AUSTRALIAN JOURNAL OF LABOUR ECONOMICS
VOLUME 24 • NUMBER 1 • 2021

Changing demand for STEM skills in Australia and gender implications

Alfred M. Dockery *Bankwest Curtin Economics Centre, Curtin University*
John Phillimore *John Curtin Institute of Public Policy, Curtin University*
Sherry Bawa *School of Economics, Finance & Property, Curtin University*

Abstract

A method is developed for measuring the intensity with which skills in science, technology, engineering and mathematics (STEM) are used in different occupations based on workers' field of education of their highest qualification and weighted by the wage premium associated with that level of qualification. This is used to model changes in demand for STEM skills, and in other fields, based on the changing occupational composition of employment in Australia between the 2006 and 2016 censuses, and on projected changes to 2024. The approach offers a number of advantages over previous measures used to define STEM workers. Most importantly, by generating a continuous measure of STEM-intensity rather than a binary STEM versus non-STEM definition, it incorporates VET qualifications rather than just university level qualifications, and allows for transferability of STEM skills to what might be considered 'non-STEM' jobs. Contrary to popular narratives around STEM and the future of work, we find that the changing nature of work is actually reducing the demand for STEM skills relative to skills in other fields of education. Health stands out as the field in which the demand for qualifications has been growing most strongly. We also find that technical and trade jobs account for almost the same level of demand for STEM skills as professional occupations, reflecting the importance of including the VET sector in any STEM agenda. While governments have actively sought to promote 'women in STEM', our results suggest that, if anything, women are benefitting in terms of the demand for their skills by the fact that they are under-represented in STEM, and over-represented in key services such as Health and Education. We caution against an uncritical acceptance of the need for a higher proportion of people to specialise in STEM fields. More explicit and testable statements of the rationales and assumptions behind STEM definitions and associated policy are needed to further advance skills forecasting and the appropriate role, if any, of a unique STEM agenda within that framework.

JEL Codes: J16, J20, J21, J24, J30, J70
Keywords: employment, gender, occupational segregation, industrial segregation

---

Acknowledgements: This paper is based on a methodology developed as part of a research project funded by the WA State Government Department of Jobs, Tourism, Science and Innovation (JTSI). It uses unit record data from the Household, Income and Labour Dynamics in Australia (HILDA) Survey. The HILDA project was initiated and is funded by the Australian Government Department of Social Services (DSS) and is managed by the Melbourne Institute of Applied Economic and Social Research (Melbourne Institute). The findings and views reported in this paper, however, are those of the authors and should not be attributed to the WA State Government, JTSI, DSS or the Melbourne Institute.

Corresponding author: A.M. Dockery, Principal Research Fellow, Bankwest Curtin Economics Centre, Curtin University, GPO Box U1987, Perth WA 6845, Australia, m.dockery@curtin.edu.au

Introduction

The need to increase the level of skills and qualifications of the Australian workforce in the fields of science, technology, engineering and mathematics (STEM) features regularly in narratives of the future of work. Enhanced productivity through the development of a workforce with high STEM capacity across many industry sectors is seen as key to innovation and competitive advantage, and thus for continued economic growth and employment in high wage jobs. So too, is it seen as essential that the workers of the future embrace automation and increased use of data and information sciences in the workplace. Given the under-representation of women in STEM subjects in school and post-school education (Department of Industry, Innovation and Science 2019, Marginson *et al*. 2013, Office of the Chief Scientist 2016, Wajngurt and Sloan 2019), there has been a concerted push to encourage women into STEM careers as part of this agenda to embrace the evolving nature of the jobs of the future.

Despite a continuing focus on promoting a STEM savvy workforce, it is difficult to point to a clear evidence-base to support the assumptions underlying this narrative. In large part this is due to definitional and measurement issues, with ambiguity surrounding exactly what fields of education should be included as ‘STEM’ and how to identify STEM requirements of jobs or workers. In much of the empirical research that seeks to capture the prevalence of STEM capabilities in the Australian workplace, the notion of what represents a ‘STEM worker’ or a ‘STEM job’ is binary – that is to say, they are categorised as either STEM or non-STEM. In Australia, the assignment of a person as a STEM worker is often based on whether they hold a university degree or higher qualification in the disciplines of Natural and Physical Sciences, Information Technology or Engineering and Related Technologies (see, for example, Healy, Mavromaras and Zhu 2011; PwC 2015: 14). In reality, of course, different jobs require varying levels of STEM skills and the focus on university qualifications disregards the potentially important contribution of STEM-related skills accrued at the level of vocational certificates and diplomas.

In this paper we propose a method for measuring the ‘STEM-intensity’ of jobs at a relatively detailed level of classification of occupations, based on the qualification profile of workers by occupation using data from the Australian Bureau of Statistics (ABS) Census of Population and Housing. The measurement approach is designed to address two key challenges to measuring the STEM content of jobs: it generates a continuous measure of the demand for STEM skills within a job, rather than a binary divide, and incorporates vocational level qualifications from Certificate Level 3 and above. Using this measure, it is possible to infer the changes in demand for skills in STEM and in other fields associated with past and projected changes in the occupational composition of employment in Australia. This approach is used to describe how the demand for STEM skills is evolving in the Australian labour market, and the differential implications for the demand for skills held by men and women.

We find little support for the notion that the changing nature of work has heightened demand for STEM skills relative to skills in other fields of education over the past decade, or that it will do so in the near future given existing projections for employment by occupation. Health stands out as the field of education in which the demand for qualifications has been growing most strongly. Moreover, women have, if anything, benefitted in terms of the demand for their skills by the fact that they are under-represented in STEM relative to men, and over-represented in employment in key services such as Health and Education. We caution against an uncritical acceptance of the need for a higher proportion of people to specialise in STEM fields, and call for greater clarification around the justification for such policies to guide measurement issues and, thereby, ensure claims and assumptions can be subject to testable hypotheses.

Background

Claims of the need to increase the proportion of the workforce with STEM qualifications typically follow three main, interrelated lines of argument: that it would boost economic growth; the jobs of the future will increasingly demand STEM skills; and that employers face shortages of STEM qualified workers (Australian Industry Group 2013, 2015; Bradley *et al.* 2008; Dawkins 1988; Department of Jobs, Tourism, Science and Innovation [JTSI] 2019; Office of the Chief Scientist 2013, 2015, 2016; PwC 2015). Similar arguments focus on the requirement, more specifically, for higher-level STEM skills such as university degrees and PhDs. As there is a strong correlation between studying STEM subjects in secondary school and entry into university level-STEM courses, there is concern at what is seen as a declining interest, participation and performance in STEM in schools in Australia, particularly for girls (Office of the Chief Scientist 2012, Rothwell 2013, Timms *et al.* 2018). This progression of students from STEM in schools to post-school courses and eventually into STEM jobs invokes the metaphor of the ‘STEM pipeline’, extended to the ‘leaky pipeline’ with reference to people who divert into other courses or into non-STEM jobs (Cannady *et al.* 2014, Metcalf 2010).

The demand for labour and skills is a derived demand related to the output of goods and services in the economy and the production technologies (functions) with which they are produced. Conceptually, we can think of changes in the demand for STEM skills as coming from four sources: 1. changes in the overall level of output; 2. changes in the composition of *existing* goods and services in the output mix; 3. changes in production technologies; 4. the development of entirely new goods and services, and their associated production functions.

A fundamental role of the education and training system is to embody into the emerging labour force the knowledge and expertise needed to meet the requirements of the economy. Hence, a key reason for trying to anticipate the future skill needs – such as STEM – is to minimise mismatch between the skill requirements of industry and the skills possessed by the workforce in order to maximise output. The Australian Industry Group (AIG) (2015), for example, argues there is an urgent need to lift the level of STEM qualified employees. The AIG point to evidence from the ABS that ‘… STEM skills jobs grew at about 1.5 times the rate of other jobs in recent years’ (2015: 5); and to international evidence that ‘… 75 per cent of the fastest growing occupations require STEM skills and knowledge’ and in the US ‘STEM employment grew three times more than non-STEM employment over the past 12 years’ (p. 8).

However, evidence on the existence of emerging shortages of STEM workers is inconclusive. Healy *et al.* (2011) found mixed evidence of the presence of skills shortages in STEM, with signs of shortages most acute in engineering, while Norton (2016) argues Australia actually has more science graduates than the labour market can absorb in related jobs. There is also evidence that women who complete university degrees in a STEM field experience worse labour market outcomes than other female graduates upon labour market entry (Li *et al.* 2017) and across their working lives (Dockery and Bawa, 2018).

Existing empirical projections of future employment for Australia use generic time series methods that rely heavily on past aggregate trends, with *ad hoc* industry-specific adjustments (see for example Department of Employment, Skills, Small and Family Business 2019). Other projections are based either on employer survey data (e.g., Deloitte Access Economics 2014), on nationally representative household data such as the Household, Income and Labour Dynamics in Australia (HIILDA) survey or the ABS Survey of Income and Housing (SIH) (Borland and Coelli 2017); or the Australian panel component of the international adult skills data collection Programme for the International Assessment of Adult Competencies (PIAAC). Recent empirical studies of the labour market effects of automation have been based on a similarly naïve approach, one that applies a fixed view of the task composition of workers' jobs. This has led to the publication and popularisation of research findings that speculate up to 40 per cent of jobs will become redundant as a result of automation (Frey and Osborne 2013, Committee for Economic Development of Australia [CEDA] 2015).

Of course, all projection exercises are inherently difficult, but even more so when predictions or assumptions are sensitive to future technological innovations. Fifty years ago, for example, no Australian consumers were purchasing mobile phones, personal computers or microwave ovens, or receiving MRI scans. The internet had yet to be introduced. None of the jobs associated with these products and services existed. There is also potential endogeneity between the level of education and skills of the workforce and what is produced. By generating a strong supply of workers with qualifications used in the production of particular goods and services, a country may be able to develop a comparative advantage in those industries. This is particularly desirable if those industries are seen to offer high paying and high quality jobs. Among many others, the Office of the Chief Scientist argues that the promotion of STEM is key to shaping our industrial fortunes:

> "Australia's future is not one of vastly lower wage rates seeking to compete in low-end manufacturing. Our future lies in creating a high technology, high productivity economy; to innovate and to compete at the high-end of provision. To do so, the technical skills and scientific awareness of the entire workforce must be raised." (Office of the Chief Scientist 2012:12)

The argument is that, in the emerging knowledge economy, it is the innovators who will capture higher returns, and STEM is critical to innovation. As Marginson notes, "Many of the data-based international comparisons in education and innovation policy are centred explicitly on the STEM disciplines" (2015: 23).

Taking stock of, or projecting the demand for, STEM skills is further complicated by measurement and definitional issues. Highlighting the lack of a clear rationale for grouping the fields of science, technology, engineering, and mathematics together, various analysists have called for the inclusion of other fields, such as adding an M (medicine/health) or A (arts) in the definition, making it STEMM or STEAM. Among others, Card and Payne (2017) argue that nursing should be included in STEM, arguing that nursing requires the same prerequisites as many other STEM programs such as maths, chemistry and biology. Wajngurt and Sloan (2019) recommend adding Arts into the traditional definition of STEM, changing it to STEAM to make it more inclusive of women and students who are uninterested in traditional fields of STEM, further arguing that STEM and the arts are not mutually exclusive. Vestberg (2018) argues for the incorporation of humanities because of their importance in providing a 'moral and cultural' compass to transform technological innovations into improvements in human wellbeing (cited in Jobs Queensland 2019: 65). Boy (2013) also recommends a shift to STEAM to promote creativity, problem solving and the 'possibility of longer-term socio-technical futures'. Among others, Bequette & Bequette (2012), Costantino (2017), Maeda (2013), Rolling (2016) and Vestberg (2018) also support STEAM as the definition, arguing that science and arts are complementary and, further, that the STEM subjects alone will not lead to the innovation the 21st century demands. In contrast, May (2015) warns that the inclusion of the Arts threatens to dilute the potential of the STEM agenda to promote innovation.

