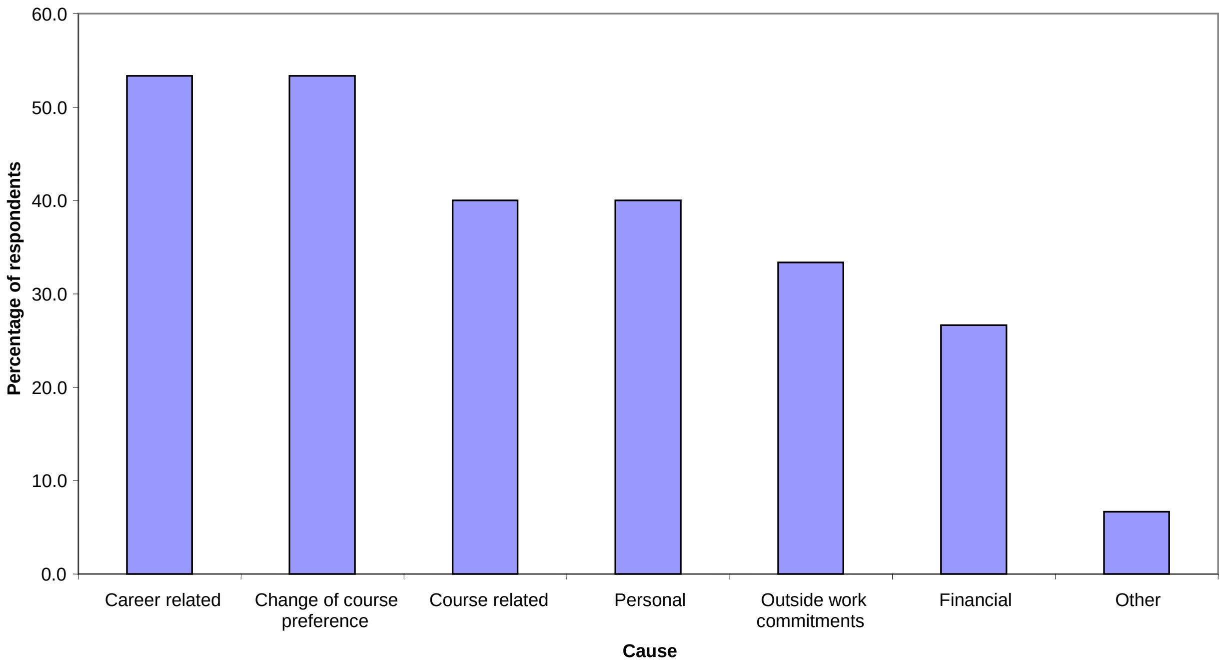
> We now use selected 3rd year students to demonstrate first year pracs. This pays them relatively well while simultaneously forcing them to revise basic concepts.

When asked what the university provided, similar responses to that of the department were offered, with financial help and student support being two of the most common answers. From the comments provided, it can be assumed that many universities take an active interest in the well-being of their students, are aware of the issues facing them and try to provide the students with assistance, including practical, financial and pastoral assistance.

4.2.1.12 Main reasons cited as to why students do not pursue chemistry studies

Respondents were asked to indicate as many issues as appropriate from a list of seven issues what they saw as the main difficulties as to why undergraduate chemistry students discontinued their studies. In total there were 38 responses, with an average of 2.5 responses per university. The two most common responses were *career related* and *change of course preference* both, with eight responses, or just under half of all respondent (see Figure 8).

Figure 8: Percentage of universities indicating major reasons for students discontinuing studies



Comments on why students discontinued included comments relating to the subject matter:

> Chemistry is seen as irrelevant and potentially resulting in unemployment.

> Chemistry is perceived as being 'too difficult' and is also seen as demanding in terms of the required time commitments to study it.

Practical matters pertaining to timetabling, viz:

> The inflexibility of pracs timetabling may result in some students choosing not to study chemistry as they cannot fit work commitments around the pracs.

And also course related matters:

> A few of our students are in chemistry to try and get into a related course such as pharmacy.

> Increasingly student/staff ratios and infrastructure decline in teaching laboratories due to budget constraints have not helped encourage students to pursue chemistry studies.

The main reasons that universities believe to be the cause of chemistry student attrition are course related, either due to the difficulty of the course, or due to the student wishing to move into different subject areas. For undergraduate students financial difficulties are not deemed by the universities to be a major factor in the attrition rates of students.

4.2.1.13 Suggested strategies to assist students

Universities were asked to provide suggestions as to strategies that could be put into place in order to retain more undergraduate students. Six universities provided responses with the most common response being the need to promote the discipline (n=3/5), either through general publicity in the area, or specifically through information on career opportunities. As the above section pointed out financial difficulties were not seen to be the major reason why students did not continue with chemistry, however, two universities suggested that a financial incentive in the form of a scholarship or bursary was a proven method of retaining students.

4.2.1.14 Undergraduate Student issues

As indicated above, the aim of the section on undergraduates was to determine the change in quality and quantity of undergraduate students in the Australian tertiary sector, with a focus on recruitment and industry connections.

The information collected by DEST suggests that the number of students undertaking chemistry has dropped over the last decade. The results of this survey did not concur strongly with the DEST results, although, not all of the responding universities supplied information on student number trends over the last ten years and not all universities teaching chemistry replied to the survey. There was also no consensus between the responding universities on the issue of student quality, with responses evenly spread over the categories.

One area that did have a clear result was that of the benefit that links between industry and undergraduate students provided, with the mean rating of benefit being 4.9 on a 5-point scale, where 5 is the most benefit. This was much higher than the mean rating of benefit ascribed to the interaction between secondary schools and university departments, which rated only 3.3. This indicates that the responding universities saw the interactions that they had with industry to be very beneficial, more so than their interactions with secondary schools. There was also concern amongst universities that undergraduate students did not have access to information about future career prospects, which was a factor in high attrition rates.

4.2.2 Graduate students

The second section of the university survey was aimed at obtaining information on postgraduate students. As with questions pertaining to undergraduate teaching the aim of these questions was to determine the change in quality and quantity of postgraduate students in the Australian tertiary sector, with a focus on recruitment and industry connections. All of the seventeen responding universities provided some responses to this section, with all states and territories being represented except for one.

4. 2.2.1 Department capacity

The questionnaire required respondents to state how many students were undertaking postgraduate studies within their university, and what the capacity of their department was.

There was a large variance in the number of postgraduate (PhD candidates and Masters students) that each of the seventeen universities currently supervised, with there being 643 postgraduate students overall. The mean ± std dev number of postgraduate students was 40.2 ± 31.3.

When asked what percentage capacity of the department these students represented, the mean± std. dev. percentage per university was 62 ± 23.7 %. This suggests that many of the departments have the ability to take on more postgraduate students. However, as some respondents commented that they found the wording of the question ambiguous as they did not know if the question referred to applicants or current students, care must be taken in interpreting this result.

The majority of postgraduate students were PhD candidates, with there being 573 PhD candidates in 16 universities (one university did not provide a response to this section). The mean number of PhD candidates at each university was 35. Of the 10 universities that could supply information on the what percentage capacity of the department was the mean was 56, indicating that a number of universities could take on more PhD candidates as their current capacity was less than 100%.

Besides Doctoral students, 13 universities had a research Master of Science (Chemistry) course in place. There were far fewer students undertaking this degree than a PhD, with the mean number of students ±std dev being 4.9± 4.9. Three universities also offered a Masters by Coursework in Chemistry, with the enrolment at one university being 20 students, one with 10 students, and the one university with only two students.

While care needs to be taken in interpreting the responses as to department capacity, it is safe to say that many of the universities have more positions for postgraduate students than are currently taken up.

4.2.2.2 Influencing factors on postgraduate numbers

As the previous section indicated, some universities had the capacity to take on more postgraduate students. If this is the case, then the responses from the universities as to why students do not take on positions may assist in the development of strategies as how to increase department numbers of postgraduate students.

Universities were asked to comment in an open-ended question how the numbers of graduate students were determined and what the influencing factors were. The most common response was the lack of scholarships available for students (n=6/18 responses) with the second most influencing factor was seen to be lack of student demand (n=4/18). Table 6, following, presents this data.

Table 6: Influencing factor that determine the number of graduates in departments

Influencing factor	Number of responses
Scholarships	6
Student demand	4
Ability to recruit students	2
Staff to supervise	2
Academic qualifications	2
Capacity of Department	1
University quota	1

The most pressing factors nominated to influence the decisions of student to undertake postgraduate studies were different to those nominated to be of most importance to undergraduate students. Undergraduate student were thought to be more influenced by course related issues and issues relating to subject matter, whereas the issue deemed to be of most influence to potential postgraduate students was the availability of scholarships.

<u>4.2.2.3 Time taken and course completions</u>

Respondents were asked to indicate how much time students were allocated by the university/department to complete a postgraduate degree and how long they took on average to complete it. There was no significant difference between the two lengths of time (T-test paired samples, two tailed $p>.05$). This indicates that most students are able to finish a research degree in the time allocated by the university. Table 7, below, presents this data.

Table 7: Mean times for postgraduate courses, allowed and taken

Course	Mean Time (in Years) Allowed	Mean Time (in Years) Taken
PhD	3.7±0.4	3.9±0.2
Masters Research	2.1± 0.5	2.6± 0.8
Masters Coursework	1.5± .07	1.5 ±0.7

Universities were asked to indicate what percentage of their postgraduate students completed their degrees. The vast majority of those who start a PhD in chemistry complete it, with the mean ± std dev percentage of completions being 87.9± 6.2 %. The completion rate for Masters by Research was also very high, with 90.4 ± 8.6% of students completing. Only one university indicated how many of the Masters by coursework finished. At 75 %, this completion rate was slightly lower than that for the PhD and Masters by Research degrees.

From the above data, the most commonly citied issue that affected prospective postgraduate students was access to scholarships. Many departments suggested that they had the capacity to take on more students, and once students were enrolled in a postgraduate degree the majority of them completed in about the time allowed for the degree.

4.2.2.4 Course coverage

As for the undergraduate population, respondents were asked to rate on a five point scale (1 being least, 5 being most) how skilled their postgraduate chemistry students were in eight different areas. The skill areas we asked the universities to comment on were a mixture of chemical skills, generic skills and skills which are useful within industry. Table 8, below, presents the mean ranking of these areas.

Table 8: Mean rating (± std dev) of postgraduate skills

Area of Chemistry	**Rating ± std.dev**
Fundamental Chemistry	4.2 ± .08
Analytical Chemistry	4.0± 1.0
Applied Chemistry	3.4 ± 0.9
Teaching	2.6 ± 1.2
Intellectual property	2.0 ± 0.8
Operational areas	1.8 ± 1.1
Commercialisation areas	1.6± 0.7
Business areas	1.1 ±0.3

The ranking of the eight areas of skills was the same for the postgraduates as for the undergraduate students. Even thought the means for each group were higher for the postgraduate skill levels than for the undergraduate skill level there was no significant difference between these groups.

When asked to comment about these skill levels, five people provided responses. Two suggested that the skills that are acquired by a PhD candidate during the course of the degree were dependant on the project undertaken. Another two people suggested that the skill base acquired through a PhD was far too narrow. One of these comments on the narrow skill base and the need to tap into industry demands follows:

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

Another person suggested that the project that a PhD candidate undertook was very dependant on the academic staff at that institution. This factor was often a disadvantage for smaller institutions that had a small staff base. The respondent further commented:

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

Overall, the responding universities believed that the chemical (fundamental, analytical and applied) skills that their students acquired were quite satisfactory, with other skills such as commercialisation and business areas ranking much lower. Although some respondents believed that the skills that students acquired in a postgraduate degree were often linked to the project undertaken, some respondents saw a need for a postgraduate degree to incorporate broader skills so that students would be prepared for working within industry.

4.2.2.5 Interaction between postgraduate students and industry

Universities in the above section indicated that the curriculum for postgraduate students does not prepare them well in non-science skilled areas. With this in mind, the interaction between universities and industry may be seen as a measure to fill the gap in the curriculum, or at least give students a chance to acquire skills in a non-academic setting. When universities were asked if they had programs in place for interaction between postgraduates and industry just under two-thirds of the respondents (n=11/17) had responded positively. However, fewer universities have interaction in place between postgraduates and industry than with undergraduates and industry (n=12/16).

As for the programs between universities and secondary schools, the responses as to what programs were undertaken were coded and placed in a table with the ranking ascribed to them. As the descriptions of the interactions between universities and industry were not as clear as that for the undergraduate/industry connections, a comparative table was not able to be created. It was also difficult to ascertain what the mean number of programs that each university undertook, as a number of universities did not quantify their programs, preferring to classify the programs in terms of 'many', 'some' and 'significant numbers of projects'. The difficulty of coding the responses may be due to the fact that just as the skills of a postgraduate are dependant on their project, their project area is often dependent on the type of funding they receive (for example an industry scholarship) or on the interest area of their supervisor. Table 9, below, presents this data.

