CHAPTER 1

INTRODUCTION

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Australia's future will rely on science, technology, engineering and mathematics (STEM)—disciplines at the core of innovation. Our businesses will rely on STEM to compete in the emerging sectors that new technologies will create, as well as in the existing sectors which new technologies will transform. Our workforce will require specialised skills in STEM as well as high STEM literacy across the board to sustain economic growth.

We know that STEM will be critical; and yet we know very little about who possesses these skills in Australia, where they work or how their careers progress from graduation.

This report is a comprehensive overview of the data we have; and as such a measure of our capability for STEM-led change.

It is also a foundation for the important decisions which need to be made about the skills base we develop through public policy and individual action.

Preliminary data on the qualifications, industries, occupations and wages of STEM graduates was published in Appendix B of *Benchmarking Australian Science, Technology, Engineering and Mathematics*, (the Benchmarking report) (Office of the Chief Scientist, 2014). This report builds on the data presented in the Benchmarking report.

WHAT IS STEM?

STEM, or science, technology, engineering and mathematics, refers collectively to a broad field of distinct and complementary approaches to knowledge (Chief Scientist, 2014).

Each has a critical role to play in its own right, but also enables discovery and progress in other fields. While definitions vary, for the purposes of this document:

Science encompasses disciplines within the natural and physical sciences, and selected disciplines from agriculture and environmental studies: astronomy and the earth sciences, physics, chemistry, the materials sciences, biology, agricultural and environmental science. These sciences are characterised by systematic observation, critical experimentation, and the rigorous testing of hypotheses.

Technology provides goods and services to satisfy real world needs; operating at the cross-section of science and society. Information and communications technology is playing an ever increasing role in our society and provides enabling capacity to the other STEM disciplines. The output of the technology provided must eventually stand the test of users and the marketplace.

Engineering draws on scientific, mathematical and technological knowledge and methods to design and implement physical and information-based products, systems and services that address human needs, safely and reliably. Engineering takes into account economic, environmental, and aesthetic factors.

Mathematics seeks to understand the world by performing symbolic reasoning and computation on abstract structures and patterns in nature. It unearths relationships among these structures, and captures certain features of the world through the processes of modelling, formal reasoning and computation.

A STEM education does not merely impart content knowledge in these fields—it seeks to provide frameworks in which new problems can be tackled.

STEM graduates cite higher order skills in research, logical thinking and quantitative analysis as the return on their degrees; alongside the qualities of creativity, open-mindedness, independence and objectivity.

WHY STEM?

WHY IS STEM IMPORTANT TO AUSTRALIA?

Science, research and innovation are widely recognised as key to boosting productivity, creating more and better jobs, enhancing competitiveness and growing an economy (Bell, et al., 2014).

Their importance has been accepted in mainstream economic theory for some time, despite the difficulties of quantifying phenomena so pervasive and dynamic in the modern world. In the US, scientific and technological advances were estimated to account for roughly half of all national economic growth in the 50 years to 2004 (Jobs for the Future, 2005). More recently, a number of studies on the impact of specific STEM fields on the economies of Australia, Italy, the Netherlands and the United Kingdom have revealed the significant contribution of these fields. As summarised in Table 1.1 below, it is estimated that the advanced sciences (biological, physical and mathematical sciences) directly underpinned around 14 per cent of Australian economic activity in 2012-13 (Australian Academy of Science, 2016). When flow on effects are considered, the impact of these STEM fields amounts to over 26 per cent of Australian economic activity, or about $330 billion per year. (Australian Academy of Science, 2016).

The data in Table 1.1 has been extrapolated to suggest that in advanced economies, advanced science directly underpins between 10 per cent and 15 per cent of economic activity, and this relationship is independent of the overall structure of the economy (Australian Academy of Science, 2015).

The critical engine of this growth is a workforce equipped with STEM skills and knowledge.

Table 1.1: Direct economic impact of selected STEM fields

Economy	Fields investigated	Size of science-based sector (share of economy)	Source
Australia	Physics, chemistry, mathematics, earth sciences, biological sciences	14 per cent	Australian Academy of Science, 2015
Italy	Physics	7 per cent	Deloitte, 2014
Netherlands	Mathematics	10 per cent	Deloitte, 2014
UK	Physics	9 per cent	Deloitte, 2012

Adapted from Australian Academy of Sciences (2015), Table 11.1

WHY ARE STEM SKILLS VALUABLE?