Similarly, Oleson *et al*. (2014) point out that, like researchers, government agencies vary considerably on which fields of education and occupations should be considered as STEM. The Australian Bureau of Statistics, for example, includes qualifications in Agriculture, Environmental and Related studies (ABS 2014), as does the Office of the Chief Scientist (2016) and the Western Australian State Government in the definition used for its STEM skills strategy (JTSI 2019).

Compounding the question of the disciplinary boundaries of STEM is the question of the level of qualifications. The use of a bachelor degree as the STEM entry level has been criticised both in Australia (Korbel 2016, Siekmann 2016) and in the US (Rothwell 2013) for overlooking a significant contribution of the vocational education and training (VET) sector. Siekmann (2016) argues that accurate labour market predictions and workforce planning in the face of the restructuring of labour and industries requires consideration of all education sectors.

The use of a binary STEM versus non-STEM divide has itself been criticised. STEM skills are transferable between jobs that are considered STEM and non-STEM jobs, as are non-STEM skills, and STEM graduates work in a variety of jobs outside their original field of study (Korbel 2016, Office of the Chief Scientist 2016). Metcalf (2010) criticises the 'leaky pipeline' analogy for failing to recognise the value of this transferability and varied career pathways involving multiple ways of entering and re-entering STEM. Rothwell (2013) and Siekmann and Korbel (2016a, 2016b) propose continuous indices of science and maths intensity or of workers' STEM skills by occupations as a better method for measuring STEM jobs, in line with the approach we develop in the following section.

Measuring the STEM-intensity of jobs

The STEM tag is often assigned to people rather than to jobs, so the 'STEM workforce' refers to people with qualifications in STEM fields (for example, Office of the Chief Scientist 2016). For the purposes of this analysis, we include the fields referred to by the Australian Council of Learned Academies (ACOLA) as the 'core' STEM disciplines, or the Australian Standard Classification of Education (ASCED) fields of Natural and Physical Sciences (NPS), Information Technology (IT) and Engineering and Related Technologies (ERT) (see Healy *et al.* 2011, Marginson *et al.* 2013: 30, Siekmann and Korbel 2016a: 6; and ABS 2001 for details on ASCED). Imposing a somewhat arbitrary threshold level of qualification, the 'STEM workforce' could be defined as the set of persons holding such university level qualifications in one of those fields. This approach is depicted in Table 1, which shows 2016 Census data for employed persons that hold a post-school qualification by broad ASCED field, with the shaded area representing the STEM workforce.

Being based on the characteristics of workers, not on the characteristics of jobs, this definition takes a purely supply-side perspective. It also leads to a binary distinction between STEM and non-STEM workers. Here we propose and develop a measure of the intensity with which STEM skills are used in different occupations, allowing us to estimate how the demand for STEM skills is changing based on the changing occupational composition of the employed workforce. An important innovation in this method is that it provides for a more nuanced treatment of skill level. It can be seen from Table 1 that the NPS field has the highest proportion of post-school qualifications at the postgraduate degree level, and at the bachelor's degree level and higher (88.0 per cent). However, a substantial proportion of workers with qualifications in the fields of IT and ERT have a diploma or advanced diploma as their highest post-school qualification. As discussed above, it would seem important that such non-university qualifications be taken into account in any assessment of the demand for STEM skills or of the STEM capability of the workforce.

We concentrate on occupational classifications as the best indicators of the type of jobs involved in the various production functions. Since 2006, occupations have been classified in official Australian statistical collections using the Australian and New Zealand Standard Classification of Occupations (ANZSCO) (ABS 2006). The ANZSCO structure consists of eight major occupational groups, under which there are four finer levels of definition: 43 sub-major groups; 97 minor groups, 358 unit groups, and 998 'occupations'. The conceptual model underlying the classification framework defines jobs on the basis of their attributes in terms of the combination of skill levels and skill specialisation. A job is seen as a set of tasks performed in employment (whether as an employee or self-employed), and occupations as a grouping of jobs requiring the performance of similar sets of tasks: that is, tasks performed at a similar skill level and involving a similar skill specialisation.

The measure of STEM-intensity here is calculated at the level of the 97 minor groups. Relative to the major and sub-major groups, which are largely distinguished on the basis of skill level, minor groups within each sub-major category are distinguished from one another '… mainly on the basis of a finer application of skill specialisation than that applied at the sub-major level' (ABS 2006: 4). Skill specialisation refers to:

- Field of knowledge required
- Tools and equipment used
- Materials worked on
- Goods or services produced.

When disaggregated to a fine enough level, a particular occupation should consist of a set of jobs that involve much the same work, irrespective of their associated geographical location, industry sector, contractual status or various other dimensions of that job. We can infer that such a set of jobs involves a given level of skill, relates to a common field of knowledge and utilises similar technologies. Take, for example, the minor group 'Database and Systems Administrators, and ICT Security Specialists'. Whether working in mining, financial and insurance services or arts and recreation services, we would anticipate persons in that occupation to undertake similar tasks and, in doing so, apply similar skills, knowledge and technologies. On this basis, we argue that the changing occupational composition of the workforce can be used to proxy change in the nature of work. If it is possible to link STEM skill requirements to occupations, then it is possible to relate changing occupational composition – past and projected – to changing requirements for STEM skills. This is done by a cross-tabulation of the skill level and field of education of workers' post-school qualifications for each of 97 minor-group occupational categories for Australia.

Table 1. Employed persons with post-school qualifications by field of education and highest level of qualification: Australia 2016

Field of education	*Level of education not stated/ inadequately described*	*Certificate*	*Diploma/ advanced diploma*	*Bachelor's degree*	*Graduate diploma/ certificate*	*Post-graduate degree*	*Total*	*Persons with post-school qualifications*
	%	%	%	%	%	%	%	
Natural and Physical sciences	1.7	4.2	6.2	59.4	2.6	26.0	100.0	231,080
Information technology	3.7	12.2	17.9	42.9	3.6	19.8	100.0	274,920
Engineering and related technologies	2.1	65.4	10.2	17.0	0.6	4.7	100.0	1,170,252
Architecture and building	2.0	76.0	7.9	10.1	0.7	3.2	100.0	474,196
Agriculture, environmental and related studies	2.4	49.8	18.4	20.9	1.8	6.7	100.0	168,830
Health	3.3	13.1	18.1	47.5	6.1	11.9	100.0	799,564
Education	1.7	11.0	10.1	49.1	16.2	12.0	100.0	586,189
Management and commerce	3.0	25.7	23.6	30.2	4.0	13.5	100.0	1,592,254
Society and culture	2.0	27.1	18.2	34.7	5.1	12.8	100.0	921,815
Creative arts	1.7	14.8	25.4	48.0	2.8	7.2	100.0	290,661
Food, Hospitality and Personal Services	2.3	73.3	21.8	2.6	0.1	0.0	100.0	384,836
Mixed field programmes	72.2	22.8	4.2	0.6	0.0	0.1	100.0	10,574
Inadequately described/not stated	42.7	26.2	7.8	18.7	0.9	3.7	100.0	289,616

Source: ABS 2016 Census of Population and Housing, retrieved from online Tablebuilder facility.

To approximate STEM skill requirements by occupation, we consider a matrix consisting of a separate table such as Table 1 for employed persons in each of the 97 minor group (or '3-digit') occupations. We also retain Census categories of 'not fully defined' (nfd), giving 134 occupational classifications in total.[1] With reference to all persons working in an occupation, the proportion with post-school qualifications in STEM fields can be calculated as a measure of the 'intensity' with

---

[1] For example, within the major group of '2 Professionals', the 3-digit table from the Census includes a category of '200 Professionals, nfd' including employed persons who were identified as professionals, but could not further be allocated to a sub-major group. Sub-major groups also include nfd categories: the sub-major group of '26 ICT Professionals' includes a category of '260 ICT Professionals, nfd', along with '261 Business and systems analysts', '262 Database and systems administrators' and '263 ICT Network and support professionals'. For completeness, we have retained these 'nfd' categories in the analysis.

which STEM skills are used in each occupation. To overcome the arbitrary dichotomy in which STEM qualifications are defined only at the bachelor's degree or above, we instead incorporate all post-school qualifications within the STEM fields and apply a weighting based on the level of education.

This begs the question of what weighting to apply to different educational levels. Ideally, the weighting should relate to the intensity of STEM knowledge or skill. One option would be to use an approximation of the typical number of years of education required to complete each qualification, on the assumption that STEM-intensity increases directly with time spent in training and education. A robustness check following this approach is presented in Appendix 3. Our preferred approach is to infer the level of skill embodied in each qualification level on the basis of its associated wage premium realised in the labour market since, in theory, such wage differentials equate to differences in marginal productivity. This takes into account both the supply side (i.e., training and education outputs) and the demand side for such qualifications. A wage equation was estimated using the pooled sample of employees from HILDA waves 2001 to 2017. In the model the dependent variable is the logarithm of hourly real wages expressed in 2017 dollars, and we control for key supply side characteristics, such as gender, age, marital status and migrant background (see Appendix 1 for detailed results). We also include dummy variables for the workers' highest level of post-school qualification attained corresponding to those in Table 1, along with dummy variables for completion of Year 12 and completion of Year 11 or below. The model is estimated with bachelor's degree as the omitted or base category. Under this specification, the coefficient on each post-school qualification variable corresponds to the average per cent increase or decrease in wages associated with attaining that level of qualification relative to a person who has attained a degree.

The estimated coefficients from the wage equation are shown in Table 2. By example, the coefficient of 12.9 indicates that a person with a postgraduate degree earns, on average, 12.9 per cent higher hourly wages than similar persons with a bachelor's degree. A worker with a Certificate level III/IV, on the other hand, typically earns 27.8 per cent lower. From this we can derive expected earnings at each level of qualification relative to a degree holder. Given that, in theory, earnings equate to productivity, these relativities can be used as a basis to assign weights to different levels of qualification, as shown in the final column of Table 2. By construction, the implied weight or level of STEM skills associated with a worker with a bachelor's degree held in a STEM field is equal to 1. A postgraduate qualification carries a 56 per cent higher weighting than a Certificate III/IV level qualification, reflecting the estimated differences in wages between workers with those qualification levels.

Table 2. Weightings assigned to workers' STEM qualifications by level of education

	Regression Coefficient (%)	*STEM skill weighting*
Postgraduate (masters/doctorate)	12.9	1.129
Graduate diploma or certificate	4.8	1.048
Bachelor's or honours degree	—	1.000
Advanced diploma or diploma	-17.1	0.829
Certificate level III or IV	-27.8	0.722
Completed Year 12	-26.0	n.a.
Completed Year 11 or lower	-37.8	n.a.

The STEM skill intensity is calculated for each occupation as:

$$S = \frac{(0.722N_{Cert} + 0.829N_{Dip} + 1.000N_{Degree} + 1.048N_{Grad.dip} + 1.129N_{Higher.deg})}{N_{Total}} \qquad \text{(Equation 1)}$$

where N_{Cert}, N_{Dip}, N_{Degree}, $N_{Grad.dip}$, and $N_{Higher.deg}$ respectively refer to the number of persons employed in the occupation with a certificate, diploma, bachelor's degree, graduate diploma/certificate and higher degree in a STEM field. The denominator, N_{Total}, is the total number of persons employed in the occupation, encompassing those with and without post-school qualifications. Hence an occupation's STEM 'skill intensity' is directly related to the proportion of workers with their post-school qualification in a STEM field, and the level of those qualifications.