Table 9: Type of program for encouraging connections between postgraduates and industry, description of it and a rating of its perceived benefits

Type of program	Description	Mean ranking (1=no benefit, 5= high benefit)
Industry	Many projects are industrially sponsored close collaboration.	5
	Some industry funded projects	5
	Industrial sponsorship of PhD and MSc scholarships.	5
	Various partnership projects.	5
	Polymer Industry	4
	A significant proportion of projects (~50%) are industry	4

	linked. Some projects have Industry partners Some PhD students have projects linked with industry	
Mean		4.7
Companies/Research Organisation*	[Research organisation] [Large Australian Chemical Company] [Development company] [Research organisation] [Multi National Pharmaceutical company] Company sponsorship	5 5 5 5 5 5
Mean		
ARC Grants	ARC Linkage grants	5
Mean		5
Staff research	Some staff members have close industry links and are working on applied problems Some staff members have links with specialist institutions There are many individual relationships between research groups and all types of industries.	5 5 4
Mean		4.7
Overall mean ranking		**4.8**

* All names have been changed for to ensure anonymity

The mean ranking ± std.dev of these programs was 4.8 ± 0.44, indicating a very high satisfaction with these programs.

Six respondents offered suggestions for new initiatives. Two indicated that they were working on ARC linkage programs between industry and postgraduates, two respondents were looking to increase their ties with industry, one was looking to establish a fixed term research Masters course and a further respondent suggested:

> Increasingly and actively instigating cross-disciplinary research collaborations to attract p/g students shared with other areas/disciplines.

This comment indicates an understanding of the need to tap into non-traditional areas in order to attract more students (for a German example see box 1).

4.2.2.6 General state of Postgraduate studies

The quantitative data on postgraduate students suggests that there may be capacity for universities to take on more postgraduate students, however, lack of access to suitable scholarships was seen as the major reason as to why students did not continue with postgraduate study in chemistry. Postgraduates were seen to be quite skilled in fundamental, analytical and applied chemistry, however, their skills in more industry related skills were not seen to be as well developed. Links between postgraduates and industry were seen as being highly beneficial with most universities providing some sort of program for their students.

4.2.3 Staff

The third section of the university survey was directed towards staff issues and numbers. It included questions on condition of department, staff morale, staffing numbers and physical resources of the department.

4.2.3.1 Department condition

Universities were asked to indicate if their department currently fitted into the following three categories: state of growth, status quo, or decline. Five universities suggested the department was currently in a state of growth, ten marked status quo and two suggested that the department was in a state of decline. The open-ended comments included reference to declining staff numbers, which have a cascade effect on reducing student numbers, publications and the success rates of grant applications. Other comments suggested that the 'maximum decline' had probably passed, with a there being a number of new appointments recently. The questionnaire also asked the respondents to rate on a scale of 1 to 5 with one the lowest, the level of morale amongst their staff members. The mean ±std.dev was 3.2±1.0.

Overall, the majority of universities suggested that the staffing levels in their departments were in a state of status quo, with some minor changes in staffing levels occurring.

4.2.3.2 Physical resources of the department

Access to good equipment is important for good science. In order to gauge the state of physical resources within the universities we asked them to rate four categories of physical resources of the department on a five-point scale (1 least, 5 best). The highest mean ± std dev rating category was computer resources at 3.6 ± 1.0. The mean rating for laboratories was the lowest at 3.0± 1.1. There was, however, no significant difference in the means of the four categories (ANOVA, $p>.05$, $df=3$). Table 10, below, presents the mean scores of the four categories.

Table 10: Mean rating for Physical Resources

Physical Resource	**Mean rating ±std dev**
Computer resources	3.6± 1.0
Equipment	3.4± 1.0
Library services	3.2±1.1
Laboratories	3.0±1.1

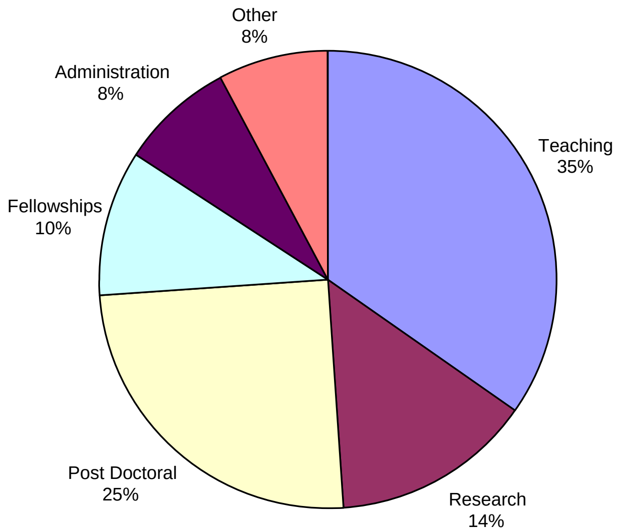
When rating their laboratories, there were some respondents who suggested that there were a number of laboratories on campus that were ranked differently. One respondent rated the laboratories at their university '3', but suggested that it was only a '1', or least satisfactory, in undergraduate labs. Another respondent suggested that some laboratories were a '5', or state-of-the-art, where as others at the same university were only ranked a '3'. A further university ranked the research laboratories as a '3.5' and the teaching labs as only a '2'.

This difference in laboratories, especially the lower quality of laboratories being provided for undergraduates or teaching, may create a 'Catch-22' situation, where students do not want to continue with chemistry at higher levels (even within an undergraduate degree) as the facilities are not satisfactory. If there are not enough students undertaking chemistry as a subject, then the department will not receive sufficient funding in order to upgrade the laboratories in order that students will be attracted to the discipline.

4.2.3.3 Staff numbers and age

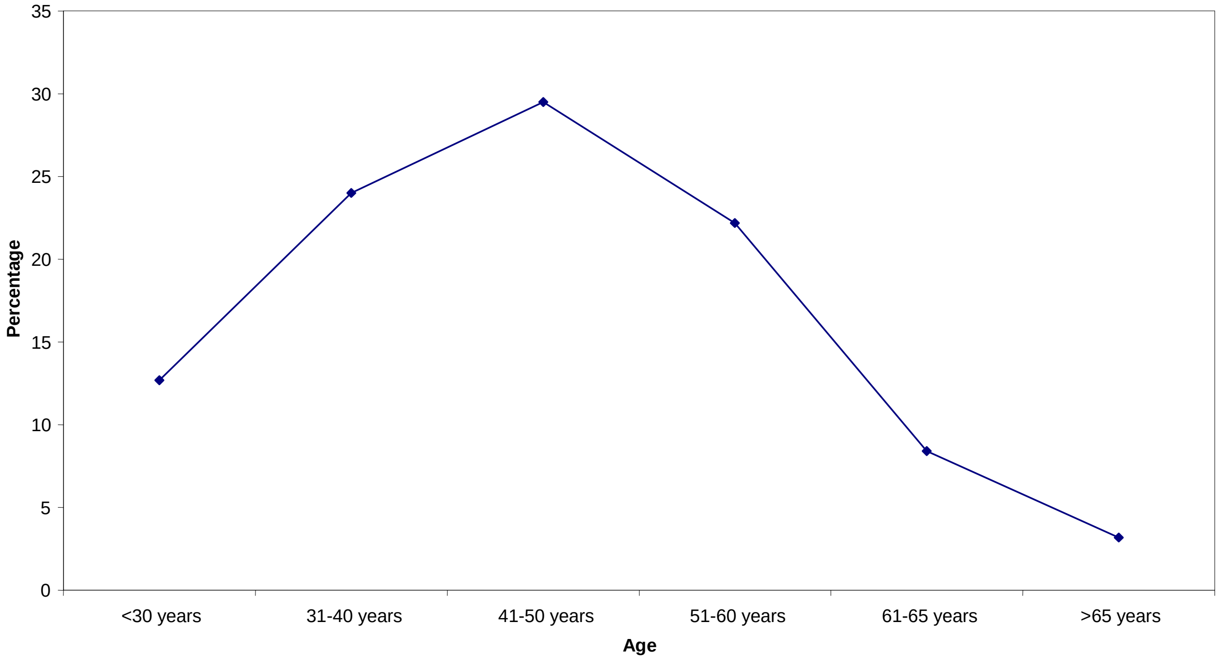
Universities were asked about the number of staff within the department/section. This is a complicated question to answer, for many universities had sessional staff, part-time staff or academic staff whose appointments were divided amongst the different areas (ie teaching, research and administration). Although the following figure, Figure 9, which presents this data, cannot be taken as an indicator of exact numbers, it does function as an estimate of *how* staffing levels are divided over the following areas.

Figure 9: Percentage of staff employed in different areas



As can been seen in the above figure, over double the number of staff are employed in teaching duties than research duties. The number of postdoctoral fellows is almost equal to the number of staff who were employed in teaching duties. When analysing the ages of the staff employed in chemistry departments, the modal age is between 41-50 years old. Figure 10, below, presents this information.

Figure 10: Percentage of all Staff by age



4.2.3.4 Status of chemistry

When respondents were asked to indicate if they thought that the status of chemistry had: risen; remained constant, or had fallen over the last ten years. 5.5 of 13 respondents suggested that the status of chemistry had fallen, with one person suggesting that the status had fallen for students and risen for industry. (As the response was split, the two categories were given 0.5 each). Many of the respondent who suggested that the status of chemistry had fallen pointed to the negative image of chemistry in the media as a contributing factor in the decline in student numbers and interest in the subject. Only 2.5 respondents suggested that the status of chemistry has risen, with five of the 13 suggesting that it had remained constant.

4.4 Overview

Within the tertiary sector there has been a trend over the last 15 years for fewer students to undertake chemistry studies at university level. From the information provided by the 17 universities participating in our survey, there was a mixed response when respondents commented on the quantity of students in undergraduate degrees. Although some universities had increased their numbers of undergraduates, others had lost a large numbers of students. There was also no consensus when it came to the quality of students, with a number of those who thought the quality had decreased commenting on the falling standard of secondary school education. When commenting on laboratories, a number of universities indicated that there was a lower quality of undergraduate laboratories compared to that of research laboratories, with the implication being that low quality laboratories acted as a disincentive for students to continue with chemistry at higher levels. The general feeling, amongst respondents was that the status of chemistry had fallen.

For both undergraduate and postgraduate students, universities had created many links to industry, with these links deemed very beneficial by the universities. The links created between university chemistry departments and secondary schools, however, were not deemed to be as beneficial. This, however, could be due to the fact that potential benefits of such programs are difficult to evaluate. Generally, university chemistry departments were deemed to be currently in a state of status quo.

Chapter 5: The State of Chemistry in Australian Industry

This chapter summarises some of the recent of a literature on the state of the chemical industry in Australia and incorporates some comments from interviews with people involved in the chemical industry. The main focus of the chapter is to present results from an on-line survey devised by the RACI and completed by employers of chemists.

5.1 Industry Sectors

The chemical industry in Australia adds significantly to the Australian economy. In 1999/2000 the industry had a combined turnover of almost $28 billion and total value added of $8.7 billion, which was 12.7% of value added by the manufacturing sector as a whole. The sector also employs a large number of people, with latest estimates at over 90,000 people (Upstill et al, draft).

5.1.1 Broad Chemical Industry

From a review of literature and preliminary interviews it is clear that the size and scale of the traditional chemical industry has changed significantly over the last couple of decades. The industry has been described as comprising three distinct groups in terms of their outputs, level of innovation and their research and development intensities (Simpson et al, 2002) and are as follows:

1 – companies engaged in the production of bulk chemicals, like petrochemicals that typically have low innovation expenditures and research and development intensities

2 – companies manufacturing special purpose chemicals like paints, that typically have more low to medium innovation expenditures and research and development intensities

3 – companies that operate in technology intensive segments including the pharmaceutical, biotechnology and nanotechnology companies

The traditional chemical industry is comprised largely of the first two of these groups and is discussed below. The pharmaceutical, nanotechnology and biotechnology areas will be discussed separately as each area presents a very different picture.

5.1.2 Traditional chemical industry

Since the 1980s, the chemical industry has faced a number of changes in government policy and also increasingly competitive worldwide conditions. For many within the first two groups detailed above the current imperative is to make the existing industry and plant as efficient as possible. This is against a backdrop of low (and declining) re-investment in existing facilities; a lack of investment in new facilities, a growing share of the domestic market being supplied by imports; reduced spending on innovation and low rates of uptake of technology; and a shortage of appropriately skilled employees (CPAAST, 2001). This view was shared by one person interviewed from the chemical manufacturing industry, who commented that 'organizations in this industry need to be constantly improving their production processes and looking for efficiencies in the order of 4% per annum to survive'. With this in mind, Australia faces significant challenges in the chemical business.

Overall performance indicators for the chemicals and plastics sector have been described as static to declining with ongoing challenges that include the following;

- A small domestic market
- No world scale plants
- Supplies of major feedstocks are remotely located
- Australia is geographically removed from major markets
- Tariff protection levels are still high in many countries
- The chemical deficit (exports less imports) is widening (CPAAST, 2001)

Within this context there has been a change in the nature of research activities. Anecdotal reports suggest that the big research and development laboratories that used to be in Australia as part of the larger chemical companies have now been closed. In the case of the multinational organizations research is performed in the home countries and/or in close proximity to the large markets. This in turn erodes the advantages that Australia once had of being able to provide an educated research and development workforce at reasonable cost with good facilities have been surpassed by other countries within the region that offer these advantages with market proximity.