STEM skills are critical to the management and success of R&D (research and development) projects as well as the day-to-day operations of competitive firms.

They are the lifeblood of emerging knowledge-based industries—such as biotechnology, information and communications technology (ICT) and advanced manufacturing—and provide competitive advantage to established industries—such as agriculture, resources and healthcare.

Strong performance in STEM is also critical to our education sector—now Australia's fourth largest export industry.

An education in STEM also fosters a range of generic and quantitative skills and ways of thinking that enable individuals to see and grasp opportunities. These capabilities—including deep knowledge of a subject, creativity, problem solving, critical thinking and communication skills—are relevant to an increasingly wide range of occupations. They will be part of the foundation of adaptive and nimble workplaces of the future (Chief Scientist, 2014).

The importance of STEM skills to the prosperity of economies is not only recognised by governments, but also by employers.

The Australian Industry Group reports:

"Australia's productivity and competitiveness is under immense pressure. A key way to meet the emerging challenge of developing an economy for the 21st Century is to grow our national skills base – particularly the Science, Technology, Engineering and Mathematics (STEM) skills of our school leavers. Our relative decline of STEM skills is holding back our national economy and causing real frustration for employers." (Australian Industry Group, 2013).

The relationship between STEM skills, innovation and competitiveness is well documented. Businesses that report using these skills are 33 per cent more productive than those that do not (Palangkaraya, Spurling, & Webster, 2014). Innovative businesses and exporters have significantly higher use of STEM skills than non-innovators (Office of the Chief Economist, 2014). It is estimated that labour productivity in the advanced physical and mathematical sciences sector is 75 per cent higher than productivity in other parts of the economy (Australian Academy of Science, 2015).

In a recent survey of employers, respondents agreed that people with STEM qualifications are valuable to the workplace, even when their qualification is not a prerequisite for the role. Employers value the workplace skills that STEM-qualified employees offer, particularly in providing innovative solutions and their ability to adapt to changes in the workplace (Deloitte Access Economics, 2014). This reflects the value of the generic or transferable skills that an education in STEM fosters.

In addition to the benefits of specialised STEM skills, a general understanding of scientific ideas and technologies is increasingly important to enable individuals to participate fully in the modern workplace. As the Royal Society has observed, "*science and mathematics are at the absolute heart of modern life. They are essential to understanding the world and provide the foundations for the UK's future economic prosperity*" (The Royal Society Science Policy Centre, 2014).

Similar sentiments are expressed in many other advanced economies of the world and most OECD and G20 countries have policies in place to develop their STEM skills base.

ABOUT THIS REPORT

This report is divided into two parts. To plan for future STEM skill demand, we first need to evaluate the current STEM-qualified population in Australia. **Part One** analyses the demographic characteristics and employment outcomes of STEM skilled people in Australia.

To plan for the future, students, policy-makers, industry and universities need an understanding of the employment prospects of STEM graduates and which industries employ graduates in what occupations. **Part Two** investigates and compares the workforce destinations of graduates from different STEM fields.

DEFINING THE STEM-SKILLED WORKFORCE

In this report, the term 'post-secondary qualifications' includes qualifications obtained at the following levels as defined in the Census Dictionary (ABS, 2011b):

- Doctoral degree
- Masters degree
- Graduate diploma and graduate certificate
- Bachelor degree
- Advanced diploma and diploma
- Certificate III & IV

Certificate to advanced diploma qualifications are grouped as vocational education and training (VET) qualifications, while the remainder are grouped as Higher Education, or university qualifications.

In **Part One** of this report the term **STEM-qualified** refers to those members of the Australian population with a post-secondary qualification at the level of Certificate III or above in any of the following fields of education as defined by the Australian Standard Classification of Education (ASCED) (ABS, 2001):

- Natural and Physical Sciences (NPS)
- Information Technology (IT)
- Engineering and Related Technologies (ERT)
- Agriculture, Environment and Related Studies (AERS)

The field of Mathematical Sciences has been extracted from the Natural and Physical Sciences.