Potentially the measure ranges from zero, if no workers in an occupation held a post-school qualification in a STEM field; to 1.129 if every worker in the occupation held a postgraduate degree in a STEM field. It is true that the employment of persons with STEM qualifications in an occupation does not necessarily equate to 'use' or demand for those particular skills. Some people with STEM qualifications will be employed in an occupation and not be using their STEM skills. Equally, some people with no formal STEM skills will be employed in jobs where having STEM skills would increase their productivity, and their employers would prefer that they did hold such skills. Such a direct matching is not required with this approach. All that is required for the measure to be valid is that people with STEM qualifications are disproportionately allocated, through the various labour market processes, to occupations in which those skills are most valued or most in demand.

While assigning a weighting of 1 to a bachelor's degree is somewhat arbitrary, it makes no difference to the results as to which qualification level is chosen as the base category or what the base value is set to: any changes would simply result in scaling the measures generated up or down proportionately. However, choosing a bachelor's degree as the unitary base offers some consistency with existing studies which only consider a person to be part of the STEM workforce if they have a bachelor's degree or higher. A limitation is that it is not possible to take account of STEM skills embodied in peoples' school level qualifications – ideally one would like to know the extent of STEM subjects that workers had undertaken in their Year 12 graduation, and whether this was associated with their occupational destination.

A second limitation is that the Census variable used to capture level of education aggregates all certificates into a single category incorporating certificates from Level I to Level IV. However, the variable for highest level of post-school qualification in HILDA includes only certificates III and IV at the certificate level. Generally returns to certificate levels I/II are lower than to completion of Year 12, and thus the wage premium associated with certificates and estimated using the HILDA data would over-estimate the wage premium associated with certificates more generally as defined in the Census. However, this is likely to have minimal effect in our case. An analysis of the more detailed level of qualification data for the 2016 Census reveals that virtually all certificates held in the STEM fields are in fact at the certificate III/IV level, with less than one-fifth of one per cent of certificate holders reporting certificates at the I/II level. Hence the wage premium of -27.8 per cent associated with certificate Level III/IV relative to a bachelor's degree, as estimated from HILDA, is the most appropriate one to use in applying weights to STEM qualifications.

Third, the returns to different levels of qualification estimated using HILDA apply to qualifications in all fields, not just to STEM. In reality, wage relativities associated with different levels of qualification may vary substantially across fields of education: a diploma in IT may be associated with a very different return to a diploma in hospitality, for example. Following the logic of using expected wages as a measure of STEM skills, ideally it is the returns to qualifications specific to STEM fields of education that would be used. These are difficult to estimate because field of highest post-school qualification has only been collected in HILDA's supplementary education modules contained in the Wave 12 and Wave 16 surveys, but potentially could be done using just cross-sectional estimates or replicating the approach of Dockery and Bawa (2018). Restricting the data to Waves 12 and 16 only and estimating the return to STEM qualifications returns a marginally lower premium to a postgraduate degree (10.8 per cent), a higher return for a graduate diploma (+8.5 per cent) and similar returns for other qualifications (-16.5 per cent for an advanced diploma/diploma and -28.1 per cent for a certificate, relative to a degree). Hence using STEM specific returns should not greatly alter the general findings. An advantage of using the more general weighting is that it can also be applied for comparisons with other fields, as is done below.

Which are the STEM jobs?

The resulting STEM skill-intensity measure calculated for all minor group occupations using 2016 Australian Census data is presented in Appendix 2, while Table 3 reports the 25 most STEM intensive and 25 least STEM intensive occupations, along with the derived STEM-intensity measure.[2] As would be expected professional occupations,

---

[2] Occupational categories of 'not further defined', such as '260 ICT Professionals, nfd' have been excluded for the purposes of Table 3, but have been included in all relevant calculations.

notably in engineering and ICT, feature prominently among the list of STEM-intensive occupations. Engineering professionals top the list as the occupation with the most heavily STEM qualified workforce. However, many occupations classified within the major category of ‘3 Technicians and Trades workers’ also appear in the top 25 STEM intensive occupations, and even one from the lower skilled major group of machinery operators and drivers (stationary plant operators). Employment in such occupations would be neglected under those approaches to measuring STEM skills which use a bachelor’s degree as the minimum level of qualification required to be considered a ‘STEM worker’. Indeed, using the wage premium associated with each qualification level to weight STEM skills intensity implies that technicians and trades workers accounted for almost the same proportion of employment of STEM skills (28.6 per cent) in 2016 as professional workers (29.6 per cent), followed by managerial occupations (14.8 per cent).

Given the disagreement over whether medicine should be considered a STEM discipline, it is interesting to note that three medical professions rank amongst the seven least STEM intensive occupations: midwifery and nursing professionals, health therapy professionals and medical practitioners.

Table 3. Twenty-five most and least STEM-intensive occupations, 2016

Highest STEM-Intensity (S.I.)		*Lowest STEM-intensity (S.I.)*	
Occupation	*S.I.*	*Occupation*	*S.I.*
Engineering Professionals	0.834	Hairdressers	0.004
Business & Systems Analysts, Programmers	0.721	Midwifery & Nursing Professionals	0.007
ICT Network & Support Professionals	0.641	Health Therapy Professionals	0.013
Mechanical Engineering Trades Workers	0.590	Legal Professionals	0.019
Electricians	0.584	Child Carers	0.020
Natural & Physical Science Professionals	0.570	Personal Assistants & Secretaries	0.020
Air & Marine Transport Professionals	0.565	Medical Practitioners	0.022
Database & Systems Administrators, ICT Security Specialists	0.564	Health & Welfare Support Workers	0.025
Automotive Electricians & Mechanics	0.557	Accountants, Auditors & Company Secretaries	0.025
ICT Managers	0.516	Receptionists	0.025
Fabrication Engineering Trades Workers	0.500	Social & Welfare Professionals	0.026
Panelbeaters, Vehicle Body Builders, Trimmers & Painters	0.490	Plumbers	0.028
ICT & Telecommunications Technicians	0.486	Education Aides	0.031
Electronics & Telecoms. Trades Workers	0.456	School Teachers	0.032
Wood Trades Workers	0.384	Bricklayers, & Carpenters & Joiners	0.033
Printing Trades Workers	0.356	Personal Carers & Assistants	0.034
Building & Engineering Technicians	0.334	Food Trades Workers	0.035
Agricultural, Medical & Science Techns.	0.314	Hospitality Workers	0.038
Miscellaneous Specialist Managers	0.258	Glaziers, Plasterers & Tilers	0.038
Construction, Distribution & Production Managers	0.229	Checkout Operators & Office Cashiers	0.038
Tertiary Education Teachers	0.222	Education, Health & Welfare Services Managers	0.039
Textile, Clothing & Footwear Trades Wrkrs	0.206	Sports & Fitness Workers	0.041
Stationary Plant Operators	0.203	Personal Service & Travel Workers	0.042
Misc. Technicians & Trades Workers	0.178	Financial & Insurance Clerks	0.042
Contract, Program & Project Administrators	0.177	Accounting Clerks & Bookkeepers	0.042

Note: 3-digit occupational categories of 'not further defined' excluded from this Table.

The logic behind our application of the intensity measure in the analysis that follows is that the fine-level occupational classifications can be used to differentiate between jobs in line with their requirements for STEM skills and knowledge. An important test of the validity of this assumption is that the relative ranking of occupations in terms of their STEM-intensity should be quite stable over time. The quantum of the measure will change, by definition, with changes in the supply of STEM skills – if more workers gain post-school qualifications in STEM fields, the measured intensity will increase – and this may be unrelated to requirements of jobs.

It is the stability of the relative ranking of occupations that is critical. To test this, the STEM-intensity measure was also generated for each occupation using the 2006 Census data. The straight correlation between the 2006 and 2016 measures, at 0.99, is almost unitary. More importantly, the rank correlation of the occupations is 0.94, demonstrating strong persistence in the differences in STEM requirements between different occupations over time. Large changes in rank occur primarily for the 'nfd' categories with very few workers, and hence their measured STEM-intensity will be sensitive to changes in the qualifications held by a small number of workers. However, as the number of workers in these categories is small, such changes will have minimal impact on the results. The 2016 STEM-intensity for each occupation, and their ranks for 2006 and 2016 can be seen in Appendix 2.

This gives us confidence that changes in employment by occupation can be used as a robust measure of changes in the demand for STEM skills in the labour market. Further, changes in STEM requirements can be approximated wherever employment data by occupation is available or can be inferred, such as between regions or industries, between different time periods, and for future projections. The following sections look retrospectively at changes in STEM requirements in the Australian labour market between 2006 and 2016, and then changes in STEM requirements based on existing national employment projections.

Recent trends in employment in STEM occupations

To assess the relative growth of STEM employment, counts of employed persons in the 2006 Census were divided into quintiles according to the STEM-intensity of their occupation as derived in 2016. That is, into the one-fifth of workers with the lowest STEM-intensity in their jobs, followed by the next fifth, and so on to the 20 per cent of workers in occupations with the highest STEM-intensity. With the Census recording 8.94 million Australians in employment in 2006, each quintile contains around 1.79 million workers. We then looked at how the number of workers employed in those occupations changed in the decade between 2006 and 2016.

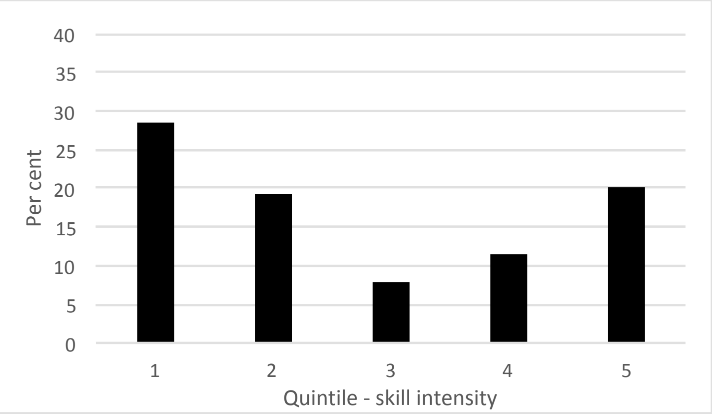
In total, employment in Australia grew by 17.4 per cent in the decade between the 2006 and 2016 censuses.[3] As Figure 1 shows, it was the least STEM-intensive jobs that grew most quickly, with the number of jobs in those occupations increasing by 28.4 per cent, more than 50 per cent faster than employment growth overall. Employment in jobs in the top quintile of STEM-intensity also expanded more rapidly than the overall workforce, increasing by 20.2 per cent over the decade. Jobs in occupations with moderate STEM-intensity (from the 3rd and 4th quintiles) grew markedly more slowly. In fact, over half of all jobs growth (54 per cent) was observed in jobs in the bottom two quintiles of STEM-intensity. Rather than a general increase in requirements for STEM skills, the picture is more one of a 'shrinking middle' featuring growing demand for jobs that are very STEM-intensive and for those with low STEM requirements. The pattern also fits with perceptions of technological

---

[3] Calculations exclude persons for whom occupation was inadequately described or not stated. These amounted to 1.7% of employed persons in Australia in the 2016 census, and 1.8% in the 2006 Census.

change contributing to 'jobs polarisation' in which there is an increase in the share of high-skilled and low-skilled jobs, at the expense of middle-skilled jobs (Borland and Coelli 2017: 381).