Despite this situation, the traditional chemical industry remains optimistic that there are opportunities for Australia. These include successfully leveraging the capacity and knowledge of public research base in order to provide a source of innovation to the industry, niche manufacturing of high value chemicals and attracting research and development activities of multinational organizations to Australia through the so called 'open innovation models' (Harris-Rees, 2005). An opinion was expressed by people interviewed for this paper that opportunities for the chemical industry existed through the linkages across scientific boundaries. For example, the building of teams of multidisciplinary scientists that included chemists and biologists was seen as a way to obtain better research outcomes.

As the chemical industry is a recognized feeder to a number of other industries within Australia (see Figure 11 below), it may benefit from linkages to these feeder industries. The research scope of the Interim Report had not been able to cover these linkages in any depth, but plans to include some more interviews with people in industry for the final report. The traditional chemical industries are represented by a range of organizations including the Plastics and Chemicals Association, the Australian Consumer and Specialty Chemicals Association, the Australian Industry Research Group and the Australian Industry Group.

Figure 11: Industries to which the Traditional Chemical Industry links into

Source: The Australian Chemicals and Plastics Industry Action Agenda *Government Response*, October 2002.

<u>5.1.3 The Pharmaceutical Industry</u>

The Australian pharmaceutical industry include a turnover of $8.2 billion in 2002/03 (PWC, 2004). In 2000/01, the pharmaceutical manufacturing industry accounted for approximately 28% of Australia's overall chemical industry (on the basis of revenue) (IBIS World, 2001). There are a number of associations that represent this industry including Medicines Australia, Ausbiotech and the Generic Medicines Industry Association.

The pharmaceutical industry has been defined as 'those who contribute to the discovery, creation and supply of pharmaceutical products (chemical and biological) and services. It covers everything from research through clinical trials, to manufacturing of generic pharmaceuticals' (DITR, 2002). In terms of process, pharmaceutical companies receive starting chemicals from the chemical industry and transforms these together with other ingredients into pharmaceutical products under a highly regulated and controlled production, marketing and sales regime.

The Federal Government, through the Department of Industry, Tourism and Resources, works together with industry to create Action agendas, designed to 'enable industry and government to work together to realise opportunities and overcome impediments to growth in specific industries' (DITR, 2005). Through this process the industry has identified and embraced an agenda for action that requires significant investment in research and development particularly in biotechnology to enable Australia to become world class in a global value chain and double Australia's share of the global industry by 2012. Strategies include positioning Australia as a global pharmaceutical hub for research, development and commercialization and as a global exporter of both products and services for the industry. Progress towards the agenda is contained in the *First Year Implementation Report* (DITR, 2003).

At a state level there have also been many initiatives. The Queensland Government has, for example, developed a Pharmaceuticals and Nutraceuticals Skills Formation Strategy to support the existing industry in that state (DSDI, 2005). They also commissioned a study into the pharmaceutical industry within Queensland to examine trends and future outlook, the economic profile of the industry, issues, constraints and opportunities (PWC, 2004). As part of this research there were telephone surveys of forty companies and seven industry associations and a series of workshops on skills development (68 people attended). Most respondents advised of difficulties in attracting and retaining appropriately qualified analytical chemists, including scientists with awareness of Good Manufacturing Practice (GMP), regulatory affairs and quality assurance.

5.1.4 The Emerging Industries – Nanotechnology and Biotechnology

According to Biotechnology Australia 'Biotechnology is a broad term generally used to describe the use of biology in industrial processes such as agriculture, brewing and drug development. It also refers to the production of genetically modified organisms and the manufacture of products from them. Much of the newer activity in biotechnology involves directly modifying the genetic material of living things' (BTA, 2004).

Australia has approximately 400 biotechnology companies employing around 6,000 people, with total revenues of around $2.1 billion dollars in 2004. These companies have high research intensity with an estimated $414 million spent on biotechnology research in 2004 including through the organic chemistry and biochemistry activities. In their comprehensive 2005 BioIndustry Review, Hopper and Thorburn suggest that the outlook for the industry holds promise although there are some gaps in performance and an ongoing dependency on government support (Hopper & Thorburn, 2005).

A number of governments have been active in the biotechnology area, providing support and investment for the emerging Australian industry. The Victorian Government, for example, has stated that: 'Governments, state and federal, have a vital role to play in facilitating growth and development in the biotechnology sector. They do this by creating the right conditions for the industry to succeed, by setting the policy and regulatory framework and through constructive intervention to address market failures' (DIIRD, 2004). They have developed a Strategic Development Plan for Biotechnology in Victoria that aims to position Victoria as one of the top five biotechnology hubs in the world. This Government has provided $500 million in projects to strengthen the sector in order to achieve its aim.

The Federal Government has been active within the Biotechnology space having launched the National Biotechnology Strategy in 2000 to help strengthen Australia's competitiveness in this area and has through the provision of additional funding through the Innovation Statement Backing Australia's Ability. According to the Biotechnology Australia website Federal funding to date for this initiative has been $107 million.

Nanotechnology has been defined by the US National Nanotechnology Initiative (NNI) as including all of the following aspect:

1. Research and technology development at the atomic, molecular or macromolecular levels, in the length scale of approximately 1 - 100 nanometer range.
2. Creating and using structures, devices and systems that have novel properties and functions because of their small and/or intermediate size.
3. Ability to control or manipulate on the atomic scale.

Nanotechnology research involves the interaction of a range of disciplines including chemistry, physics, mathematics, materials science, molecular biology and engineering. The science has potential application in and across a large number of industries including biotech applications, nanoassemblers, nanocomputers, and nanochips along with molecular electronics. It is a growing area that government and business alike are continuing to invest more money in, with global government investments only in 2002 approaching $3 billion (Tegart, 2002).

Worldwide it has been estimated that people needed for nanotechnology research and development will be in the order of 800,000 – 900,000 in the United States of America, 500,000 - 600,000 in Japan, 300,000 – 400,000 in Europe, 100,000 – 200,000 in the Asia-Pacific region without Japan and about 100,000 in other regions (Tegart, 2002).

Within Australia there have been a number of reviews and reports into the nanotechnology industry. For example, research by the Victorian Government, reported on in Chapter 1, highlighted significant shortages across a range of disciplines including chemistry, particularly in the areas of polymer, colloid, organic, bio-inorganic, theoretical and formulations chemistry - all areas which are important in the development and growth of the nanotechnology industry. The Victorian Government has suggested that nanotechnology is an enabling platform that will transform the traditional and advanced manufacturing, health and energy industry sectors. To support the development and growth of nanotechnology in that state an additional 12,000 skilled graduates and workers in micro and nano-enabling disciplines will be required by 2010 (DIIRD, 2003).

5.2 Employer Survey

The RACI devised a questionnaire for employers of chemists. These people were deemed to have a good knowledge of the state of chemistry. They were seen to be in a position to comment on the current, past and future requirements of chemists in regard to numbers, qualifications and experience level of chemists over a number of organisational sectors and chemistry disciplines. The questionnaire was on-line via the RACI web-site from 14 November 2004 until 13 January 1005.

A total of 132 employers responded to the invitation to complete the survey,[1] with the number of chemists employed by these organisations totaling approximately 4,000. The major quantitative findings

[1] A total of 136 responses were received, however, only 132 responses could be used since there were three cases in which two people from the same organisation responded to the questionnaire.

from the data are presented here. The qualitative data will be coded and analysed before the submission of the final report.

Since there are no reliable data sources that predict the number of people working as chemists, it is not possible to predict if the results of this survey are representative of the broader industry although issues which are affecting many people who employ chemists can be discerned from the survey data.

As the RACI is the peak professional body for chemists within Australia, it can be assumed that a large proportion of chemists are members of the RACI. Taking the RACI membership numbers for 2004, an estimate can be made as to the proportion of the chemists that may be captured within the survey sample. Using data from the last three years of RACI membership, it is predicted that in 2004 there were approximately 5410 members who were employed (ie not students or retired). This suggests that the survey collected data from organisations that employed chemists equivalent to approximately 73.9 per cent of the RACI membership. As over two-thirds of the respondents received notification about the survey through RACI communications (n=89/132), this estimate seems likely.

5.2.1 Responding organisations

5.2.1.1 Respondents' Organisational classifications

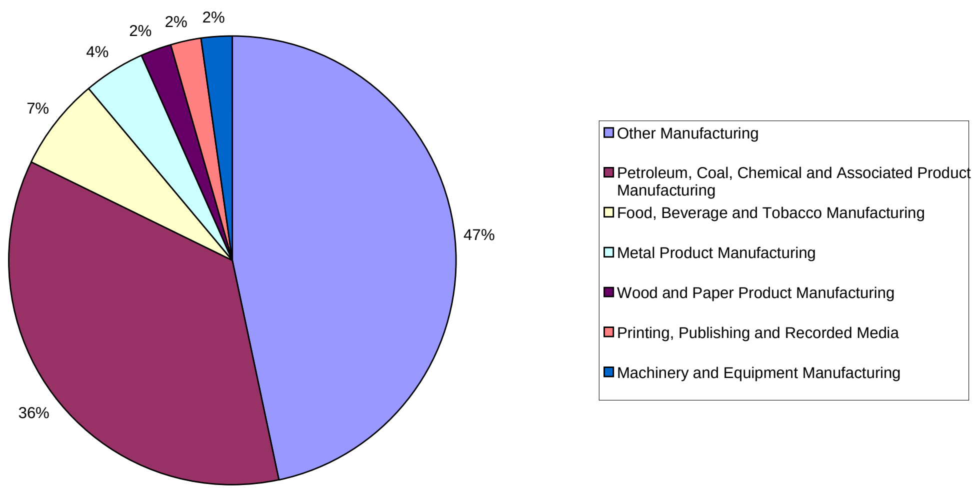
By asking the respondents to classify their organisations an understanding was gained as to what type of organisations employed chemists. The respondents were asked to select from a list of seventeen Australian and New Zealand Standard Industrial Classifications the classification that best described the organisation's core business. The largest group of respondents was from the manufacturing sector, consisting of just over a third of all respondents. The second largest sector was the personal and Other services sector, with 14.5 per cent of all respondents. Three of the seventeen categories recorded no responses, being *Construction*, *Accommodation*, *Cafes and Restaurants* and *Finance and Insurance*. Table 11, below, presents this information.

Table 11: Classification of responding organisations by Number and percentage of total respondents

Organisation's core business	**Number of responses**	**Percentage of respondents (n=132)**
Manufacturing	45	34.1 %
Personal and Other Services	19	14.4 %
Government Administration and Defence	13	9.8 %
Mining	12	9.1 %
Education	9	6.8 %
Health and Community Services	9	6.8 %
Agriculture, Forestry and Fishing	8	6.1 %
Electricity, Gas and Water Supply	4	3.0 %
Property and Business Services	4	3.0 %
Wholesale Trade	3	2.3 %
Transport and Storage	3	2.3 %
Retail Trade	1	0.8 %
Communication Services	1	0.8 %
Cultural and Recreational Services	1	0.8 %

The respondents who classified their organisation's core business as manufacturing were also asked to further specify the type of manufacturing that they were involved in. The largest percentage of these respondents specified that their business was *Other Manufacturing*, with 48 per cent of the respondents. Figure 12, below, presents a graphical breakdown of the type of manufacturing these organisations were involved in.

Figure 12: Types and Percentages of Manufacturing respondents

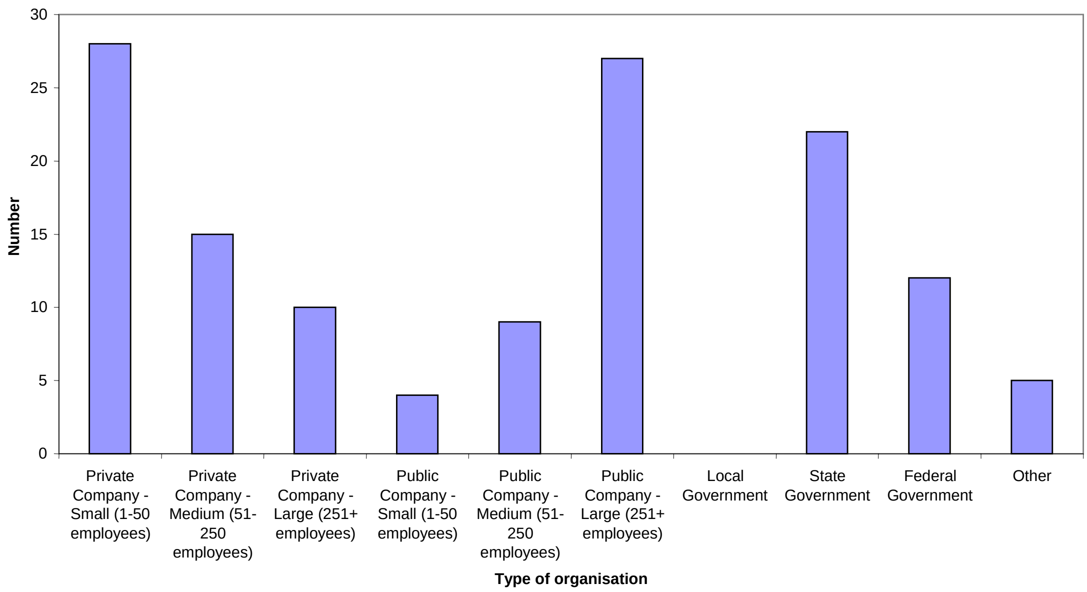


Of the 132 organisations that responded to the survey, over a third of them classified themselves as part of the manufacturing sector, however, the classifications that were on offer to the respondents were not sufficiently specific to categories almost half of the responding manufacturing organisations.