Table 1.2: Terms used in this report to describe the STEM fields

STEM component	Discipline	ASCED field
S	Science	Natural and Physical Sciences (excluding Mathematical Sciences)
	Agriculture and Environmental Science	Agriculture, Environmental and Related Studies
T	Information Technology, or IT	Information Technology
E	Engineering	Engineering and Related Technologies
M	Mathematics, or maths	Mathematical Sciences

The term **Non-STEM-qualified** refers to people with post-secondary qualifications in all other fields, including mixed fields programs.

Appendix A provides a summary of the STEM fields of education which are referred to in this report. A comprehensive list of the fields of education and the corresponding Higher Education and Vocational Education and Training (VET) discipline groups can be found in the Australian Standard Classification of Education (ABS, 2001).

For the purposes of this analysis, terms used to describe the STEM fields have been simplified from the ASCED fields and aligned to the component parts of STEM as outlined in Table 1.2.

This report does not include qualifications in Health in the definition of STEM. However, it is a closely related field and is often included in other, broader definitions. It is important to note that the field of Other Natural and Physical Sciences (which is included in this report) is comprised of Medical Science, Forensic Science, Food Science and Biotechnology and Pharmacology, Laboratory Technology, and Natural and Physical Sciences not elsewhere classified.

In **Part Two** of this report the term **STEM graduates** refers to the population with a higher education qualification at the bachelor degree level or higher in any of the STEM ASCED fields outlined above. The term **Non-STEM graduates** refers to people with higher education qualifications in all other fields, including mixed fields programs.

The term **graduates** does not include those with vocational education and training, or VET, qualifications—those with an advanced diploma or below.

The qualification level and field of education are self-reported by individuals in the Australian Bureau of Statistics (ABS) Census of Population and Housing. The 2006 and 2011 Census of Population and Housing captured information on respondents' highest qualification only. Therefore, it is likely that this data does not include all people with post-secondary qualifications in STEM fields, as some people will have higher qualifications in Non-STEM fields, such as a Master of Business Administration (MBA). Analysis of the 2010-11 Learning and Work report; however, indicated that approximately 90 per cent of those with STEM qualifications at the level of Certificate III and above reported it as their highest post-secondary qualification (ABS, 2014) (ABS, 2012).

DEFINING INDUSTRIES AND OCCUPATIONS

Australian industries are classified through the Australian and New Zealand Standard Industrial Classification (ANZSIC), where an individual business entity is assigned to an industry based on its predominant activity (ABS, 2006a). The ANZSIC is a hierarchical classification with four levels: Divisions (the broadest level, 1-digit), Subdivisions (2-digit), Groups (3-digit) and Classes (the finest level, 4-digit). **Appendix B** provides a summary of the specific industry levels that are referred to in this report.

Occupation data are classified according to the Australian and New Zealand Standard Classification of Occupations (ANZSCO); a skill-based classification used to classify all occupations and jobs in the Australian and New Zealand labour markets (ABS, 2013). ANZSCO has five hierarchical levels grouped on the basis of their similarities in terms of both skill level and skill specialisation. The broadest level, major group, is denoted by a 1-digit code, followed by sub-major group (2-digit), minor group (3-digit), unit group (4-digit), and the most detailed level, occupations, which are denoted by a 6-digit code. **Appendix C** provides a summary of the specific occupation levels that are referred to in this report.

Both industries and occupations are self-reported by individuals in the ABS Census of Population and Housing.

DEFINING LABOUR FORCE CHARACTERISTICS

Employed people are defined as those aged 15 years and over who worked for payment or profit, or as an unpaid helper in a family business, during the week prior to Census night, or had a job from which they were on leave or otherwise temporarily absent.

Unemployed people are those aged 15 years and over who were not employed during the week prior to Census night and had actively looked for work in the previous four weeks and were available to start work in the week prior to Census night.

Persons not in the labour force are defined as people aged 15 and over who were neither employed nor unemployed, as defined above.

The **employment to population ratio** is calculated as the number of people employed as a percentage of the total population for that particular group.

The **unemployment rate** is calculated as the number of unemployed people as a percentage of the labour force (i.e. employed and unemployed).

DATA SOURCES

The information presented in this report was collected from the following ABS reports:

- The Census of Population and Housing, 2006 and 2011 (ABS, 2006b) (ABS, 2011c)
- Learning And Work, Australia, 2010-11 (ABS, 2012)
- Australian Census Longitudinal Dataset, 2006–2011 (ABS, 2011a)

The information in this report was also compiled from several internal projects commissioned by the Office of the Chief Scientist to the ABS.