Figure 1. Percentage growth in jobs from 2006 to 2016, by quintile of STEM skill intensity

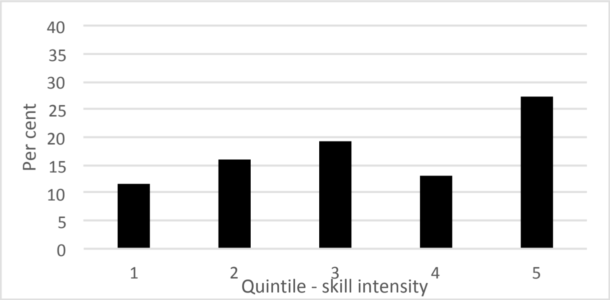


This same analysis can be repeated for the individual fields within STEM (Figure 2), and for the non-STEM fields of education (Figure 3). Figure 2 contains the respective employment changes by quintile of skills intensity for the Natural and Physical Sciences (NPS); Information Technology (IT); and Engineering and Related Technologies (ERT). It can be seen that jobs growth in the top quintile of skill intensity for NPS and ERT contributed to the faster growth of STEM-intensive jobs, with jobs making intensive use of skills in NPS leading the way. The fifth of jobs in occupations with the highest skill intensity in NPS in 2006 increased in number by 27.3 per cent between 2006 and 2016 (Figure 2(a)). However, structural change over the past 10 years appears to have been relatively neutral in terms of the share of jobs with intensive demand for IT skills, and to significantly reduce the share of jobs requiring skills in the field of ERT.

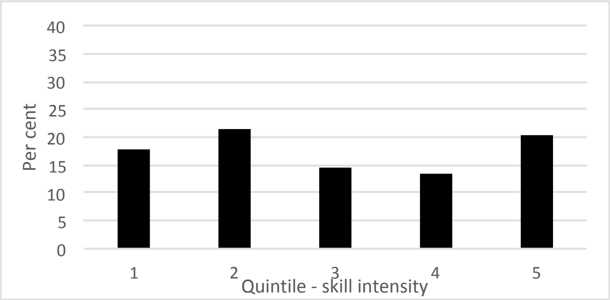
Structural change in the labour market, as proxied by changing occupational composition, strongly favoured jobs demanding health skills and qualifications (Figure 3(c)). Jobs in occupations in the highest quintile in terms of their intensity of health-related skills and qualifications grew by 34.9 per cent between 2006 and 2016, double the rate of overall employment growth. These 20 per cent of jobs in 2006 accounted for 40 per cent of all jobs growth over the 10 years. Interestingly, the field of Society and Culture was also strongly favoured by structural change, with the top quintile contributing 37.0 per cent of all jobs growth. This is notable given the arguments noted above that STEM needs to incorporate humanities to become 'STEAM'. There appears to have been a stronger shift to jobs utilising these skills than STEM skills, for which the top quintile of jobs in 2006 had a 23.2 percentage share of subsequent jobs growth. Changing occupational composition of the labour market also appears to have favoured qualifications in education, but worked against the fields of Agriculture, Environmental & Related Studies; Architecture and Building; and Food, Hospitality & Personal Services.

Figure 2. 2006-2016 growth in jobs by skill-quintile, individual STEM fields

(a) Natural and Physical Sciences



(b) Information Technology



(c) Engineering & Related Technologies

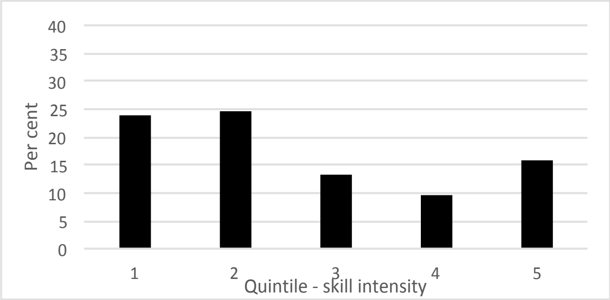
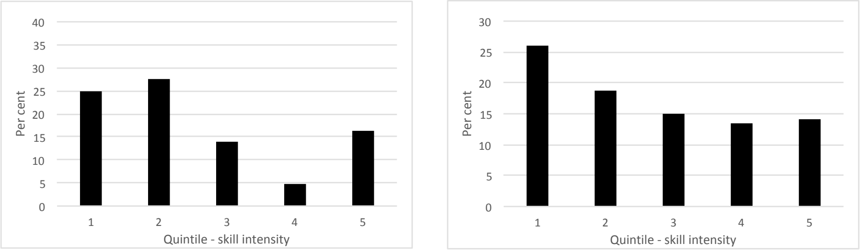


Figure 3. 2006-2016 growth in jobs by skill-intensity decile, non-STEM fields

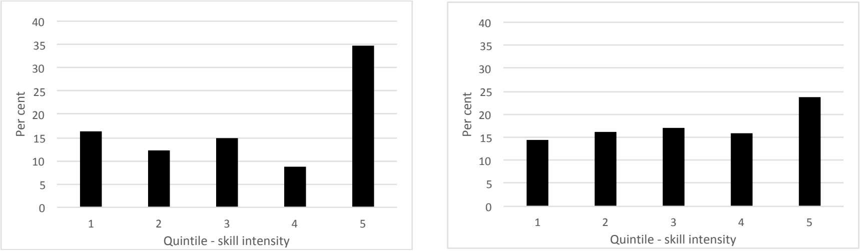
(a) Architecture and Building

(b) Agriculture, Environmental and Related Studies



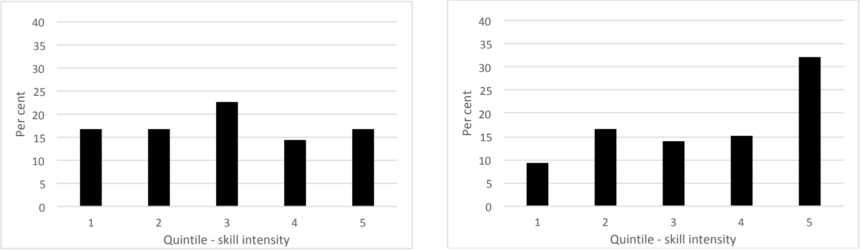
(c) Health

(d) Education



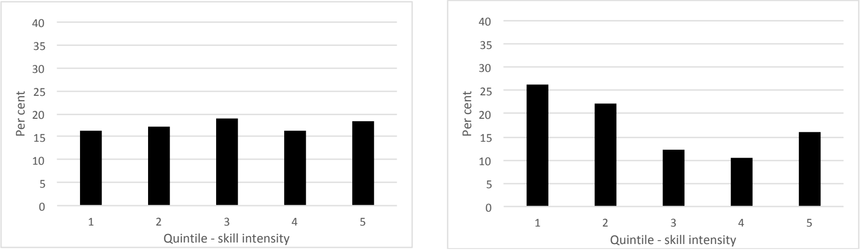
(e) Management and Commerce

(f) Society and Culture



(g) Creative Arts

(h) Food, Hospitality and Personal Services



A more direct measure of changing skill requirements can be derived by calculating the change in employment weighted by skill intensity. Again, this can be done for STEM skills overall, as well as for the individual fields and for non-STEM fields. The results of this exercise, shown in Table 4, suggest that growth in demand for STEM skills associated with the changing occupational profile of employment, at 17.3 per cent, has actually been substantially slower than overall growth in skills across all fields (21.5 per cent). Growth in demand for NPS skills was on par with overall (weighted) skills growth, with higher growth for IT skills and very low growth in demand for skills in the ERT field. Changing employment by occupation increased demand at a stronger rate for Health (35.9 per cent), Society and Culture (29.0 per cent) and Education (24.3 per cent). In terms of the absolute number of employed persons weighted by skill level, the largest increase was observed for Management and Commerce, followed by Health and Society and Culture.

Table 4. Change in skill requirements: STEM and non-STEM (employed persons weighted by skill level)

	Weighted employment			*Per cent growth*
	2006	*2016*	*Change*	
STEM	**1,181,533**	**1,385,791**	**204,258**	**17.3**
Natural & Physical Sciences	187,185	227,356	40,170	21.5
Information Technology	192,774	250,410	57,635	29.9
Engineering & Related Technologies	801,573	908,026	106,453	13.3
Non-STEM				
Architecture and Building	305,585	355,667	50,082	16.4
Agriculture, Environmental & Related	124,467	135,889	11,422	9.2
Health	536,504	728,926	192,422	35.9
Education	449,246	558,434	109,188	24.3
Management and Commerce	1,173,464	1,379,822	206,358	17.6
Society and Culture	629,419	812,242	182,823	29.0
Creative Arts	218,086	261,311	43,225	19.8
Food, Hospitality & Personal Services	238,497	280,543	42,045	17.6
All Fields	**4,856,800**	**5,898,623**	**1,041,823**	**21.5**

Projected growth in demand for STEM skills

The estimates above offer little support for the view of growing demand for STEM skills in the Australian labour market over the 10 years from 2006 to 2016, relative to skills in other fields. By necessity of having to rely on the five-yearly Census data to obtain sufficiently detailed data on workers' qualification levels by field of education and occupation, this provides a somewhat rear-mirror view of changes in the nature of work, whereas much of the STEM narrative appeals to supposed changes in demand associated with 'the future of work'. Having developed measures of STEM-intensity by occupation, and of skill-intensity for other fields, it is a mechanical procedure to project future trends in skills demand based on projections of employment by occupation. The Department of Education, Skills, and Employment (DESE) regularly produces such a set of projections, and at the time of writing projections were available to 2024.[4] Available down to the 4-digit ANZSCO level, the projections are generated using time-series forecasting methods applied to past trends supplemented by '… adjustments made to take account of research undertaken by the National Skills Commission and known future industry developments'. The projections are for total persons employed (including full-time and part-time employment), consistent with the Census data used above.

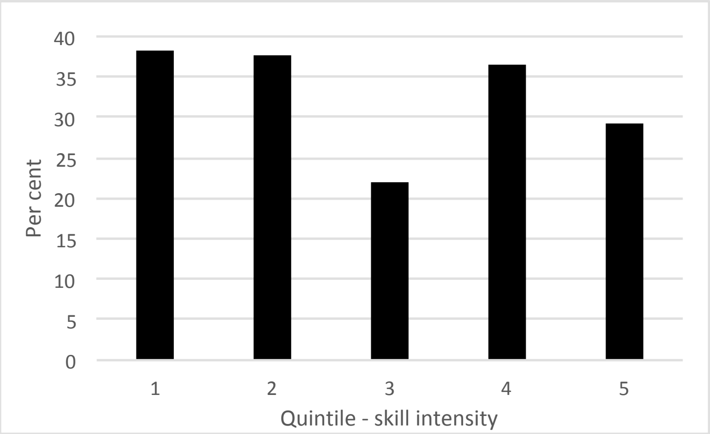
The Department projects total employment of 13.9 million persons by 2024, an increase of 32.7 per cent over the 2016 ABS Census count. Applying the STEM-intensity coefficients by occupation, we can impute the changing demand for STEM skills associated with those projections. Sorting the 2016 data into quintiles of employment by STEM skill-intensity, Figure 4 shows the projected growth in employment in occupations in each of those quintiles from 2016 to 2024. It can be seen that the Department's projected trends in employment by occupation imply an ongoing shift in occupational structure of the labour market away from STEM skills. Growth is projected to be highest in the two quintiles with lowest requirement for STEM skills: 38.3 per cent in the first quintile and 37.6 per cent in the second quintile, respectively. The one-fifth of jobs with the highest STEM skill requirements are projected to grow by just 29.2 per cent.

Jobs in the occupations in the two quintiles (or 40 per cent of jobs in 2016) with the lowest STEM requirements are expected to account for 46.4 per cent of all employment growth, compared to 40.2 per cent for the two quintiles with the highest STEM requirements. As with trends from 2006 to 2016, there is evidence of a polarisation or 'disappearing middle' in the distribution of jobs according to demand for STEM sills.