5.2.1.2 Type and size of organisation

In addition to classifying their type of organisation, the respondents were asked to indicate if they worked for private or public industry or for Government organisations. Public companies were deemed to be those publicly listed on the stock exchange. The organisations were also asked to indicate their size, with the categories being: small (a total of 1 to 50 employees, including non-chemists); medium (51-250 employees), and large (250 plus employees). The largest group of respondents, with just over a fifth of all respondents, was small private companies. The second largest group was comprised of large public companies (over 250 employees), also with over a fifth of total respondents. Figure 13, below, presents this data.

Figure 13: Type and Category of responding organisations



Overall, the questionnaire received a good spread over different sectors and sizes of industry, although local governments were not represented.

5.2.1.3 Position of respondent within the company

Respondents were also asked to indicate what their position within the organisation was. Of the 132 respondents almost half described their position within the company/business as general management/research management (n=65). The second most common response was that of Chief Executive Officer/Managing Director, with 13.0 per cent of the responses, with the least most common response being Board Members at only 1.5 per cent of the responses.

5.2.1.4 Number and type of business that chemists are employed in

The total number of chemists employed by the 132 organisations was 3779. However, as one organisation suggested that they employed *100's* of chemists, (which was entered as 200), and three other organisations respond *many* or *lots*, which were not entered numerically, the actual number would be closer to 4000. Table 13 presents the average number of chemists per type of organisation.

Table 12: Average number of chemists per type of business

Type of business	Number of organisations	Number of chemists employed	% of all chemists (n=4000)	Mean ± std.dev number of chemists per company
Private Company - Small (1-50 employees)	28	144	3.6	5.1 ± 4.17
Private Company - Medium (51-250 employees)	15	265	6.6	17.7 ± 16.0
Private Company - Large (251+ employees)	10	142	3.6	17.7 ±16.8
Public Company - Small (1-50 employees)	4	56	1.4	14.0 ± 11.2
Public Company - Medium (51-250 employees)	9	161	4	17.9 ± 15.2
Public Company - Large (251+ employees)	27	1844	46.1	63.6 ± 184.6
Local Government	0	0	0	0
State Government	22	410	10.3	18.6 ± 23.9
Federal Government	12	840	21	70.0 ± 97.0
Other	5	128	3.2	25.6 ± 24.2
All Private	**53**	**551**	**13.775**	**10.4**
All Public	**40**	**2061**	**51.525**	**51.5**
All Government	**34**	**1250**	**31.25**	**36.8**

As can be seen from Table 12, above, Federal government employed the largest mean number of chemists from all respondents to the survey, with a mean number of 70 chemists per organisation. When grouped into public, private or government, the public sector employed the most number of chemists as well as employing the highest mean number of chemists per organization with 51.5 chemists per organisation.

5.2.2 Qualifications of Chemists employed in separate sectors

In order to ascertain if different sectors within organisations employed chemists of different training, were asked the respondents to indicate if they employed chemists over 13 distinct organisational areas, and if so, what training the chemists had undertaken. The categories for level of training were; predominantly university trained chemists; predominantly technically trained chemists; an equal combination, or other.

Over the thirteen categories, businesses were more likely to employ predominantly university trained chemists than technically trained chemists, or even a combination of the two. Within the *predominantly university trained chemists* group there were differences over the thirteen categories, with almost all of the *research only* chemists being predominantly university trained (92 per cent, n=50) and only 26.7 per cent of chemists employed in computing being predominantly university trained (n=15). Table 13, below, presents this data.

Table 13: Percentage of employers who predominantly hire university trained Chemists in 13 various organisational sectors

Organisational sector	% university trained
Research only	92
Management and Administration	87.7
Development	86.2
Research and teaching	77.3
Consulting	70
Production	66.1
Other Organisational Area	65.2
Marketing	62.5
Sales and Service	61.3
Quality Assurance	60.7
Teaching only	60
Analysis and Testing	60
Computing	26.7

Overall, organisations are more likely to employ predominantly university trained chemists. It is only within the computing category that employers are significantly less likely to employ university trained chemists (t-test, $p<.05$).

5.2.3 Is the need for Chemists changing?

There is much anecdotal evidence to suggest that industry's needs for chemists is changing. In this section respondents were asked if their needs for chemists would change in the future, and what the outlook may be.

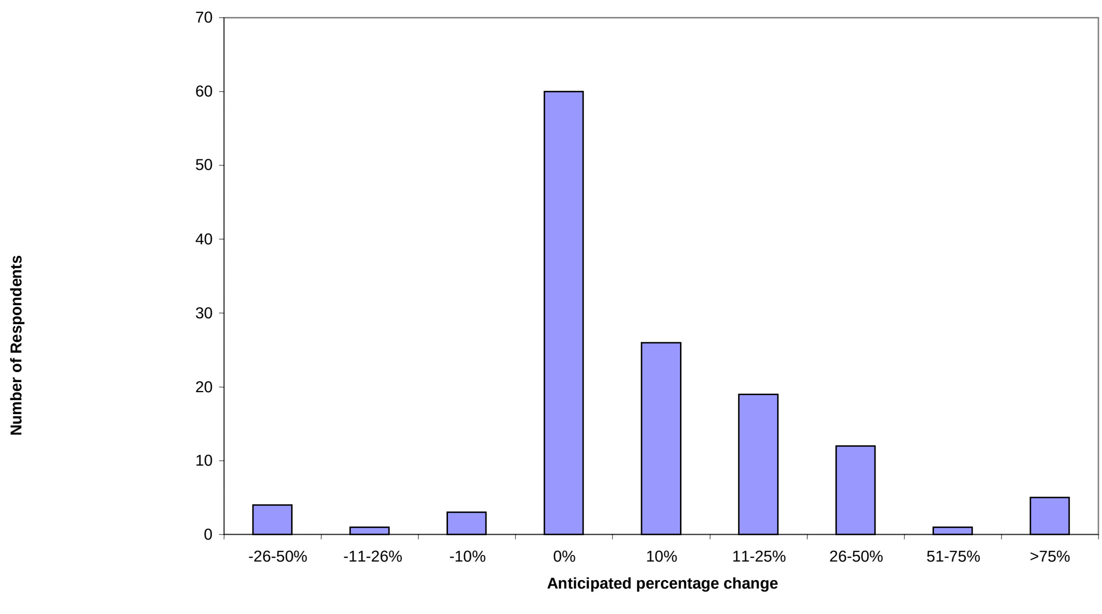
5.2.3.1 Change in the numbers of Chemists needed

Respondents were asked to indicate if their needs for chemists would remain the same or change in ten-years time. There were slightly more respondents who predicted that their needs would change compared with those who believed that their needs would remain stable (n=132, 53.8 cf 46.2 per cent).

The 71 respondents who believed that their requirements for chemists would change were further asked to indicate if their needs for chemists would; grow, or decline. The overwhelming majority (88.7 per cent) believed that their needs for chemists would increase. Only eight respondents believed that the needs for chemists would diminish in ten years time.

Following on from this, respondents were asked to indicate what percentage change that they envisaged would occur in the next ten years. The majority of those who believed change would occur thought it would be a 10 per cent increase on current chemist numbers. Figure 14, presents the numbers and percentage change predicted to occur in the next ten years.

Figure 14: Number of companies predicting percentage change in employment of chemists in 2014



Overall, there is a modest positive grown anticipated for chemists in the next ten years. When the current numbers of chemists captured by this survey are taken into account (ie. 4000), the expected growth in the next 10 years would require an additional 6.5 per cent increase over the next ten years from present levels.

5.2.4 Are the requirements for chemists changing?

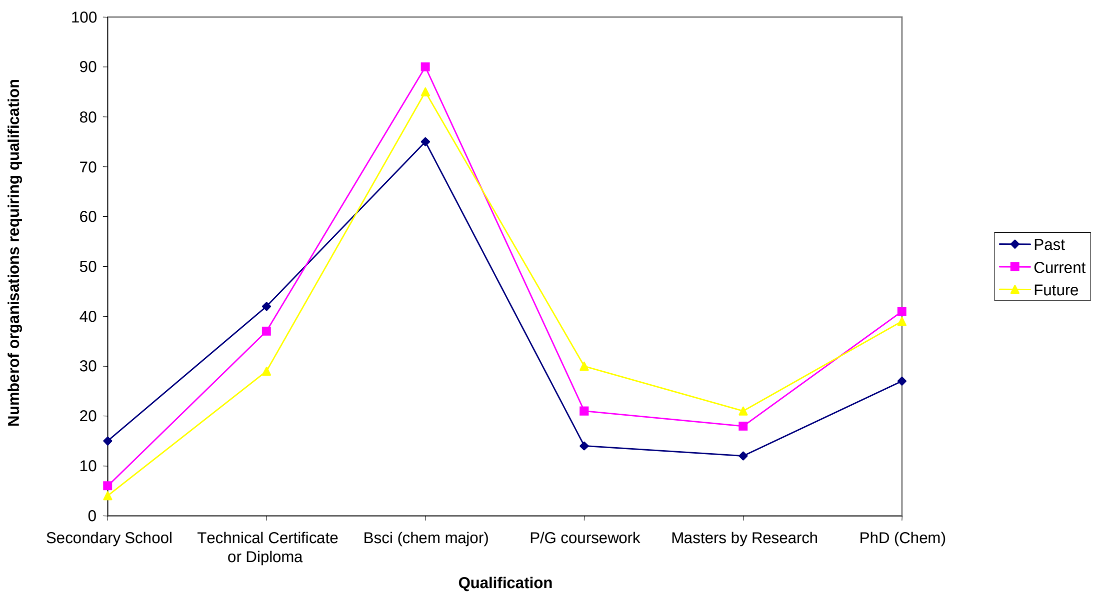
Following on from the previous section, respondents were asked to indicate if the qualifications for chemists employed by their business had in the last ten years, or would in the next ten years change. They were further asked to indicate if their needs had changed in different disciplines of chemistry over the last ten years. The expectation being that if changes in qualifications and/or specific chemical disciplines were indicated then a change in current training techniques may be required.

5.2.4.1 Changing qualification needs

Respondents were asked to indicate from six different qualifications levels which qualification levels of new staff within the organisation were typically required, what they currently require and if the organisation expects their new recruits to have these qualifications in ten-years time. The responses indicate a trend towards more highly qualified chemists from past to current qualifications needed by employees, and for this to change to even higher qualifications needed for chemists in the future.

Employees with a BSc qualification are the most required in all three time phases, indicating that this qualification continues to be the benchmark qualification in the field. However, currently more employees have a BSc than either the past or predicted future needs, with the future tend moving towards more highly qualified employees, especially a predicted need for postgraduate coursework and masters by research. Figure 15, below, demonstrates the number of organisations and their requirements for qualifications of chemists in the past, currently and in the future.

Figure 15: Levels of qualifications typically required



The difference in ratio of past to current qualifications of chemists within organisations is not significant, nor is the difference in the ration of current to future qualifications of chemists (Wilcoxcon signed-ranked test, $n=6$, $p>.01$) indicating that there is no significant change in the distribution of qualifications.

However, there is a trend for more highly qualified chemists in postgraduate course work and masters research.

5.2.4.2 Difficulties experienced in recruiting people with chemistry qualifications

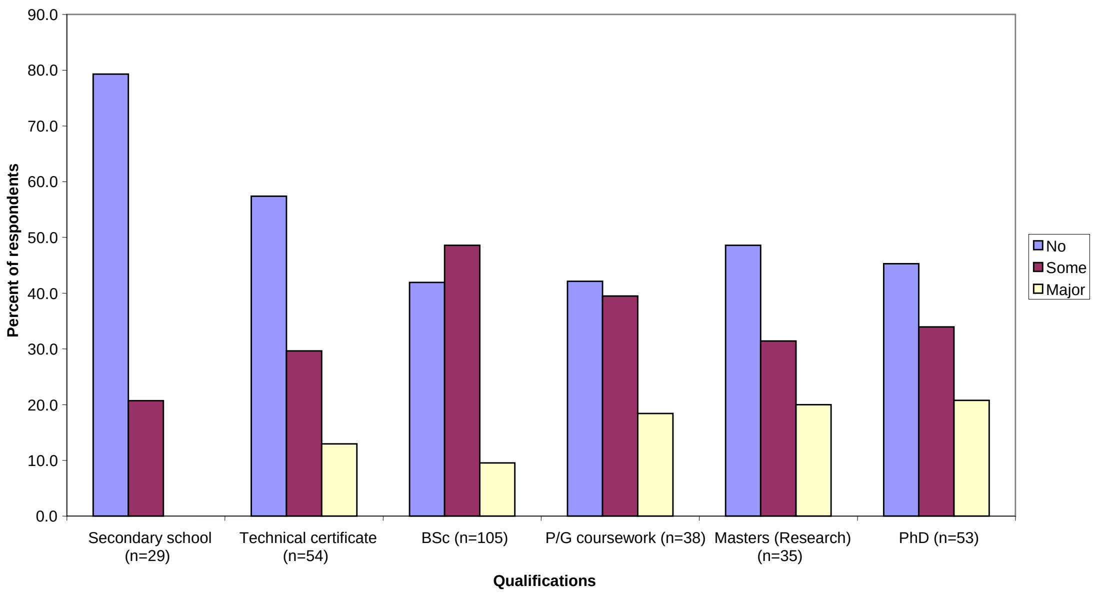
Following on from questions of qualifications of employees, the respondents were asked to comment on whether they had experienced problems when trying to recruit people from the six qualification categories used above. Responses to this question were optional and 122 people chose to answer the question in some form. Respondents were given the option of indicating; No difficulty; some difficulty, or major difficulty.