---

[4] The data were downloaded from https://lmip.gov.au/default.aspx?LMIP/EmploymentProjections on 23 July, 2020. The webpage also contains a description of the forecasting methodology. The responsible Department at the time these projections were published was the Department of Employment, Skills, Small and Family Business (DESSFB).

Figure 4: Percentage growth in jobs from 2016 to 2024, by quintile of STEM skill intensity



The occupational intensity of skill use by different fields of education can be used to make an assessment of future growth in skills demand associated with the projected changes in employment by occupation, as was done above for past trends in Table 4. Importantly these provide some gauge of the magnitude of projected skill demands as well as percentage changes. We can see in Table 5, demand for STEM skills is projected to be marginally higher than the growth in skills overall, but this is due only to the strong projected growth in demand for IT skills. A number of the non-STEM fields of education are projected to experience stronger growth in percentage terms than STEM, including (in order) Architecture and Building; Health; Society and Culture; and Creative Arts.

In terms of the absolute numbers, as opposed to percentage changes, a substantial increase in skills-weighted employment is projected for the STEM fields taken together. However, for individual fields of education, the increases are projected to be largest for Management and Commerce, Society and Culture, Engineering and Related Technologies and Health.

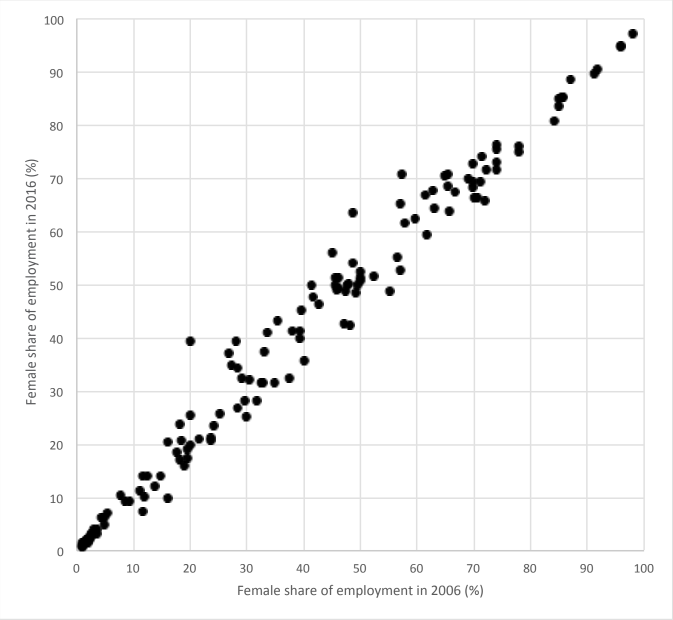
Table 5. Projected changes in skill requirements: STEM and non-STEM (employed persons weighted by skill level), 2016-2024

	Weighted employment			*Per cent growth*
	2016	*2024*	*Change*	
STEM	**1,385,791**	**1,882,867**	**497,076**	**35.9**
Natural & Physical Sciences	227,356	298,023	70,667	31.1
Information Technology	250,410	377,175	126,765	50.6
Engineering & Related Technologies	908,026	1,207,669	299,644	33.0
Non-STEM				
Architecture and Building	355,667	493,573	137,906	38.8
Agriculture, Environmental & Related	135,889	176,366	40,477	29.8
Health	728,926	1,004,591	275,665	37.8
Education	558,434	740,358	181,924	32.6
Management and Commerce	1,379,822	1,795,249	415,427	30.1
Society and Culture	812,242	1,118,360	306,118	37.7
Creative Arts	261,311	356,829	95,518	36.6
Food, Hospitality & Personal Services	280,543	371,034	90,491	32.3
All Fields	**5,898,623**	**7,939,226**	**2,040,603**	**34.6**

Changes in skills demand by gender

As noted, there has been a concerted effort on the part of government to encourage women into STEM, as they are typically under-represented among students in STEM subjects at school and in post-school courses, such as engineering and IT. In this section, we consider how the changing occupational composition of employment affects demand for skills in jobs held by women and men. While it may seem a bit old-fashioned to talk of ‘men’s jobs’ and ‘women’s jobs’, the truth is that occupational segregation by gender is still quite an entrenched feature of the Australian labour market. As the scatter plot in Figure 5 demonstrates, there is close to a 1 to 1 correspondence between the gender distribution within occupations in 2006 and the distribution 10 years later. The occupations that were female dominated in 2006 were similarly female dominated in 2016, such as Personal Assistants and Secretaries (98.1 per cent of workers were female in 2006 versus 97.2 per cent in 2016), Receptionists (96.0 per cent v. 94.8 per cent) and Child Carers (95.9 per cent v. 95.1 per cent). The male dominated end of the spectrum is populated by trade occupations, including Bricklayers, Carpenters and Joiners (0.9 percent female in 2006, 0.8 per cent in 2016), Fabrication Engineering Trades Workers (0.9 per cent v. 1.0 per cent) and Automotive Electricians and Mechanics (1.0 per cent v. 1.4 per cent).

Figure 5. Female share of employment by occupations: 2016 versus 2006



Source: ABS 2016 Census of Population and Housing, retrieved from on-line Tablebuilder facility.

Taking the skill-intensity of each occupation, skills demand by field of education was calculated for the jobs held by women and by men in 2006 and 2016. The skills intensity of jobs is based only on the occupation specific intensity measures generated from the 2016 Census data as described above. Hence, the estimated changes in skills demand are associated purely with changes in employment by occupation, and unrelated to changes in educational attainment of the labour force. The results are presented in Table 6, which is essentially a decomposition by gender of the figures presented in Table 4. A number of salient points can be seen from this exercise. Changes in employment levels by occupation between 2006 and 2016 saw a huge increase in demand for skills in the field of Health for women. This can be seen in terms of both the percentage growth (38.3 per cent) and in absolute numbers: an estimated increase in skill-weighted employment of 140,000, almost double the contribution of the STEM fields combined (Table 6(a)). In absolute terms, changes in employment also imply large increases in skills demand for women in the fields of Society and Culture and Management and Commerce.

An additional column, headed ‘Growth share’, has been added to Table 6 (a) and (b). This reports the change in skill-weighted employment as a proportion of the total change (male and female) in skill weighted employment across the labour market. It can be seen from the final row, that most of the increase in skill-weighted employment went to jobs held by women (59.0 per cent share) rather than to men (41.0 per cent share). It can also be seen that increased employment in occupations requiring skills in the fields of Health, Society and Culture made substantial contributions to women capturing a disproportionate share of growth in skilled employment.

Table 6. Changes in skill requirements by gender: STEM and non-STEM (employed persons weighted by skill level), based on 2006 and 2016 employment by occupation

(a) Females

	Weighted employment			*Per cent growth*	*Growth share (%)*[a]
	2006	*2016*	*Change*		
STEM	**306,816**	**380,410**	**73,594**	**24.0**	**7.1**
Natural & Physical Sciences	88,539	113,129	24,590	27.8	2.4
Information Technology	65,352	82,113	16,761	25.6	1.6
Engineering & Related Technologies	152,925	185,168	32,243	21.1	3.1
Non-STEM					
Architecture and Building	51,823	64,560	12,737	24.6	1.2
Agriculture, Environmental & Related	44,153	50,531	6,377	14.4	0.6
Health	365,832	505,916	140,083	38.3	13.4
Education	307,598	395,927	88,328	28.7	8.5
Management and Commerce	618,375	737,263	118,888	19.2	11.4
Society and Culture	359,437	485,554	126,117	35.1	12.1
Creative Arts	107,381	133,401	26,020	24.2	2.5
Food, Hospitality & Personal Services	128,165	150,436	22,272	17.4	2.1
All Fields	**2,289,580**	**2,903,998**	**614,418**	**26.8**	**59.0**

(b) Males

	Weighted employment			*Per cent growth*	*Growth share (%)*[a]
	2006	*2016*	*Change*		
STEM	**874,717**	**1,005,381**	**130664**	**14.9**	**12.5**
Natural & Physical Sciences	98,647	114,226	15580	15.8	1.5
Information Technology	127,422	168,297	40875	32.1	3.9
Engineering & Related Technologies	648,649	722,858	74209	11.4	7.1
Non-STEM					
Architecture and Building	253,763	291,107	37344	14.7	3.6
Agriculture, Environmental & Related	80,313	85,358	5045	6.3	0.5
Health	170,672	223,010	52338	30.7	5.0
Education	141,648	162,507	20859	14.7	2.0
Management and Commerce	555,088	642,558	87470	15.8	8.4
Society and Culture	269,982	326,688	56706	21.0	5.4
Creative Arts	110,705	127,910	17205	15.5	1.7
Food, Hospitality & Personal Services	110,333	130,106	19773	17.9	1.9
All Fields	**2,567,220**	**2,994,625**	**427405**	**16.6**	**41.0**

Notes: a. Percentage share of all (male plus female) weighted growth from 2006-2016.

Comparing Tables 6(a) and (b) it can be seen that men and women are employed in relatively equal numbers in skill-weighted terms for the field of Natural and Physical Sciences, but there are around half as many women as men in the field of IT and around one-quarter as many in the field of Engineering and Related Technologies. So, is the relatively minor contribution of projected employment growth in STEM-intensive occupations for women simply a consequence of their stark under-representation in those jobs? The answer is clearly ‘no’. For both men and women, changes in employment occupation point to slower growth in skills demand in the STEM fields than for all fields. Hence, if anything, men experienced a lower increase in skills demand because of their over-representation in STEM-intensive occupations. However, there was a narrowing of the gender divide in STEM related occupations over that decade, with women’s employment in STEM intensive occupations growing more rapidly than for men.

Like women, men also experienced a very high increase in skilled employment in Health (30.7 per cent), but they did not capture anywhere near the share of skilled employment growth that women did because of the under-representation of skilled males in Health. Essentially, structural change in the labour market over the decade from 2006 to 2016 shifted strongly in favour of demand for women’s skills because of their over-representation in Health, Society and Culture and Education.

The corresponding tables comparing skill-weighted employment by field of education in 2016 and in 2024, based on the (then) DESSFB’s employment projections, are presented in Table 7. This is calculated assuming constant employment shares by gender within occupations in 2016 and 2024, which, as shown in Figure 5, seems a justifiable approximation. Following our methodology, the Department’s projections for growth in employment by occupation imply an increase in skill-weighted employment that will be shared relatively evenly between men (51.2 per cent) and women (48.8 per cent). In this case, forecast structural change does contribute to a strong increase in demand for STEM skills for men, due largely to projections for a big increase in employment in occupations intensive in Engineering and Related Technology skills and a very high rate of growth in demand for IT skills. Projections for strong growth in occupations requiring skills in the field of Architecture and Building also translate to increased skills demand for men. However, it remains the case that the projections imply the share of growth in skills demand predicted to be captured by women due to their over-representation in the fields of Health, Education and Society and Culture is greater than the share captured by men due to their over-representation in the STEM fields.