As may be expected, respondents did not have any difficulties recruiting people with secondary school chemistry qualifications. However, respondents reported some to major difficulties when trying to recruit people with a Bachelor of Science (Chemistry major) or with a postgraduate coursework qualification.

There is a significant difference between the percentages of respondents who indicated that they had no difficulties compared with those who had difficulties in recruiting over the different levels (t-test test, two-tailed, $p<.05$), indicating that more people have problems in recruiting than not.

Respondents were asked to indicate if they had had no, some or major difficulties. Over a fifth of the respondents (n=27/122) indicated that they had major difficulty in recruiting chemists at some level. Of these, the majority had difficulties in only one area of qualifications, seven respondents reported difficulties in recruitment in two areas and four respondents in three areas. Figure 16, below, presents this information.

Figure 16: Difficulties in recruitment with different chemistry qualification



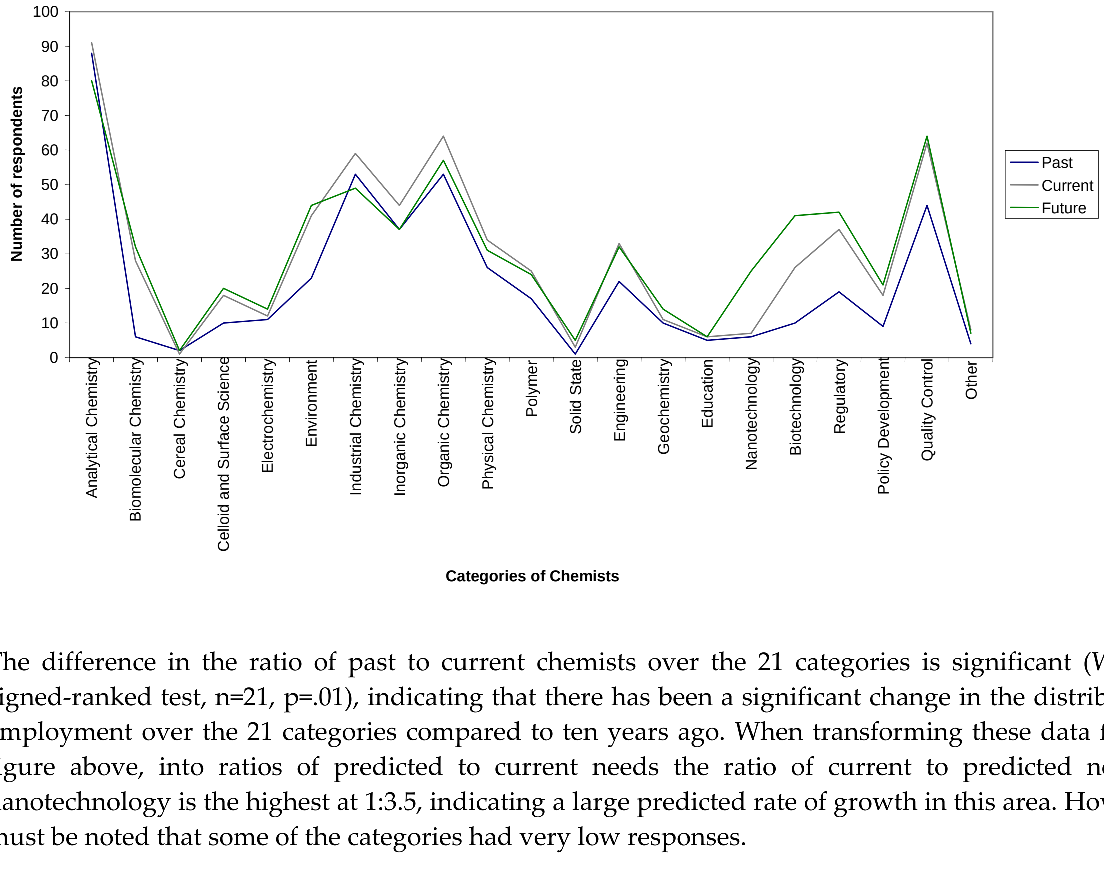
Overall, respondents had difficulty in recruiting suitably qualified chemists, with the Bachelor of Science qualification being the most common qualification in which organisations had difficulties filling.

5.2.4.3 Changing needs in types of chemists required

In order to obtain information on the changing needs of industry in regards to specific chemistry areas, respondents were asked to indicate what areas of chemistry (traditional and/or emerging) have the staff within their organisation typically required, currently require and also what areas will they require in ten years time.

Currently, the area in which most organisations employ chemists is analytical chemistry, with over two-thirds of the respondents employing chemists in this area (n=91/132). This is also the area in which traditionally most chemists were employed, and also the area in which it is predicted that the most chemists will be employed. Figure 17, below, presents the numbers of past, current and predicted numbers of chemists needed over 21 areas.

Figure 17: Numbers of respondents that employ types of chemists



The difference in the ratio of past to current chemists over the 21 categories is significant (Wilcoxon signed-ranked test, n=21, p=.01), indicating that there has been a significant change in the distribution of employment over the 21 categories compared to ten years ago. When transforming these data from the figure above, into ratios of predicted to current needs the ratio of current to predicted needs for nanotechnology is the highest at 1:3.5, indicating a large predicted rate of growth in this area. However, it must be noted that some of the categories had very low responses.

5.2.4.4 Difficulties in recruiting people with chemistry qualifications in specific disciplines

Respondents were asked to indicate if they had experienced difficulties in recruiting people with qualifications in the 21 categories described in the above section. They were asked to indicate if they had

had the following difficulties in recruiting; none; some or major. Of the 125 respondents who responded to this question, 29.6 per cent of the (n=37) reported major difficulties in recruiting people in the 21 categories listed.

The largest proportion of respondents reporting major difficulties in recruiting people, were those in the *Colloid and Surface Science* sub-group. Of the twelve people who responded, five recorded major difficulties in recruiting. Table 14, below, presents the percentage of people who had had no difficulties in recruiting, along with the percentage of people who have had difficulties.

Table 14: Percentage of respondents who have had difficulties in recruiting and those who had not had difficulties in recruiting

Area	No	Yes
Analytical Chemistry (n=82)	45.1	54.9
Biomolecular Chemistry (n=25)	44.0	56.0
Cereal Chemistry (n=3)	66.7	33.3
Colloid and Surface Science (n=12)	25.0	75.0
Electrochemistry (n=12)	33.3	66.7
Environment (n=36)	38.9	61.1
Industrial Chemistry (n=51)	31.4	68.6
Inorganic Chemistry (n=37)	35.1	64.9
Organic Chemistry (n=50)	36.0	64.0
Physical Chemistry (n=27)	37.0	63.0
Polymer (n=20)	40.0	60.0
Solid State (n=4)	75.0	25.0
Engineering (n=23)	39.1	60.9
Geochemistry (n=9)	44.4	55.6
Education (n=4)	75.0	25.0
Nanotechnology (n=11)	18.2	81.8
Biotechnology (n=19)	21.1	78.9
Regulatory (n=25)	32.0	68.0
Policy Development (n=9)	44.4	55.6
Quality Control (n=44)	59.1	40.9
Other (n=8)	50.0	50.0

The areas of solid state and education, were significantly less likely to have had trouble with recruitment than any other areas (t-test, $p<.05$), however, it must be noted that both of these areas both only had four respondents. Amongst those who had had difficulties in recruiting, there were no significant differences amongst the groups, indicating that no one area had had significantly more difficulties than others (t-test, $p>.05$).

5.2.5 Level of Experience required by Industry

5.2.5.1 Experience required of new employees

Respondents were asked to indicate what level of experience that they required of their new recruits, the options being; non-university trained chemists; fresh university trained graduates; chemists with some experience, and chemists with significant experience. The question was mandatory with the three categories of time being: never; sometimes, or most of the time.

Over half of all responses to this question (52.7 per cent) were *sometimes*. There is a significant variance between groups (ANOVA, df=3, $p<.05$), indicating that each group is treated differently in the hiring process. Table 15, below, presents the percentage over three categories that respondents employ new employees with different qualifications.

Table 15: Percentage of time respondents employed new employees with different qualifications

	Non uni trained	Graduates	Chemist with some experience	Chemists with significant experience
Never	50.0%	12.1%	2.3%	8.3%
Sometimes	43.9%	72.7%	39.4%	54.5%
Most of the time	6.1%	15.2%	58.3%	37.1%

As Table 15 indicates, half of the respondents *never* employed non-university trained chemists. When indicating how often they hire graduates, respondents indicated that mostly they *sometimes* hire fresh graduates (72.7 per cent).

Over half of the respondents (58.3 per cent) suggested that *most of the time* they employed Chemists with some experience. Amongst those chemists with significant experience, over half the respondents (54.5 per cent) suggested that they employed this group *sometimes*, with over a third (37.1 per cent) indicating that *most of the time* such chemists were hired.

5.2.5.2 Strategies undertaken by organisations to ensure that they attract/recruit and /or retain chemists

Respondents were asked if they undertook specific strategies to attract, recruit and/or retain chemists. Over half (60 per cent) suggested that they had strategies in place. The respondents were further asked to rank from a list of 17 strategies those that they used on a scale from 1 to 5, where one was the least important and five was the most important.

In order to ascertain if the design of the survey captured significant patterns of variation in encouraging employment, a one-way ANOVA was performed on the data, which produced a highly significant result (ANOVA, df=16, $p<.001$). This indicates that the ranking of results is not random.

The three most common responses to this question were *Career development opportunities / promotions into management* (n=76), *Pay for training and development* (n=74) and *Conference attendance* (n=74). Amongst the 17 strategies, the two with equally the highest mean was *Pay for training and development* and *Career development opportunities/promotions (other)*, both with a mean score of 3.8. The next highest mean was for the strategies of *Career development opportunities/promotions into management* and *Pay above the award salaries*, both with a mean of 3.7.

These top rating strategies suggest that organisations place worth on training and development and ensuring that their employees have access to promotions. However, the fact that *Career development opportunities/ promotions into management* as a strategy to attract, recruit or retain chemists has a high mean may reflect the internal hierarchies of many organisations. Table 16 below, presents these strategies and their corresponding means.

Table 16: Strategies that organisations employ to attract, recruit or retain chemists

Strategies	Mean
Pay for training and development	3.8
Career development opportunities / promotions other	3.8
Career development opportunities / promotions into management	3.7
Pay above the award salaries	3.7
Work/life balance arrangements	3.6
Provision of state of the art equipment and facilities	3.5
Conference attendance	3.3
Participation in professional associations	3.3
Pay award salaries	3.1
Salary sacrificing schemes	3.1
Incentive / bonus scheme	2.9
Employee benefits eg parking, car, insurance, travel opportunities	2.7
Payment of professional association fees	2.6
Publication of scientific findings in peer journals	2.6
Employee share option scheme	2.1
Other	2
Recruit from international markets	2

The strategies which organisations placed the least emphasis on was *Recruiting from international markets* (mean 2), indicating that there is no major undertaking from within the respondents of this survey to recruit offshore.

Overall, 60 per cent of organisations had measures in place to attract, recruit or retain chemists, with the two measures seen to be the most important being 'career development' and 'pay above the award salaries'.

5.2.5.3 Strategies undertaken to ensure there will be an ongoing supply of chemists for Australia

Although sixty per cent of the respondents indicated that they had strategies in place in their own organisation to ensure that they attracted, recruited and retained chemists, over three quarters of the total respondents (n=100/132) did not have any strategies in place to ensure that there will be an ongoing supply of chemists for Australia.

The 32 respondents who indicated that they did have strategies in place were asked to indicate from a list of nine options, whether they currently had a strategy in place, or if this strategy was under consideration. Each of the 32 respondents marked on average 5.7 of these strategies, indicating a large commitment on behalf of the organisations.

In regard to ensuring that there will be a constant supply of chemists within Australia, the most common response to current strategies was that the organisation was itself *Active in professional associations* (n=25), with the second most common strategy actively engaged in now being *Sponsorship of undergraduate students/PhD or other scholarships* (n=20).

The strategy which was under consideration by the largest proportion of organisations was becoming *Active in scientific and technical networks* (n=8), with *Have links into tertiary institutions (universities and TAFEs) to influence curriculum and training* and *Other* both being the second most common strategy under consideration with four responses each.

5.2.6 Is there a shortage of chemists, and if so, why?

5.2.6.1 The shortage of chemists

When asked if there was a shortage of chemists within Australia, respondents were relatively evenly divided, with slightly more respondents (51.5 cf 48.5 per cent) believing that there was a shortage than those who did not think there was a shortage. Respondents were also asked to fill out an open-ended comment as to why they held the view they did. These responses will be coded and analysed before the final report is presented. Some of the themes which came out of the open-ended comments include the image of chemistry in a school environment, the public images of chemists, and low wages.

Comments relating to education include the following:

> The increasing unpopularity of chemistry as a career and as a school subject. Maybe the average school student does not understand what a broad range of employment is available to chemists. Many experienced chemists eventually find themselves in management roles where their chemical skills are no longer used.
>
> Chemistry is classed as "too hard" subject in school.

And,

> The shortage is a shortage of TRAINED or suitably experienced chemists. I believe a prime cause of this is the course material being offered often is not targeted at what the majority of students will do in the industry - it has a more academic approach which is suitable for those wanting to go on and perform pure research in Universities as a career. I also believe a prime cause is because a lot of students don't see chemistry as a career in itself, so it is taken as an extra course to add some additional skills to their main career path/degree.

Comments relating to the image of chemistry included:

> For decades the media has portrayed chemistry with only negative connotations - chemistry presented as 'polluting, dangerous, toxic etc' and there has been no attempt by RACI to correct these emotive misconceptions and promote the positive benefits of chemistry to the media.

And,

> As an industry we don't sell ourselves well and struggle to compete with the perception that other occupations are more attractive…Industry in Australia does not invest adequately in chemical research and development and is not active enough in encouraging young people to undertake chemistry as a career. Media coverage of science in Australia is pathetic and tends to focus on the negative aspects of science. Outside of forensic science there are no positive examples of chemistry as a career in TVs/shows.

Overall, there was no clear view on whether there was a shortage of chemists or not. However, what is clear is that if the image of chemistry needs to be improved amongst students and the general public, in order to ensure a continued supply of people willing to study chemistry.

5.2.6.2 The status of chemistry

Given the options of falling, constant, or constant, 62 per cent believed that the status of chemistry in Australia was falling (n=82/132). Almost a third of respondents believing that the status was remaining constant (n=42/132) and only eight respondents believing that the status of chemistry in this country was rising. As with the above question, respondents were also asked to fill out an open-ended comment as to why they held the view they did. These responses will be coded and analysed before the final report is presented.

Within the responses there were a number of associated themes including the relationship between remuneration and prestige, and the need for chemistry to be better understood amongst the general public. A sample of representative responses follows:

Comments on remuneration and prestige include:

> I believe that chemists are not valued. The most common reason I hear why people avoid chemistry and science in general is that you do not get the financial reward for the effort required.

And,

> Chemistry, and technical professions in general, are typically not rewarded well either financially or accorded much prestige in Australia. With an increasing "Americanisation" of our culture and the accompanying rise in the relative importance of being rich and "important" the relative merits of technical work are increasingly discounted.

Comments relating to the general public's impression included:

> It is a classical discipline that hasn't embraced new thinking and technology. It needs to be slowly but surely packaged differently. I am sure the man on the street would still equate chemistry to white coats and explosions. Chemicals are probably still seen to be harmful.

And,

> Chemists seemed to be viewed as pariahs or worse by the community at large. Our profession is more identified with environmental disasters and weapons of mass destruction than with many positive contributions that chemistry makes to our everyday lives.

The final comment presented here relates to the standing of the profession in the eyes of the general public:

> Without professional registration we are not taken seriously. The professions with registration boards are able to control the public image of the profession, enforce continuing educations, maintain standards and ethics and control the market and thus wages. We can do none of theses.

Overall, the status of chemistry was seen to be falling in the view of industry respondents. The factors affecting this were related to low remuneration, which was seen to be linked to low prestige, and the general public's misconception about chemists, chemistry and chemicals.

5.2.7 Overview

The Australian chemical industry comprises of traditional and emerging technologies. These sectors have different factors which will influence their future potential. Some industries, such as nano- and biotechnology industries have been, have been the focus of Federal and State attention as areas of potential growth. Other, such as the pharmaceutical industry, have created action agendas to position themselves as world class participants in the global markets. The common feature of all of these industries, however, is the need for a supply of quality chemists.

The 132 respondents to the RACI employer survey represented an estimated 4000 chemists working within industry in Australia. The responding organisations included many different sectors, with manufacturing being the largest responding sector, and also had responses from all states and territories within Australia. Respondents were more likely to employ university trained chemists, with there being a modest expected growth predicted for the next ten years in the industry. There was a trend towards hiring more qualified chemists, with there being recruitment difficulties over all levels of qualifications and also areas of chemistry, except for solid state and education. There was no clear conclusions as to if there was a shortage of chemists, however, it was clear that industry respondents believed that the status of chemistry was falling.

The final report will include some in-depth interviews with industry representative and also with those working as chemists within the industry.

Chapter 6: Summary of issues

The future of chemistry is tied to the industries that provide the pathways for chemists, including the traditional and emerging technologies. From the research that has been undertaken for this Interim Report it is apparent that the future of the chemical industry in Australia is very much dependent on research and development activities that will provide an ongoing source of innovation. This will enable such industries to continue to compete in the global marketplace while making significant economic contributions to the country.

Research and development has been identified by both the EU and the USA as an engine for growth. The EU has established a research and development target of 3% of GDP by 2010 with 2/3 of this being performed within the private sector. The US is already performing at near these levels.

While Australia does not have research and development targets, if it is realistically going to achieve the industry goals of the chemical, pharmaceutical, biotechnology and nanotechnology industries then many more scientists and engineers (and therefore chemists) will be needed.

From the research to date a number of trends and challenges have emerged:

- The status (or standing) of chemistry is declining according to 62% of respondents of the on-line employer survey and 42% of the universities who answered the questionnaire.
- The respondents of the employer survey was fairly evenly split in terms of believing there to be a shortage of chemists (51.5% Yes compared to 48.5% No).
- A fifth of responding organizations experienced major difficulties in recruiting chemists for their organizations (n=27/122).
- Employers were more likely to employ university trained chemists, with there being a trend over the last ten-years to hire more qualified chemists.
- There has been a decline in the number of students studying chemistry over the period 1989 – 2003 as a percentage of total students (2.3% down to 1.7%).
- There is a general concern that science teaching at secondary levels is not preparing students suitably for university level chemistry courses, and that the level of student engagement in secondary school science has declined.
- Agendas for the chemical industry see opportunity for the traditional chemical companies in the specialist manufacturing area, attracting investment through the research and development sector, innovation and application from the emerging areas of science- biotechnology and nanotechnology

- The pharmaceutical industry through its Action Agenda Local Priority – Global Partner is aiming to double its share of the global pharmaceutical industry by 2010 through a range of strategies including becoming a global research and development and innovation hub

- Governments and organisations are increasing their investments in the biotechnology and nanotechnology areas to foster new industries for Australia. The initial phases involve policy development and soft research and development investments as well as hard infrastructure investments

The purpose of this Interim Report is to generate feedback within the community and to invite comments about whether or not Australia is going to pursue and will be able to pursue the agenda of these industries and build a strong research and development sector.

The RACI is committed to ensuring a healthy and vibrant community of chemists in this country and looks forward to hearing from you to assist it in completing the picture (or pictures) of the future of chemistry.

Responses should be sent by April 29, 2005 to future@raci.org.au

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Appendix 1: University Survey

QUESTIONNAIRE FOR HEADS OF CHEMISTRY DEPARTMENTS
YOUR UNIVERSITY___________________________Campus:____________
SECTION 1 - UNDERGRADUATE STUDENTS

AREA	QUESTION	ANSWER	
Entry scores	1 (a) What is the current (2004) University Entry Score for Bachelor of Science (Chemistry) courses or equivalent?	Score	
	1 (b) Do you have any comments on the current TER score?		
Trend on entry score	2 (a) In the last 10 years has the Entry Score been	Rising	
		Constant	
		Falling	
		Do not know	
	2 (b) If able, please provide a 10 year history of entry scores to substantiate your answer and for our research.	1994	
		1995	
		1996	
		1997	
		1998	
		1999	
		2000	
		2001	
		2002	
		2003	
	2 (c) Do you have any comments on the impact of this trend?		
	2 (d) If able, please provide a longer historical perspective on the entry scores in five year intervals?	1990	
		1985	
		1980	
Department capacity	3 (a) How many places are there in undergraduate chemistry courses?	First year	
		Second year	
		Third year	
		Fourth year	
	3 (b) What is this number as a percentage of	Total science students	

		Total students at your university	
	3 (c) In the last 10 years has the places in undergraduate chemistry courses been?	Rising	
		Constant	
		Falling	
		Do not know	
	3 (d) If able please provide a 10 year history of this figure to substantiate your answer and for our research purposes?	1994	
		1995	
		1996	
		1997	
		1998	
		1999	
		2000	
		2001	
		2002	
		2003	
Quality of students	4 (a) Over this 10 year period has the quality of the students been	Rising	
		Constant	
		Falling	
		Do not know	
	4 (b) Do you have any comments on the quality of students?		
	5 (a) Over the duration of the undergraduate course, what percentage of time is spent in each of these areas?	Laboratory	
		Classroom	
		Computer Lab	
		Field trips	
		Other	
	5 (b) Is this appropriate?	Yes	
		No	

	5 (c) Please provide comments.		
Secondary School Interaction	6 (a) Is there specific interaction between your department and secondary schools and their students?	Yes	
		No	
	6 (b) If yes please describe (i) the nature of the activity and the schools and/or organisations involved?		
	(ii) rate the level of benefit from 1 to 5 (1 not beneficial - 5 very beneficial)		
Industry Interaction	7 (a) Is there specific interaction between your department and industry in the undergraduate area?	Yes	
		No	
	7 (b) If yes please describe (i) the nature of the activity and the companies involved?		
	(ii) rate the level of benefit from 1 to 5 (1 not beneficial - 5 very beneficial)		
Chemistry Curriculum	8 (a) Have there been significant changes to the chemistry curriculum in the last 10 years?	Yes	
		No	
	8(b) If yes please describe the changes and rate the level of benefit from 1 to 5 ? (1 not beneficial - 5 very beneficial)		
Course Coverage	9 (a) Do you believe that at the end of the undergraduate courses that students are skilled in the following areas?	**Area**	**Rating 1 -5**
		Applied chemistry	
		Fundamental chemistry	
		Analytical chemistry	
		Intellectual property	
		Commercialisation areas	
		Business areas	
	use a rating system of 1 – 5 (1 not skilled to 5 very skilled)	Operational areas	
		Teaching	
	9 (b) Do you have any comments in regard to course coverage?		
Student Issues	10 (a) What do you see as the main difficulties faced by the undergraduate chemistry students? (please indicate as	Career related	
		Course related	
		Financial	

	many as appropriate)	Outside work commitments	
		Personal	
		Other	
	10 (b) Please provide comments.		
	10 (c) What does the department do to provide assistance with these difficulties?		
	10 (d) What does the university do to provide assistance with these difficulties?		
	11 (a) What do you see as the main reasons that undergraduate students do not continue with chemistry studies? (please indicate as many as appropriate)	Career related	
		Change of course preference	
		Course related	
		Financial	
		Outside work commitments	
		Personal	
		Other	
	11 (b) Please provide comments.		
	12 Do you have any suggested strategies to provide assistance to students?		

SECTION TWO – GRADUATES

AREA	**INFORMATION**	**ANSWER**			
Department capacity	1 (a) How many graduates do you have in each of the following areas?	**Course**	**Number**	**% of graduates**	**% capacity of department**
		PhD Research			
		PhD Coursework			
		Masters Research			
		Masters Coursework			
		Other			
	1 (b) How are				

	these numbers determined and what are the influencing factors?	
	2 For each of these courses please answer the following	(see table below)

Course	**No of applicants**	**% local**	**% overs.**	**% fee paying**	**% HECS**	**% industry scholar.**	**APA etc Scholar**
PhD Research							
PhD Coursework							
Masters Research							
Masters Coursework							
Other							

	3 What are the allowable times and average times to complete these courses?	(see table below)

Course	Time allowed	Average time taken
PhD Research		
PhD Coursework		
Masters Research		
Masters Coursework		
Other		

Graduate Student Issues	4 What percentage of graduate students complete their course?	(see table below)

Course	**%**
PhD Research	
PhD Coursework	
Masters Research	
Masters Coursework	
Other	

Course Coverage	5 (a) Do you believe that at the end of the graduate courses that students are skilled in the following areas? use a rating system of 1 – 5 (1 not skilled to 5 very skilled)	(see table below)

Area	**Rating 1 - 5**
Applied chemistry	
Fundamental chemistry	
Analytical chemistry	
Intellectual property	
Commercialisation areas	
Business areas	
Operational areas	
Teaching	
Other (please describe)	

	5 (b) Do you have any comments in regard to course coverage?		
Industry Interaction	6 (a) Is there specific interaction between your department and industry in the graduate area?	Yes	
		No	

	6 (b) If yes please describe (i) the nature of the activity and the companies involved?	
	(ii) rate the level of benefit from 1 to 5 (1 not beneficial - 5 very beneficial)	
	6 (c)Do you have any suggested new initiatives?	