Table 7. Projected changes in skill requirements by gender: STEM and non-STEM (employed persons weighted by skill level), 2006 and 2024

(a) Females

	Weighted employment			*Per cent*	*Growth*
	2016	*2024*	*Change*	*growth*	*share (%)*[a]
STEM	**380,410**	**503,292**	**122,882**	**32.3**	**6.0**
Natural & Physical Sciences	113,129	148,009	34,880	30.8	1.7
Information Technology	82,113	115,937	33,824	41.2	1.7
Engineering & Related Technologies	185,168	239,346	54,178	29.3	2.7
Non-STEM					
Architecture and Building	64,560	87,056	22,496	34.8	1.1
Agriculture, Environmental & Related	50,531	65,386	14,855	29.4	0.7
Health	505,916	702,547	196,632	38.9	9.6
Education	395,927	526,939	131,012	33.1	6.4
Management and Commerce	737,263	959,454	222,191	30.1	10.9
Society and Culture	485,554	674,924	189,370	39.0	9.3
Creative Arts	133,401	180,704	47,303	35.5	2.3
Food, Hospitality & Personal Services	150,436	200,292	49,856	33.1	2.4
All Fields	**2,903,998**	**3,900,594**	**996,596**	**34.3**	**48.8**

(b) Males

	Weighted employment			*Per cent*	*Growth*
	2016	*2024*	*Change*	*growth*	*share (%)*[a]
STEM	**1,005,381**	**1,379,575**	**374,193**	**37.2**	**18.3**
Natural & Physical Sciences	114,226	150,014	35,787	31.3	1.8
Information Technology	168,297	261,237	92,941	55.2	4.6
Engineering & Related Technologies	722,858	968,323	245,465	34.0	12.0
Non-STEM					
Architecture and Building	291,107	406,517	115,410	39.6	5.7
Agriculture, Environmental & Related	85,358	110,979	25,622	30.0	1.3
Health	223,010	302,044	79,033	35.4	3.9
Education	162,507	213,419	50,913	31.3	2.5
Management and Commerce	642,558	835,795	193,237	30.1	9.5
Society and Culture	326,688	443,436	116,748	35.7	5.7
Creative Arts	127,910	176,125	48,215	37.7	2.4
Food, Hospitality & Personal Services	130,106	170,742	40,636	31.2	2.0
All Fields	**2,994,625**	**4,038,631**	**1,044,006**	**34.9**	**51.2**

Notes: a. Percentage share of all (male plus female) weighted growth from 2016-2024.

Conclusions and discussion

We argue that the methodology developed for this report offers important advantages over previous approaches to measuring the demand for STEM skills in the Australian workforce and for monitoring changes in that demand. The most significant enhancement is the move away from a binary definition of STEM and non-STEM workers to one that embodies STEM qualifications at all levels from certificate III/IV and above, and takes account of the transferability of STEM skills across occupations. This captures the demand for tradespeople and technicians with STEM qualifications that are often at the root of skills shortages, and a group that is excluded in approaches that use a bachelor's degree as the minimum qualification to be deemed a 'STEM' worker. While the approach requires assumptions regarding the weightings attributed to different levels of qualifications, these have not been chosen arbitrarily but are based on earnings differentials. Indeed, by this measure, many of the most STEM-intensive occupations are trades and technical occupations, including Mechanical Engineering Trades workers coming in at sixth out of 134 ANZSCO 3-digit categories. Workers in the Technical and Trades occupations are calculated to have accounted for almost the same level of STEM skills in 2016 as professional workers.

Second, the approach is not affected by supply-side changes, such as rising credentialism. With STEM-intensity by occupation defined in a given base year (in our case 2016), imputed changes in STEM employment arise purely through changes in employment by occupation, not changing educational attainment of the workforce. This contrasts with other approaches which would directly infer rising STEM demand if the number of graduates from STEM courses increased in the workforce. We caution against the interpretation of the weighted employment measure as a 'quantum' of STEM skills or STEM demand, but rather it should be used for comparative purposes; that is, to measure changes over time and differences between subsets of the workforce. Additionally, the approach can be used to assess changes in demand for qualifications for any grouping by field of education, including for the sub-fields within STEM, for different variations of STEM (such as STEMM or STEAM) and for non-STEM fields.

Contrary to much of the narrative surrounding STEM and the 'future of work', our results suggest that changes in the occupational structure of the workforce over the decade from 2006 to 2016 reduced the demand for STEM skills relative to other qualifications. Rather than a broad-based increase in employment in jobs utilising STEM skills, there has been a polarisation – or 'shrinking middle' – with jobs with very high STEM-intensity and jobs with very low STEM-intensity growing more rapidly than average. By a considerable margin, it is skills in Health that saw the greatest increase in demand from changing employment patterns between 2006 and 2016, and growth in demand for skills in the fields of Society and Culture and in Education also outpaced STEM. Employment projections to 2024 suggest demand for STEM and non-STEM skills will grow at a relatively similar pace.

The results are clearly inconsistent with what would be expected given popular narratives around STEM and the future of work and their associated policy prescriptions. Moreover, when it comes to the demand for their skills, women appear to be benefitting from their under-representation in STEM: policies to get women into

STEM fields and courses could be characterised as ‘pushing them off a winning horse’. While this analogy does not take into account other attributes of the jobs requiring those skills, such as status, pay and security, there is also evidence that women in STEM-related work fare badly on a number of dimensions of job quality (Dockery and Bawa 2018).[5] While these results may seem surprising they probably should not be, given that as economies develop and wealth increases, the services sector of the economy increases in importance (Buera and Kaboski 2012). As discussed, there is no consensus on exactly which fields of education should be included as STEM, and we have used a restrictive definition based on the ‘core’ fields of the Natural and Physical Sciences, Information Technology and Engineering and Related Technologies. Several Australian agencies include the field of Agriculture, Environment and Related Studies in their preferred definitions of STEM (ABS 2014, JTSI 2019, Office of the Chief Scientist 2016). Had we adopted that expanded definition, we note that the key results would have been even more pronounced, given that that field is relatively male dominated and has displayed low growth in skills demand.

Our estimates of changing skills demand, both historically and looking forward, suggest that the occupational restructuring of the workforce will increase demand for workers with qualifications in the educational fields of Society and Culture and in the Creative Arts more than in STEM. This is interesting in view of the calls for the inclusion of the Humanities and Arts in ‘STEAM’ and the Commonwealth Government’s announcement in June of 2020 of an amended fee structure for university courses that ‘incentivises students to make more job-relevant’ decisions about their education.[6] The Minister’s statement indicated the reforms are aimed at reducing the relative costs in areas of employment growth and demand, leading to more ‘job-ready’ graduates. Some effects of the proposed changes will be to substantially increase student contributions to the costs of courses in humanities (Society and Culture), while reducing student contributions in health, nursing, teaching and the STEM fields (Cassells and Bond-Smith 2020). Our results would suggest these effects are consistent with the stated aim of promoting participation in areas of growth when it comes to reducing student contributions in health and education, but not in incentivising students away from the humanities and toward STEM.

Limitations and possible extensions

While we argue the method developed to measure changes in the demand for STEM skills offers some important advantages over previous approaches, we by no means intend to suggest it is ideal or should even be considered a preferred method for measuring the STEM content of jobs. That will often depend on the particular research or policy context with which measures are being used. The approach does not take account of part-time employment or hours of work. This can perhaps be justified

---

[5] We fully endorse policies to address gender-based discrimination and bias due to gender stereotypes that limit women’s opportunities, and acknowledge these are important issues in STEM. However, those issues must be addressed as principles of fairness and equality (and in all fields), not to fit narratives around skill shortages.

[6] https://ministers.dese.gov.au/tehan/job-ready-graduates-power-economic-recovery.

since the skills intensity measure relates to skills needed for a position irrespective of the hours supplied: an engineer working half-time still needs an engineering degree, not half a degree. It would be data intensive, but the approach can be readily extended to incorporate hours worked, and this may have significant implications relating to inferences of skills demand by gender.

As noted, the methodology means that results are not affected by a general increase in the proportion of workers holding qualifications, only by changes in employment by occupation. This also means that a broad-based increase in STEM content across all jobs, rather than occupational change favouring STEM-intensive jobs, would not be detected by our methodology as an increase in demand for STEM skills. The most probable candidate for such a change is the growing need for ICT (information communication and technology) skills across jobs. However, it could be argued that a general increase in the need for STEM competencies, such as in IT, does not necessarily translate into a need for more people to specialise in STEM, but simply the incorporation of such basic competencies into other curricula.

An associated limitation is that the quantification of STEM-intensity relies on the field of education of workers' highest post-school qualification and does not take into account prior learning in STEM. While the Census is the only feasible source of detailed breakdowns of employment by occupation and qualification to support the modelling undertaken here, it does not provide information on science and mathematics subjects or level completed at high school. How completion of STEM subjects at high school relates to occupational destination and earnings would allow us to more accurately model STEM skills demand and to pick up more broad based changes in skill requirements.

Having data on field of *highest* post-school qualification only similarly leads to the neglect of other post-school qualifications gained. This would include, for example, workers who gained an initial degree in engineering, but who go on to gain a postgraduate qualification in management. Healy *et al.* (2011) also note the example of those who gain an undergraduate degree in mathematics or science and become teachers. Typically, their highest qualification is a graduate diploma or master's in education, and thus their STEM qualifications would not be captured by the methodology. Data providing a full inventory of workers' STEM skills and qualifications would provide for a more nuanced assessment of changes in skills demand.

Potential extensions or refinements of the approach include defining STEM-intensity at a more detailed level of classification of occupations and/or qualifications and allowing for part-time/full-time status of workers. However, the more detailed the occupational classification used as the basis for defining STEM-intensity, the more one will counter issues with small cell counts. Concerns over the appropriateness of the weightings applied by level of qualification could readily be assessed by testing the sensitivity of key findings to alternative weightings. Note that the common approach of defining STEM workers as those with a degree or higher is also an implicit weighting, and a special case of our approach (i.e., a weighting of one for a bachelor's degree and higher and zero otherwise). Even for those arguing that the focus for STEM capacity should be at the university level, our approach at least places greater weighting on higher degrees over undergraduate degrees.

Some critical reflections on STEM

Another element of the methodology ripe for sensitivity analyses is the choice of what fields of education to include in STEM. A challenge in determining the appropriate fields to include is the lack of a clear statement of the rationale behind the grouping of a particular set of fields together as STEM (or STEMM or STEAM). Ideally, such decisions in the modelling approach would be geared to answer specific questions or provide specific information, however, no explicit motivation seems to have been provided to guide the definition of STEM.

Much of the narrative surrounding STEM relates to what are seen as growing skills needs in response to the changing nature of work, suggesting that growing demand is common to each of the fields. However, there is little evidence to support this from the analysis. Our results suggest that changes in employment by occupation have reduced the STEM-intensity of employment overall. The long term structural shift away from manufacturing in the Australian economy is likely to have been a significant factor driving this result, with manufacturing identified as the most common industry of employment for STEM qualified workers (Office of the Chief Scientist 2016: 20). It is clearly demand for qualifications in the field of Health that have grown most as a result of the changing occupational distribution of work over recent years, perhaps offering support for the inclusion of medicine in an expanded STEMM. The conclusions drawn with respect to STEM would have been dramatically different if qualifications in the field of Health had been included in the definition of STEM, given the weighted increase in employment in Health between 2006 and 2016 was almost as great as for the three core STEM fields combined. However, if fields are included on the basis of exhibiting growing demand, the whole argument becomes circular. Moreover, the pattern of change within individual STEM fields is far from uniform, with demand for qualifications declining in ERT in relative terms, and IT being the only STEM field in which jobs that intensively use those qualifications have grown faster than average between 2006 and 2016. IT is also the only field to see above-average growth in skill demand in coming years, based on occupational projections.

As noted, there is a possibility that the methodology has failed to detect a more general or broad based increase in STEM content across all occupations. However, again the evidence casts doubt on this – the ‘shrinking middle’ pattern of growth in occupations by quintile of STEM-intensity shows that in fact there has been strong growth in occupations with the very lowest level of STEM-intensity. There is an associated policy question of whether the priority for the education system should be to promote greater general STEM literacy or strengthen capacity at the more elite level. Arguments of the need to position ourselves as an ‘innovation nation’ to maintain our competitiveness and standard of living would seem more compatible with increasing capacity at the elite level and with higher growth in STEM-intensive occupations. The latter trend is not evident in the data.