SECTION THREE – STAFF

AREA	**QUESTION**	**ANSWER**	
Department condition	1 (a) Would you describe your department in a stage of?	Growth	
		Status Quo	
		Decline	
	1 (b) Please provide comments.		
Capacity	2 (a) How would you rate your physical resources on a scale of 1 to 5? (where 1 is completely inadequate and 5 is state of the art)	**Resources**	**Rating 1-5**
		Equipment	
		Laboratories	
		Computer resources	
		Library services	
		Other (please describe)	
	2 (b) Please provide comments.		
Number of staff	3 (a) Please provide EFT numbers of staff in the following categories	**Category**	**EFT**
		Teaching	
		Research	
		Post Doctoral	
		Fellowships	
		Administration	
		Other	
	3(b) Please categorize the teaching and research staff into the following age groups	<30 years	
		31-40 years	

		41-50 years	
		51-60 years	
		61-65 years	
		>65 years	
Support	4 (a) Does the university have active career planning programs for these staff?	Yes	
		No	
	4 (b) If yes please describe the programs?		
	4 (c)Is the career planning function performed?	Within the department	
		Within the university	
		Outsourced	
	4 (d) Please provide comments.		
	5 What percentage of your staff academic staff were trained?	At your university	
		At an Australian university	
		At an overseas institution	
	6 (a) How would you describe the morale in the department using a scale of 1 to 5 with 1 being poor and 5 being very positive?		
	6 (b) Please provide comments.		
	7 (a) What do you see as the main difficulties faced by the staff within the department? Please provide comments.		
	7 (b) What does the department do to provide assistance with these difficulties?		
	7 (c)What does the university do to provide assistance with these difficulties?		
	7 (d) Do you have any suggested strategies to provide assistance?		
Industry Interaction	8 (a) Is there specific interaction with industry in the department?	Yes	
		No	

	8 (b) If yes please describe (i) the nature of the activity and the companies involved? (ii) rate the level of benefit from 1 to 5 (1 of not beneficial - 5 very beneficial)		
	8 (c)Do you have any suggested new initiatives to link industry and universities?		
Department links to Professional Associations	9 (a) What links does your department have to professional organisations and rate how beneficial have the links proved with 1 not beneficial and 5 very beneficial?	**Professional Organisation**	**Rating on how beneficial**
	9 (b) Do you have any suggested ways of better linking professional organisations and universities?		
Course Reviews	10 (a) Do you undertake course reviews?	Yes	
		No	
	10 (b) If yes how often does it happen?		
	10 (c) Please describe the process?		
RACI Accreditation	11 (a) Do you think the RACI accreditation process is beneficial?	Yes	
		No	
	11 (b) Do you have any comments?		
Industry View	12 (a) Do you believe that your staff has a clear understanding of Australian industry?	Yes	
		No	
	12 (b) Do you believe they understand how their work contributes to its continuing development?	Yes	
		No	
	12 (c) Please provide comments.		

SECTION FOUR – CHEMISTRY OVERVIEW

Chemistry at all stages	1 Do you have any comments about chemistry within the Australian context and what if any action needs to happen to keep the discipline strong, vibrant and viable?	

Value	2 What do you see as the value of a chemistry degree in Australia today?		
Marketing and Communication	3 What marketing activities do you undertake specifically in regard to your chemistry degrees and how successful do you believe these activities are?		
Have your say	4 (a) Do you believe the status of chemistry in Australia is	Rising	
		Remaining Constant	
		Falling	
	4 (b) Please provide comments?		
	5 (a) Do you have any comments on the state of Chemistry in Australia in general?		
	5 (b) Do you have any specific comments on the state of chemistry in secondary schools?		
	5 (c) Do you have any specific comments on the state of chemistry in universities?		
	5 (d) Do you have any specific comments on the state of chemistry in industry?		
	6 Please provide any further comments that you think relevant to chemistry within Austalia.		

Thank you for taking the time to complete this survey. The RACI believes that it is important to investigate the Australian University sector to identify emerging issues that will effect the supply and demand of chemists. This survey is being sent to and completed by every Australian university with a Chemistry Department.

Should you have any questions please contact Felicity Jensz at the RACI National Office on (03) 9328 2033 or via email at future@raci.org.au.

Reports about this Project will be published on the RACI website at www.raci.org.au.

Appendix 2: Where Chemistry is placed within Australian Universities

UNIVERSITY	Faculty/Division	Department/School name	Discipline/Area of Study
Australian National University, The	Faculty of Science	Department of Chemistry	Research School of Chemistry
Central Queensland University	Faculty of Arts Health & Sciences	School of Chemical and Biomedical Sciences	
Charles Darwin University	Faculty of Education, Health and Science	School of Science and Primary Industries	Discipline: Chemistry
Charles Sturt University	Faculty of Science and Agriculture	School of Science and Technology	Discipline: Chemistry
Curtin University of Technology	Division of Engineering, Science and Computing]	School of Applied Chemistry	
Deakin University	Faculty of Science and Technology	School of Biological and Chemical Sciences	
Edith Cowan University	Faculty of Computing, Health and Science	School of Natural Sciences	Discipline: Chemistry
Flinders University of South Australia, The	Faculty of Science and Engineering	School of Chemistry, Physics and Earth Sciences	
Griffith University	Faculty of Science	School of Science	
James Cook University of North Queensland	Faculty of Medicine, Health and Molecular Sciences	School of Pharmacy and Molecular Sciences	
La Trobe University	Dean, Faculty of Science, Technology and Engineering	Department of Chemistry	
Macquarie University	Division of Environmental and Life Sciences	Department of Chemistry	
Monash University	Faculty of Science	School of Chemistry	
Murdoch University	Division of Sciences and Engineering	School of Engineering	

		Science, Physical Sciences division	
Queensland University of Technology	Faculty of Science	School of Chemical and Physical Sciences	Teaching area: Chemistry
RMIT University	School of Science, Engineering and Technology	Applied Science	Applied Chemistry
Swinburne University of Technology	Faculty of Engineering and Industrial Sciences	School of Engineering and Science	
University of Adelaide, The	Dean of Sciences	School of Chemistry and Physics	Discipline: Chemistry
University of Canberra	Division of Health, Design and Science	School of Resource, Environment and Heritage Sciences	Environmental & Analytical Chemistry
University of Melbourne, The	Faculty of Science	Department of Chemistry	
University of New England, The	Faculty of the Sciences	School of Biological, Biomedical and Molecular Sciences	
University of New South Wales, The	Faculty of Science	School of Chemistry	
University of Newcastle, The	Faculty of Science and Information Technology	School of Environmental and Life Sciences	Discipline: Chemistry
University of Queensland, The	School of Science, Engineering and Technology	School of Molecular and Microbial Sciences	Subsection: Chemistry
University of South Australia	Division of Health Sciences	School of Pharmacy and Medical Sciences	
University of Southern Queensland	Faculty of Sciences	Biological and Physical Sciences	Areas of study: Chemistry
University of Sydney, The	Faculty of Science	School of Chemistry	
University of Tasmania	Faculty of Science, Engineering and Technology	School of Chemistry	
University of Technology, Sydney	Faculty of Science	Department of Chemistry, Materials and	

		Forensic Sciences	
University of Western Australia, The	Faculty of Life and Physical Sciences	School of Biomedical and Chemical Sciences	Major Discipline: Chemistry
University of Western Sydney	College of Science, Technology and Environment	School, Science, Food & Horticulture	
University of Wollongong	Faculty of Science	Department of Chemistry	
Victoria University	Faculty of Science, Technology and Engineering	School of Molecular	

Appendix 3: RACI accredited courses

UNIVERSITY	**Faculty/Division**	**Degree/Course**
Australian National University, The	Faculty of Science	BSc (Chemistry)
Central Queensland University	Faculty of Arts Health & Sciences	BSc (Chemistry)
Charles Darwin University	Faculty of Education, Health and Science	
Charles Sturt University	Faculty of Science and Agriculture	BAppSc (Analytical Chemistry) BSc (Chemistry major)
Curtin University of Technology	Division of Engineering, Science and Computing]	BSc (Applied Chemistry) BSc (Science with Chemistry Major)
Deakin University	Faculty of Science and Technology	BSc (Chemical Sciences) B Forensic Science
Edith Cowan University	Faculty of Computing, Health and Science	BTech (Applied and Analytical Chemistry)^ BSc (Applied Chemistry)
Flinders University of South Australia, The	Faculty of Science and Engineering	BSc (Chemistry)
Griffith University	Faculty of Science	BSc (Chemistry)
James Cook University of North Queensland	Faculty of Medicine, Health and Molecular Sciences	BSc (Chemistry) BSc (Industry Chemistry)
La Trobe University	Dean, Faculty of Science, Technology and Engineering	BSc (Chemistry) BAppSc (Chemistry) BAppSc (Biochemistry)*
Macquarie University	Division of Environmental and Life Sciences	BSc BA *
Monash University	Faculty of Science	BSc (Chemistry) BSc (Biochemsitry)* BE (Chemical) BAppSc (Chemistry/Applied Chem) BAppSc (Chemistry/Applied Chem) BAppSc(Chemistry/Physical Science) BAppSc (Chemistry/Biochemistry) BPharm

Murdoch University	Division of Sciences and Engineering	BSc (Chemistry)
Queensland University of Technology	Faculty of Science	BAppSc* BAppSc (Applied Chemistry) BAA\ppSc (Environmental Science co-majored with Chemistry)
RMIT University	School of Science, Engineering and Technology	BAppSc (Applied Chemistyr0 BASc (Environmental Chemistry) BE (Chemical Engineering) BAppSc, BBus (Environmental Science & Business Administration) BAppSc, BBus (Applied Chemistry & Business Administration)
Swinburne University of Technology	Faculty of Engineering and Industrial Sciences	BSc (Biotechnology)
University of Adelaide, The	Dean of Sciences	BSc (Biochemistry)*
University of Canberra	Division of Health, Design and Science	BAppSc (Environmental & Analytical Chemistry)
University of Melbourne, The	Faculty of Science	BSc (Chemistry) BSc (Biochemistry) BE (Chemical) BBiomedScience
University of New England, The	Faculty of the Sciences	BSc (Chemistry)
University of New South Wales, The	Faculty of Science	BSc (Chemistry) BSc (Applied Chemistry) BSc (Biochemistry)* BSc (Food Science and Technology)* BSc (Industrial Chemistry) BSc (Textile Technology)* BSc Tech* BE (Chemical)
University of Newcastle, The	Faculty of Science and Information Technology	BSc (Chemistry) BSc (Hons) (Chemical)
University of Queensland, The	School of Science, Engineering and Technology	BSc (Chemistry) BScApp (Materials Science)* BSc (Biochemistry)*
University of South	Division of Health Sciences	BAppSc (Chemistry)

Australia		BAppSc (chemistry & Applied Microbiology) BAppSc (Chemistry in chemical Process Technology) BMedPharmBiotech BPhar BBiomolecular Chemistry
University of Southern Queensland	Faculty of Sciences	
University of Sydney, The	Faculty of Science	BSc (Chemistry) BSc (Agricultural Chemistry) BSc Agr* BSc (Biochemistry)* BSc (Pharmacology) BA (Chemistry)* BE (Chemical Engineering) BPharm
University of Tasmania	Faculty of Science, Engineering and Technology	BSc(Chemistry) BAppSc(Chemsitry)
University of Technology, Sydney	Faculty of Science	BSc (Applied Chemistry) BSc Hons (Applied Chemistry) BSc Hons (Applied Chemistry Forensic Science)
University of Western Australia, The	Faculty of Life and Physical Sciences	BSc (Chemistry) BSc (Biochemistry)*
University of Western Sydney	College of Science, Technology and Environment	BSc (Chemistry) BAppSc (Chemistry)
University of Wollongong	Faculty of Science	BSc (Chemistry) BMedChem
Victoria University	Faculty of Science, Technology and Engineering	BAppSc (Chemistry) BAppSc (Environmental Management)

* Courses marked with an asterisk denote specific combinations of subjects
^ Courses marked with a ^ denote provisional accreditation (new course)

Appendix 4: Industry contacts

The following industry contacts were asked to disseminate information about the on-line employer of chemists survey to their members:

AVCARE
AUSBIOTECH
Australian Paint Manufacturers Federation
Medicines Australia
Plastics and Chemical Industries Association (PACIA)
Cooperative Research Centre (CRC) Association
Australian Petroleum Production and Exploration Association Ltd
Minerals Council of Australia
Australian Industry Group
Australian Industrial Research Group
Australian Consumer and Specialty Products Association
Environmental Laboratories Industry Group
Techstaff Pty Ltd
Science People Pty Ltd

Appendix 5: Details of where the information about the Future's Project was disseminated

RACI members
An email was sent out to:

- 5083 RACI members,
- Steering Committee members
- RACI Board members
- Immediately past Board members
- State representative
- Standing Committees

AAP Media Net (Australian Association Press)
All major metropolitan newspapers and talk-back radio stations were sent a media release through AAP.

Email groups
Information on the project was distributed on the following electronic email groups

- Institute of Materials Engineering Australasia (IMEA) Sydney Branch e-Newsletter, December 2004
- Australian Science Communicators Network

Government
<u>State Government</u>
At a state and territory level, cabinet ministers were emailed with information on the project and links to the on-line survey. For each state the following people were contacted:

ACT: 5 ministers were emailed
New South Wales: 11 ministers were emailed
Queensland: 14 ministers were emailed
South Australia:11 ministers were emailed
Northern Territory: 8 ministers were emailed
Tasmania: 8 ministers were emailed
Victoria: 13 ministers were emailed
Western Australia: 14 ministers were emailed
<u>Local Government</u>
The Association of Local Government was emailed with information on the project and asked to disseminate amongst their members.

<u>Australian Government Departments & Agencies</u>
43 Federal Departments and Agencies were emailed:

<u>Australian Government Councils, Committees and Boards</u>
54 Government Councils, Committees and Boards were emailed, inviting them to participate in the on-line survey.