In developing the methodology to assess changes in the demand for STEM qualifications, note that the approach taken for STEM as a whole could equally be applied to the individual STEM fields and to other fields of education. So while the approach was motivated by the STEM narrative, nothing different was done from the more general case of trying to forecast skills demand by field of education. Without some additional (and testable) information specific to those fields, there seems little to be gained from grouping them together from the perspective of forecasting skills demand.

The rationale for grouping science, technology, engineering and mathematics together may lie in pedagogical issues: common challenges in science education and communication. Indeed a substantial STEM education literature has emerged (see, for example, Freeman, Marginson and Tytler 2015). However, we believe the development of explicit and testable statements of rationales and assumptions behind STEM definitions and associated policy is necessary to further advance skills forecasting and the appropriate role, if any, of a unique STEM agenda within that framework.

Finally, we note that all the analysis in this paper is based on data collected and projections prepared prior to the outbreak of COVID-19, and does not take into account the potential impact of the pandemic on the Australian labour market. It is fair to assume those impacts will include a bleaker aggregate employment outlook, and a further relative increase in demand for skills and qualifications in the field of Health.

References

Australian Bureau of Statistics (2001), *ANZSCO – Australian Standard Classification of Education, 2001*, ABS Catalogue no. 1272.0, ABS.

Australian Bureau of Statistics (2006), *ANZSCO – Australian and New Zealand Standard Classification of Occupations*, 1st edition, ABS Catalogue no. 1220.0, ABS.

Australian Bureau of Statistics (2014), Perspectives on Education and Training: Australians with qualifications in science, technology, engineering and mathematics (STEM), 2010–11, ABS Canberra.

Australian Industry Group (2013), Lifting our Science, Technology, Engineering and Maths (STEM) Skills, Australian Industry Group.

Australian Industry Group (2015), *Progressing STEM skills in Australia*, AIG, March.

Australian Qualifications Framework Council (2013), Australian Qualifications Framework, 2nd Edition, January, Australian Qualifications Framework Council, South Australia.

Bequette, J. W., and Bequette, M. B. (2012), 'A place for art and design education in the STEM conversation', *Art Education*, 65(2), 40–47.

Borland, J. and Coelli, M. (2017), 'Are Robots Taking Our Jobs?', *Australian Economic Review*, vol. 50, no. 4, pp. 377–97.

Boy, G. A. (2013), 'From STEM to STEAM: Toward a human-centered education, creativity & learning thinking', In Proceedings of the 31st European Conference on Cognitive Ergonomics, p. 3. ACM. August.

Bradley, D., Noonan, P., Nugent, H. and Scales, B. (2008), *Review of Higher Education: Final Report* (The Bradley Review), Department of Education, Employment and Workplace Relations. Canberra: AGPS.

Buera, F. J. and Kaboski, J. P. (2012), 'The rise of the service economy', *American Economic Review*, vol. 102, no. 6, pp. 2540-69.

Cannady, M. A., Greenwald, E. and Harris, K. N. (2014), 'Problematizing the STEM pipeline metaphor: Is the STEM pipeline metaphor serving our students and the STEM workforce?', *Science Education*, 98(3), 443–460.

Card D. and Payne A. A. (2017), 'High school choices and the gender gap in STEM', NBER Working Paper. http://www.nber.org/papers/w23769

Cassells. R. L, Duncan, A. S., Mavisakalyan, A., Phillimore, J., Seymour, R. and Tarverdi, Y. (2018), 'Future of Work in Australia: Preparing for tomorrow's world', Bankwest Curtin Economics Centre, Focus on the States Series, Issue #6, April 2018.

Cassells, R. and Bond-Smith, S. (2020), 'Analysis of costs and savings of Proposed Reforms to Higher Education', Bankwest Curtin Economics Briefing Paper, July, https://bcec.edu.au/publications/analysis-of-costs-and-savings-of-proposed-reforms-to-higher-education/

Committee for Economic Development Australia (2015), 'Australia's Future Workforce?' CEDA Report, June.

Costantino, T. (2017), 'STEAM by another name: Transdisciplinary practice in art and design education', *Arts Education Policy Review*, 119(2), pp. 100- 106.

Dawkins, J. (1988), Higher Education: A Policy Statement. Department of Employment, Education and Training, Canberra: Australian Government Publishing Service.

Department of Employment, Skills, Small and Family Business (2019), 'Employment Outlook to May 2024'. Canberra: DESSFB, December.

Department of Industry, Innovation and Science (2019), Advancing Women in STEM, Commonwealth of Australia, Canberra, https://www.industry.gov.au/data-and-publications/advancing-women-in-stem

Department of Jobs, Tourism, Science and Innovation (JTSI) (2019), *Future jobs, future skills: Driving STEM skills in Western Australia*, Government of Western Australia, May.

Deloitte Access Economics (2014), 'Australia's STEM workforce: a survey of employers', report for the Office of the Chief Scientist, June 2014.

Dockery, A. M. and Bawa, S. (2018), 'Labour market implications of promoting women's participation in STEM in Australia', *Australian Journal of Labour Economics*, Vol. 21, No. 2, pp. 125-152.

Freeman, B., Marginson, S. and Tytler, R. (eds.) (2015), *The age of STEM: Educational practice across the world in science, technology, engineering and mathematics*, New York & Oxon: Routledge

Frey, C. B. and Osborne, M. A. (2017), 'The future of employment: how susceptible are jobs to computerisation?' *Technological Forecasting & Social Change*, vol. 114, pp. 254–280.

Healy, J., Mavromaras, K. and Zhu, R. (2011), *Consultant report: Securing Australia's future STEM: Country Comparisons, The STEM Labour Market in Australia*, Australian Council of Learned Academies.

Jobs Queensland (2019), *The Future of Work Literature Review*, State of Queensland, February. https://jobsqueensland.qld.gov.au/wp-content/uploads/2019/02/future-of-work-literature-review.pdf.

Korbel, P. (2016), 'Measuring STEM in vocational education and training', NCVER, Adelaide.

Li, I., Dockery, A. M., Jununkar, P. N., Mahuteau, S. (2017), 'Equity in higher education and graduate labour market outcomes', *Journal of Higher Education Policy and Management*, 39(6), 625-641.

Maeda, J. (2013), 'STEM + Art = STEAM', *The STEAM Journal*, 1(1), Article 34. doi:10.5642/steam.201301.34

May, G. S. (2015), 'STEM, not STEAM'. *Inside Higher Ed*. March 30. https://www.insidehighered.com/views/2015/03/%2030/essay-criticizes-idea-adding-arts-push-stem-education

Marginson, S. (2015), "What international comparisons tell us", in Freeman, B., Marginson, S. and Tytler, R. (eds.), *The age of STEM: Educational practice across the world in science, technology, engineering and mathematics*, New York & Oxon: Routledge, pp. 22-32.

Marginson, S., Tytler, R., Freeman, B. and Roberts, K. (2013), *STEM: country comparisons. International comparisons of science, technology engineering and mathematics (STEM) education*, Project 2 Final Report, Australian Council of Learned Academies (ACOLA).

Metcalf, H. (2010), 'Stuck in the pipeline: A critical review of STEM workforce literature', *InterActions: UCLA Journal of Education and Information Studies*, 6(2), Article 4.

Norton, A. (2016), Mapping Australian Higher Education, Report prepared by Grattan Institute, 2016-11, August. https://grattan.edu.au/wp-content/uploads/2016/08/875-Mapping-Australian-Higher-Education-2016.pdf

Oleson, A., Hora, M. T. & Benbow, R. J. (2014), 'What is a STEM job? How Different Interpretations of the Acronym Result in Disparate Labor Market Projections', Viewpoint paper 1, Sept. DOI: 10.13140/RG.2.1.1454.0003

Office of the Chief Scientist (2016), 'Australia's Stem Workforce: Science, technology, Engineering and Mathematics Report', Commonwealth of Australia, March.

Office of the Chief Scientist (2013), 'Science, Technology, Engineering and Mathematics in the National Interest: A Strategic Approach: A Position Paper', Commonwealth of Australia, July.

Office of the Chief Scientist (2012), *Mathematics, Engineering and Science in the national interest*, Commonwealth of Australia, ACT, May.

PwC (2015), *A smart move: future proofing Australia's workforce by growing skills in science, technology engineering and maths*, PwC, April.

Rolling, J. H. (2016), 'Reinventing the STEAM engine for art + design education', *Art Education*, 69(4), pp. 4–7.

Siekmann, G. and Korbel, P. (2016a), 'Defining 'STEM' skills: review and synthesis of the literature', NCVER, Adelaide.

Siekmann, G. and Korbel, P. (2016b), 'Identifying STEM occupations: national and international approaches', NCVER, Adelaide.

Siekmann, G. (2016), 'What is STEM? The need for unpacking its definitions and applications', Adelaide, SA: National Centre for Vocational Education Research.

Rothwell, J. (2013), 'The hidden STEM economy', Washington D.C.: Brookings Institution.

Timms, M., Moyle, K., Weldon, P., & Mitchell, P. (2018), 'Challenges in STEM learning in Australian schools. Policy Insights', 7. Camberwell, VIC: ACER.

Vestberg, H. (2018), Why we need both science and humanities for a Fourth Industrial Revolution education. Global Agenda. Geneva: World Economic Forum. https://www.weforum.org/agenda/2018/09/why-we-need-both-science-and-humanities-for-a-fourth-industrial-revolution-education/

Wajngurt, C. and Sloan, P. J. (2019), 'Overcoming gender bias in STEM: The effect of adding the Arts (STEAM)', *Insight: A Journal of Scholarly Teaching*, 14, pp. 13- 28.

Appendix 1: Wage equation results

Table A1. Estimated Regression coefficients - dependent variable = natural logarithm of real hourly wage; HILDA 2001-2017

Parameter	*Estimate*	*Standard Error*	*t Value*	*Pr > |t|*
Intercept	2.522	0.032	78.82	<.0001
Wave (1-17)	0.012	0.000	29.31	<.0001
Female	-0.090	0.007	-13.08	<.0001
Age in years	0.042	0.002	24.67	<.0001
Age-squared	-0.045	0.002	-20.89	<.0001
Married	0.082	0.006	14.37	<.0001
Female – number of kids	-0.026	0.006	-4.36	<.0001
Female – number of kids squared	0.002	0.001	1.38	0.1678
Has long-term disability	-0.070	0.007	-9.50	<.0001
Country of birth				
Australia	–			
English Speaking country	0.035	0.011	3.33	0.0009
Non-English speaking country	-0.071	0.010	-7.26	<.0001
Works part-time	0.028	0.006	4.80	<.0001
Tenure – years in current occupation	0.010	0.001	11.16	<.0001
Tenure-squared	-0.015	0.003	-5.87	<.0001
Proportion of time in unemployment[a]	-0.486	0.028	-17.32	<.0001
Highest post-school qualification				
Postgraduate degree	0.129	0.015	8.66	<.0001
Graduate diploma or certificate	0.048	0.014	3.55	0.0004
Bachelor's degree	–			
Diploma or advanced diploma	-0.171	0.012	-14.49	<.0001
Certificate Level III or IV	-0.278	0.009	-30.59	<.0001
Completed Year 12	-0.260	0.010	-26.81	<.0001
Year 11 and below	-0.378	0.010	-37.65	<.0001
Mean (log wage)	3.349			
Observations	136,699			
Individuals	21,755			
R-squared	0.23			
F-test (20 degrees of freedom)	546.88			<.0001

Notes: a. since leaving full-time education.

Appendix 2: Occupations by 2016 STEM-intensity, ANZSCO 3 digit level

ANZSCO code	*Occupation (ANZSCO minor-group)*	*STEM Intensity*	*2016 Rank*	*2006 Rank*
233	Engineering Professionals	0.834	1	1
261	Business and Systems Analysts, and Programmers	0.721	2	2
263	ICT Network and Support Professionals	0.641	3	5
230	Design, Engineering, Science and Transport Professionals, nfd	0.593	4	3
323	Mechanical Engineering Trades Workers	0.590	5	7
260	ICT Professionals, nfd	0.588	6	9
341	Electricians	0.584	7	6
234	Natural and Physical Science Professionals	0.570	8	4
231	Air and Marine Transport Professionals	0.565	9	8
262	Database and Systems Administrators, and ICT Security Specialists	0.564	10	10
321	Automotive Electricians and Mechanics	0.557	11	11
320	Automotive and Engineering Trades Workers, nfd	0.552	12	13
135	ICT Managers	0.516	13	14
310	Engineering, ICT and Science Technicians, nfd	0.511	14	12
322	Fabrication Engineering Trades Workers	0.500	15	17
324	Panelbeaters, and Vehicle Body Builders, Trimmers and Painters	0.490	16	15
313	ICT and Telecommunications Technicians	0.486	17	16
342	Electronics and Telecommunications Trades Workers	0.456	18	18
340	Electrotechnology and Telecommunications Trades Workers, nfd	0.408	19	26
394	Wood Trades Workers	0.384	20	21
300	Technicians and Trades Workers, nfd	0.377	21	19
392	Printing Trades Workers	0.356	22	20
312	Building and Engineering Technicians	0.334	23	22
200	Professionals, nfd	0.326	24	23
311	Agricultural, Medical and Science Technicians	0.314	25	24
139	Miscellaneous Specialist Managers	0.258	26	25
133	Construction, Distribution and Production Managers	0.229	27	27
242	Tertiary Education Teachers	0.222	28	29
510	Office Managers and Program Administrators, nfd	0.211	29	54
393	Textile, Clothing and Footwear Trades Workers	0.206	30	28
712	Stationary Plant Operators	0.203	31	35
130	Specialist Managers, nfd	0.198	32	30
700	Machinery Operators and Drivers, nfd	0.196	33	36
399	Miscellaneous Technicians and Trades Workers	0.178	34	37
511	Contract, Program and Project Administrators	0.177	35	38
731	Automobile, Bus and Rail Drivers	0.174	36	41
111	Chief Executives, General Managers and Legislators	0.170	37	33
224	Information and Organisation Professionals	0.170	38	40

ANZSCO code	*Occupation (ANZSCO minor-group)*	*STEM Intensity*	*2016 Rank*	*2006 Rank*
110	Managers, nfd	0.167	39	34
710	Machine and Stationary Plant Operators, nfd	0.157	40	44
711	Machine Operators	0.154	41	50
839	Miscellaneous Factory Process Workers	0.151	42	56
390	Other Technicians and Trades Workers, nfd	0.151	43	32
899	Miscellaneous Labourers	0.150	44	49
225	Sales, Marketing and Public Relations Professionals	0.143	45	42
149	Miscellaneous Hospitality, Retail and Service Managers	0.140	46	45
232	Architects, Designers, Planners and Surveyors	0.135	47	43
890	Other Labourers, nfd	0.132	48	82
733	Truck Drivers	0.125	49	51
220	Business, Human Resource and Marketing Professionals, nfd	0.125	50	52
590	Other Clerical and Administrative Workers, nfd	0.124	51	39
732	Delivery Drivers	0.119	52	62
721	Mobile Plant Operators	0.115	53	60
730	Road and Rail Drivers, nfd	0.114	54	58
831	Food Process Workers	0.112	55	67
441	Defence Force Members, Fire Fighters and Police	0.112	56	48
442	Prison and Security Officers	0.108	57	53
131	Advertising, Public Relations and Sales Managers	0.107	58	47
330	Construction Trades Workers, nfd	0.105	59	69
821	Construction and Mining Labourers	0.102	60	65
591	Logistics Clerks	0.100	61	61
610	Sales Representatives and Agents, nfd	0.099	62	46
500	Clerical and Administrative Workers, nfd	0.099	63	72
240	Education Professionals, nfd	0.097	64	55
561	Clerical and Office Support Workers	0.096	65	70
132	Business Administration Managers	0.095	66	63
140	Hospitality, Retail and Service Managers, nfd	0.093	67	57
832	Packers and Product Assemblers	0.090	68	77
741	Storepersons	0.089	69	73
530	General Clerical Workers, nfd	0.088	70	71
611	Insurance Agents and Sales Representatives	0.087	71	59
600	Sales Workers, nfd	0.085	72	64
540	Inquiry Clerks and Receptionists, nfd	0.084	73	80
142	Retail Managers	0.081	74	68
800	Labourers, nfd	0.080	75	86
830	Factory Process Workers, nfd	0.080	76	84
541	Call or Contact Centre Information Clerks	0.079	77	66
599	Miscellaneous Clerical and Administrative Workers	0.073	78	81
250	Health Professionals, nfd	0.073	79	83

ANZSCO code	*Occupation (ANZSCO minor-group)*	*STEM Intensity*	*2016 Rank*	*2006 Rank*
811	Cleaners and Laundry Workers	0.073	80	91
841	Farm, Forestry and Garden Workers	0.073	81	88
121	Farmers and Farm Managers	0.073	82	87
891	Freight Handlers and Shelf Fillers	0.068	83	104
251	Health Diagnostic and Promotion Professionals	0.064	84	79
630	Sales Support Workers, nfd	0.063	85	126
362	Horticultural Trades Workers	0.063	86	89
440	Protective Service Workers, nfd	0.063	87	108
141	Accommodation and Hospitality Managers	0.062	88	90
212	Media Professionals	0.062	89	78
222	Financial Brokers and Dealers, and Investment Advisers	0.061	90	85
223	Human Resource and Training Professionals	0.060	91	74
249	Miscellaneous Education Professionals	0.056	92	96
612	Real Estate Sales Agents	0.056	93	93
550	Numerical Clerks, nfd	0.056	94	92
532	Keyboard Operators	0.055	95	94
621	Sales Assistants and Salespersons	0.053	96	98
361	Animal Attendants and Trainers, and Shearers	0.053	97	97
211	Arts Professionals	0.052	98	95
639	Miscellaneous Sales Support Workers	0.051	99	100
210	Arts and Media Professionals, nfd	0.048	100	105
332	Floor Finishers and Painting Trades Workers	0.046	101	103
512	Office and Practice Managers	0.045	102	101
531	General Clerks	0.043	103	113
851	Food Preparation Assistants	0.043	104	119
551	Accounting Clerks and Bookkeepers	0.042	105	109
552	Financial and Insurance Clerks	0.042	106	111
451	Personal Service and Travel Workers	0.042	107	106
452	Sports and Fitness Workers	0.041	108	102
134	Education, Health and Welfare Services Managers	0.039	109	110
631	Checkout Operators and Office Cashiers	0.038	110	121
333	Glaziers, Plasterers and Tilers	0.038	111	107
431	Hospitality Workers	0.038	112	116
351	Food Trades Workers	0.035	113	124
423	Personal Carers and Assistants	0.034	114	123
331	Bricklayers, and Carpenters and Joiners	0.033	115	112
270	Legal, Social and Welfare Professionals, nfd	0.032	116	75
241	School Teachers	0.032	117	114
422	Education Aides	0.031	118	122
420	Carers and Aides, nfd	0.029	119	125
334	Plumbers	0.028	120	115

ANZSCO code	*Occupation (ANZSCO minor-group)*	*STEM Intensity*	*2016 Rank*	*2006 Rank*
272	Social and Welfare Professionals	0.026	121	117
542	Receptionists	0.025	122	127
221	Accountants, Auditors and Company Secretaries	0.025	123	120
411	Health and Welfare Support Workers	0.025	124	118
400	Community and Personal Service Workers, nfd	0.023	125	99
253	Medical Practitioners	0.022	126	129
521	Personal Assistants and Secretaries	0.020	127	130
421	Child Carers	0.020	128	132
271	Legal Professionals	0.019	129	128
252	Health Therapy Professionals	0.013	130	131
254	Midwifery and Nursing Professionals	0.007	131	133
391	Hairdressers	0.004	132	134
360	Skilled Animal and Horticultural Workers, nfd	0.000	133	31
450	Sports and Personal Service Workers, nfd	0.000	134	76

Appendix 3: Robustness check – weighting qualification level by years of education

The changes in skill requirements in STEM and in individual fields of education between 2006 and 2016, as reported in Table 4, were recalculated with the qualifications weighted by the years of education typically required to gain the qualification, instead of by the associated wage premium. The years to gain a qualification is calculated as the sum of typical years of schooling and the typical years in post-school education and training. Twelve years of schooling is assumed for qualifications at the bachelor's degree level and above. For lower level qualifications, the average completed years of schooling for persons holding that qualification is calculated from 2016 Census data. Time taken to complete each level of post-school qualification was taken from the 'volume of learning' typically associated with different qualification levels, as given in the 2013 Australian Qualifications Framework (Australian Qualifications Framework Council 2013). The average years of education assumed for each broad post-school qualification level took into account the proportion of employed persons with qualifications at the more disaggregated level using Census data (e.g., the proportion of people with Certificate level I, II, III and IV in 2016 is accounted for in estimating the average time taken for the broader 'Certificate' category). The estimates range from 12.36 years for a Certificate to 17.55 years for completion of a PhD. Standardising the time taken to complete a Bachelor's degree (15.75 years of education) to equal one results in the following measure of skill intensity for field of education j within each occupation i:

$$S_{j,i} = \frac{(0.785N_{Cert.j,i} + 0.834N_{Dip.j,i} + 1.000N_{Degree.j,i} + 1.086N_{Grad.dip.j,i} + 1.114N_{Higher.deg.j,i})}{N_{Total.i}} \qquad \text{(Equation 2)}$$

Comparing Equation 2 with Equation 1, it can be seen that weighting qualifications by their associated time in education, rather than their associated wage premium, results in a very similar, albeit slightly flatter, gradient by qualification level. Accordingly, the estimates of growth in skill demand by field of education vary only marginally, and the key findings are unaffected, as can be seen by comparing Table A3 to Table 4. Weighting qualifications on the basis of their associated years in education, the demand for STEM skills increased by 16.9 per cent between 2006 and 2016, lower than the 21.3 per cent growth in demand for skills across all fields. This compares to estimates of 17.3 per cent for STEM and 21.5 per cent overall using the original approach.

Table A3. Change in skill requirements: STEM and non-STEM (employed persons weighted by years of education required to attain skill level)

	Weighted employment			*Per cent growth*
	2006	*2016*	*Change*	
STEM	**1,227,431**	**1,435,278**	**207,847**	**16.9**
Natural & Physical Sciences	187,249	227,365	40,116	21.4
Information Technology	194,411	252,302	57,891	29.8
Engineering & Related Technologies	845,770	955,610	109,840	13.0
Non-STEM				
Architecture and Building	325,376	378,150	52,775	16.2
Agriculture, Environmental & Related	129,524	141,216	11,692	9.0
Health	542,524	736,615	194,091	35.8
Education	454,604	565,281	110,677	24.3
Management and Commerce	1,197,188	1,406,433	209,245	17.5
Society and Culture	641,866	828,703	186,837	29.1
Creative Arts	220,753	264,353	43,601	19.8
Food, Hospitality & Personal Services	253,902	298,569	44,668	17.6
All Fields	**4,993,167**	**6,054,598**	**1,061,431**	**21.3**