Appendix 6: Employer Survey

ROYAL AUSTRALIAN CHEMICAL INSTITUTE
FUTURE OF CHEMISTRY PROJECT

EMPLOYER SURVEY

INFORMATION FOR RESPONDENTS

The Project

The Royal Australian Chemical Institute (RACI) is undertaking this important Project into the Future of Chemistry as part of its leadership role in the development of the chemistry profession.

The Project is intended to investigate the current view of a "disconnect" between the strengthening demand for quality graduate chemists and a decline in numbers and their quality within Australia. The recommendations will then provide a robust platform from which to advocate improvements to ensure that the profession can continue to support Australian industry.

Chemistry supports a broad range of existing industry sectors including pharmaceuticals, automotive, mining, chemicals and plastics, petroleum, energy, food and agriculture. It is also crucial in the development of the new industries of biotechnology and nanotechnology.

A report will be produced on this project that will detail the quantitative and qualitative data collected through this survey. It will be available on the RACI website www.raci.org.au If you wish to know more about the Future of Chemistry Project log on to our website www.raci.org.au

RACI

The RACI was founded in January 1917, as both the qualifying body in Australia for professional chemists and a learned society promoting the science and practice of chemistry in all its branches. The Institute has almost 8,000 members. More information on the RACI can be found on the website www.raci.org.au

THE SURVEY

The survey will take between 10 and 15 minutes to complete.

For privacy purposes individual comments provided will not be attributed to individual organizations within the report, without their approval. We seek one response per organization. Responses will be filtered to ensure only one response will be tabulated in the results.

As the respondent point for your organization and for our quality assurance and feedback purposes, information will be kept confidential, please provide

1. PLEASE ENTER YOUR CONTACT INFORMATION

Name	
Phone	
Email	

SECTION 1 WHO EMPLOYS CHEMISTS?

2 PLEASE COMPLETE THE NAME OF YOUR ORGANISATION (BUSINESS OR DEPARTMENT)?

…………………………………………………………………
………………

3 HAS THIS SURVEY BEEN FORWARDED TO YOU BY?

Industry Associations	
Avcare Ltd	
Ausbiotech	
Australian Consumer and Specialty Products Association	
Australian Industry Group	
Australian Industrial Research Group	
Australian Paint Manufacturers Federation	
Australian Petroleum Production and Exploration Association Limited	
CRC Association	
Environmental Laboratories Industry Group	
Medicines Australia	
Minerals Council of Australia	
Plastics and Chemicals Industry Association	
Science Industry Australia Incorporated	
Other	

Government	
Local	
State	
Federal	

4. IF OTHER, PLEASE SPECIFY

5. PLEASE SELECT THE ANSIC[2] CLASSIFICATION THAT

BEST DESCRIBES YOUR ORGANISATION'S CORE BUSINESS?

Agriculture, Forestry and Fishing		Mining	
Manufacturing (refer b)		Electricity, Gas and Water Supply	
Construction		Wholesale Trade	
Retail Trade		Accommodation, Cafes and Restaurants	
Transport and Storage		Communication Services	
Finance and insurance		Property and Business Services	
Government Administration and Defence		Education (refer c)	
Health and Community Services		Cultural and Recreational Services	
Personal & Other Services (refer d)			

6. FOR MANUFACTURING PLEASE ALSO FURTHER SPECIFY

Food, Beverage and Tobacco Manufacturing	
Textile, Clothing, Footwear and Leather Manufacturing	
Wood and Paper Product Manufacturing	
Printing, Publishing and Recorded Media	
Petroleum, Coal, Chemical and Associated Product Manufacturing	
Non-Metallic Mineral Product Manufacturing	
Metal Product Manufacturing	
Machinery and Equipment Manufacturing	
Other Manufacturing	

7. FOR EDUCATION PLEASE ALSO FURTHER SPECIFY

Tertiary	
Secondary	
Primary	

8. IF OTHER, PLEASE SPECIFY

9. FOR PERSONAL AND OTHER SERVICES PLEASE DESCRIBE

10 PLEASE SELECT THE TYPE AND CATEGORY OF YOUR ORGANISATION?

Private Company	
Small (1-50 employees)	
Medium (51 – 250 employees)	
Large (251+ employees)	

Public Company	
Small (1-50 employees)	
Medium (51 – 250 employees)	
Large (251+ employees)	

Government	
Federal	
State	
Local	
Other	

11. IF OTHER, PLEASE SPECIFY

12 PLEASE DESCRIBE YOUR POSITION WITHIN THE COMPANY?

Board	
CEO/MD	
Executive	
General Management / Research Management	
Supervisory	
Operations	
Other	

13 IF OTHER, PLEASE SPECIFY

14 . HOW MANY CHEMISTS DOES YOUR ORGANISATION CURRENTLY EMPLOY?

Number	
Percentage of Staff	

15 WITHIN EACH CATEGORY ARE THE CHEMIST?

	University trained chemist[3]	Technically trained chemist[4]	An equal combination	Other
Development				
Production				
Research only				
Teaching only				
Research and Teaching				
Sales and Service				
Marketing				
Analysis and Testing				
Consulting				
Management and Administration				
Quality Assurance				
Computing				
Other				
TOTAL				

16 IF OTHER ORGANIZATIONAL AREA, PELASE SPECIFY

17 WE WISH TO KNOW WHETHER YOUR NEED FO RCHEMISTS IN THE NEXT 10 YEARS IS GOING TO GROW, STAY THE SAME, OR DECLINE.

DO YOU EXPECT YOUR NEED FOR CHEMISTS IN THE NEXT TEN YEARS TO GROW?

Yes		No	

18. DO YOU EXPECT YOU NEED FOR CHEMISTS TO

GROW		DECLINE	

19 WHAT PERCENTAGE CHANGE DO YOU EXPECT?

Percentage (+/-) Change

20 PLEASE COMMENT ON THE REASONS FOR YOUR RESPONSE

SECTION 2 ARE OUR REQUIREMENTS FOR CHEMISTS CHANGING?

21 WHAT LEVEL OF CHEMISTRY QUALIFICATION HAVE NEW STAFF WITHIN YOUR ORGANISATION TYPICALLY REQUIRED?

	PAST (>10 years ago)	CURRENT	FUTURE (>10 years out)
Secondary school chemistry or equivalent			
Technical Certificate or Diploma or equivalent			
Bachelor of Science (major in chemistry) or equivalent			
Post Graduate or equivalent in coursework			
Masters by research			
PhD in chemistry or equivalent by research			

22 PLEASE TICK IF NONE OF THE ABOVE ARE RELEVANT

23 HAVE YOU EXPERIENCED DIFFICULTY RECRUITING PEOPLE WITH CHEMISTRY QUALIFICATIONS IN ANY OF THESE LEVELS?

Level of difficulty	No difficulty	Some difficulty	Major difficulty
Secondary school chemistry or equivalent			
Technical Certificate or Diploma or equivalent			
Bachelor of Science (major in chemistry) or equivalent			
Post Graduate or equivalent in coursework			
Masters by research			
PhD in chemistry or equivalent by research			

24 PLEASE TICK IF NONE OF THE OTHER ARE RELAVENT

25 DESCRIBE THE NATURE OF THE DIFFICULTIES?

26 WHAT AREAS OF CHEMISTRY (TRADITIONAL AND/OR EMERGING) HAVE STAFF WITHIN YOUR ORGANISATION TYPICALLY REQUIRED?

	PAST (>10 years ago)	CURRENT	FUTURE (>10 years out)
Analytical Chemistry			
Biomolecular Chemistry			
Cereal Chemistry			
Colloid and Surface Science			
Electrochemistry			
Environment			
Industrial Chemistry			
Inorganic Chemistry			
Organic Chemistry			
Physical Chemistry			
Polymer			
Solid State			
Engineering			
Geochemistry			
Education			
Nanotechnology			
Biotechnology			
Regulatory			
Policy Development			
Quality Control			
Other			

27 IF OTHER, PELASE SPECIFY

28 HAVE YOU EXPERIENCED DIFFICULTY RECRUITING PEOPLE WITH CHEMISTRY QUALIFICATIONS IN ANY OF THESE AREAS?

Level of difficulty	No difficulty	Some difficulty	Major difficulty
Analytical Chemistry			
Biomolecular Chemistry			
Cereal Chemistry			
Colloid and Surface Science			
Electrochemistry			
Environment			
Industrial Chemistry			
Inorganic Chemistry			
Organic Chemistry			

Physical Chemistry			
Polymer			
Solid State			
Engineering			
Geochemistry			
Education			
Nanotechnology			
Biotechnology			
Regulatory			
Policy Development			
Quality Control			
Other			

29 IF OTHER PLEASE SPECIFY:

30. PLEASE PROVIDE COMMENTS ABOUT YOUR RECRUITMENT DIFFICULTIES IN THESE SPECIFIC AREAS:

31. WHEN UNDERTAKING RECRUITMENT DO YOU SEEK TO EMPLOY?

	Never	Sometimes	Most of the time
Non university trained chemists			
Fresh university trained graduates			
Chemists with some experience			
Chemists with significant experience			

32. GAINING EXPERIENCE CAN BE DIFFICULT FOR GRADUATES. DO YOU HAVE ANY SUGGESTIONS TO HELP OVERCOME THIS PARTICULAR DIFFICULTY?

33. HAVE YOU EXPERIENCED SHORTAGES OR OTHER RECRUITMENT DIFFICULTIES IN SPECIFIC STATES AND /OR REGIONS OF AUSTRALIA?

Yes		No	

34. IF YES PLEASE SELECT GEOGRAPHICAL AREAS YOU HAVE EXPERIENCED DIFFICULTIES IN?

	Capital Cities	Regional Areas
ACT		
New South Wales		
Northern Territory		
Queensland		
South Australia		
Tasmania		
Victoria		
Western Australia		

35.(a) DO YOU UNDERTAKE STRATEGIES TO ENSURE THAT YOU CAN ATTRACT/RECRUIT/ RETAIN CHEMISTS?

Yes		No	

37. IF YES PLEASE SELECT FROM THE FOLLOWING LIST USING THE RATING SCALE OF 1-5 WITH 1 BEING LEAST IMPORTANT STRATEGIES AND 5 BEING MOST IMPORTACE.

	1	2	3	4	5
Pay award salaries					
Pay above the award salaries					
Incentive / bonus scheme					
Employee benefits eg parking, car, insurance, travel					

opportunities					
Salary sacrificing schemes					
Employee share option scheme					
Career development opportunities / promotions into management					
Career development opportunities / promotions other					
Pay for training and development					
Work /life balance arrangements					
Provision of state of the art equipment and facilities					
Publication of scientific findings in peer journals					
Conference attendance					
Participation in professional associations					
Payment of professional association fees					
Recruit from international markets					
Other					

37. IF OTHER PLEASE DESCRIBE

38 DO YOU UNDERTAKE STRATEGIES TO ENSURE THERE WILL BE AN ONGOING SUPPLY OF CHEMISTS FOR AUSTRALIA?

Yes		No	

39. IF YES PLEASE SELECT FROM THE FOLLOWING LIST.

	CURRENT STRATEGY	STRATEGY UNDER CONSIDERATION
Have links into tertiary institutions (universities and TAFEs) to strengthen recruitment opportunities		
Have links into tertiary institutions (universities and TAFEs) to influence curriculum and training		
Take on trainees		
Active in scientific and technical networks		
Active in professional associations		
Undertake significant in-house training		
Sponsorship of undergraduate students/PhD or other scholarships		
Offer vocational work for students		
Other		

40. IF OTHER PLEASE DESCRIBE

SECTION 3 IS THERE A SHORTAGE OF CHEMISTS AND IF SO WHY?

41 DO YOU BELIEVE THAT THERE IS A SHORTAGE OF CHEMISTS?

Yes		No	

42. IF YES WHAT DO YOU SEE AS THE PRIME CAUSES?

43. DO YOU HAVE ANY SUGGESTIONS TO HELP ADDRESS THESE CAUSES?

44. DO YOU BELIEVE THE STATUS OF CHEMISTRY IN AUSTRALIA IS?

Rising	
Remaining Constant	
Falling	

45. PLEASE PROVIDE COMMENTS?

THIS RESEARCH PROJECT LOOKS AT ALL ASPECTSOF CHEMISTRY IN AUSTRALIA TODAY.

46. DO YOU HAVE ANY GENERAL COMMETNS ON THE STATUS OF CHEMISTRY IN AUSTRALIA?

47. DO YOU HAVE ANY COMMENTS SPECIFICALLY ON CHEMISTRY IN SECONDARY SCHOOLS?

48. DO YOU HAVE ANY COMMENTS SPECIFICALLY ON CHEMISTRY WITHIN UNIVERSITIES OR TAFE

49. DO YOU HAVE NAY COMMENTS SPECIFICALLY ON CHEMISTRY IN INDUSTRY

50 ARE YOU INTERESTED IN WORKING WITH THE RACI IN THIS AREA?

Yes		No	

51 DO YOU GIVE RACI PERMISSION TO CONTACT YOU?

Yes		No	

52 IF YES, PLEASE SELECT FROM THE FOLLOWING LIST

Participate in forum/workshop	
Participate in future conferences	
Be involved in future industry case studies	
Be involved in future surveys	
Be involved in interview	

THANK YOU FOR YOUR ASSISTANCE