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Characterising the Australian Engineering Workforce and Engineering Graduate Occupational Outcomes Using National Census Data

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Abstract

The purpose of undergraduate engineering education is to develop graduates who are capable of commencing professional engineering practice. Professional education should equip graduates with the skills, knowledge and attitudes required for their initial professional practice. It should also enable the capacity to continue the professional development required to refresh knowledge and skills as the graduates mature and the nature of professional engineering work develops. However, it is true that many graduates from professional engineering programs, either immediately or at some later time, pursue a career outside of professional engineering. The reasons for this are widely speculated upon, and are no doubt complex. In this regard, the professional engineering workforce, the undergraduate engineering education system, the links between them, and the occupational outcomes for engineering graduates in Australia are similar to many other developed nations. Using the latest Australian national census data we present a detailed analysis of the makeup of the professional engineering workforce and the occupational outcomes for graduates of undergraduate engineering programs in Australia. The data show that the Australian professional engineering workforce is comprised of people with a wide range of educational qualifications, and, even immediately post-graduation, many Australian engineering graduates pursue non-engineering occupations. This analysis presents important findings for those designing undergraduate engineering curricula that seek to equip students for the best employment outcomes, given the nature of the professional engineering work environment, and the short- and long-term occupations that engineering graduates actually pursue in Australia.

Keywords: Curriculum Design; Engineering Education Qualifications; Occupational Outcomes.

1 Introduction

A number of reviews of engineering education internationally, over an extended period of time, have concluded that there is a need to improve the quality, quantity, capability and employability of engineering graduates, and that design of undergraduate engineering curricula plays a central role in achieving this goal (Beanland & Hadgraft, 2013). Many prescriptions for achieving this improvement call for industry input into the design and review of engineering curricula to, "… enhance the industry relevance of engineering curricula." (Australian Workforce and Productivity Agency, 2014, p. 84) There are many means by which 'industry' input into undergraduate engineering curricula might be obtained, but industry advisory boards (IABs) are generally viewed as a key mechanism for providing this desired university-industry interface – "This relationship provides a way to monitor the effectiveness of curriculum by providing real-world assessment of coursework as well as scrutinizing the on-the-job performance of past graduates." (Genheimer, 2007, p. 18, citing Summers 2002) As a specific pedagogy, project-based learning (PBL) is often seen as an 'authentic' learning design in engineering education (Dym, Agogino, Eris, Frey, & Leifer, 2005), because the project-based organisation of work is common in engineering practice (Australian Workforce and Productivity Agency, 2014).

The regular appeals for engineering curricula to be more 'authentic', 'real-world', 'industry-relevant', etc. are almost always premised on a view that most, if not all, graduates from undergraduate engineering programs will go into professional engineering practice in 'industry'. However, the reality is that, internationally, many engineering graduates never work in professional engineering practice, or if they do, they do not remain in that sector very long (Choy & Bradburn, 2008; Palmer, Tolson, Young, & Campbell, in press). Even those engineering graduates that do work in an engineering role may find that their undergraduate education did not actually, "… present a realistic picture of what engineering is like 'on the job'." (Bailyn & Lynch, 1983, p.

264) Where engineering graduates do not practice in professional engineering, it is commonly framed as a ‘problem’ or ‘wasteful’. The Australian Council of Engineering Deans refers to the ‘loss’ of engineering graduates, being a ‘poor return’ on the investment in their education (Australian Workforce and Productivity Agency, 2014). The Organisation for Economic Co-operation and Development refers to the natural inter-professional mobility of engineers as a ‘concern’ not only for engineers, but also for other professions and the wider economy (Lavoie & Finnie, 1998). The Roberts’ Review investigating the supply of people with science, technology, engineering and maths (STEM) skills in the UK (Roberts, 2002), “… identified a number of *serious problems* in the supply of people with the requisite high quality skills.” (p. iii) While part of the concern related to the declining number of students electing to study STEM, the report also noted, “… other sectors from which there is strong, and growing, demand for the skills and knowledge of science and engineering graduates (for example, financial services) tend to offer more generous pay and more attractive career structures … As a result, they have *taken increasing proportions of the best science and engineering students*.” (p. 14)

Using the latest Australian comprehensive national census data we present a detailed analysis of the makeup of the professional engineering workforce and the occupational outcomes for graduates of undergraduate engineering programs in Australia.

2 The Professional Engineering Workforce

For an undergraduate engineering curriculum to authentically represent professional engineering practice, it is a necessary first step to understand the characteristics of professional engineering practice. Defining who is an ‘engineer’ has been a question debated internationally for a long time. As Parker (2004) notes, this question caused difficulty for the Superintendent of the US census in 1850, and continues to do so for those interested in labour market analysis today. Didier (1999) observes that a definitive meaning of the term ‘engineer’ in France has been an issue for more than two centuries. Bailyn and Lynch (1983) identify many definitions used in research relating to the engineering workforce, generally, “… based either on education or on current work activities.” (p. 264) Parker (2004) asks:

> By what criteria should one judge whether someone is an engineer? His self-identification as such? Her job description and job title? Having an engineering degree? Having a degree in a related field? Indeed, does an engineer have to have a degree? Should someone still be counted an engineer if she has become a manager? (p. xiv)

Didier (1999) notes that, “In France, ‘engineer’ is both a job *and* a title.” (p. 474) The job means being part of a profession requiring technical expertise, and the title is bestowed by earning an engineering degree. In Australia, the Australian and New Zealand Standard Classification of Occupations, “… counts all persons within a particular occupation as ‘engineers’ regardless of their level and nature of their qualifications.” (Australian Workforce and Productivity Agency, 2014, p. 18)

Simply defining an engineer as a graduate from an accredited engineering program is also problematic, as many people who graduate as a qualified engineer never practice engineering, or if they do, they leave to pursue work in other fields, or leave the workforce altogether. In Australia, the Australian Workforce and Productivity Agency (2014) notes, “Engineering degrees include applied problem-solving, research skills and professional skills in addition to engineering science, which are skills that are extremely attractive to employers outside the field of engineering.” (p. 94) In a previous investigation into where Australian undergraduate engineering graduates were working, the authors found that, overall, only a third were working in a professional engineering occupation, and even shortly after graduation this figure was only about a half (Palmer et al., in press). In the US, in 2011, only 26 per cent of science and engineering college graduates were working in a STEM occupation (Landivar, 2013). Specifically for engineering bachelor graduates in the US, in 1991 about 1.3 million of the 2.8 million (about 46 per cent) graduates were employed as engineers (Parker, 2004), and in a longitudinal investigation, Choy and Bradburn (2008) found that, ten years post-graduation, only about half of engineering majors were still working in a related field. It seems clear that in many countries, engineering graduates have a wide array of attractive career options beyond engineering open to them, in part because of their STEM skills are increasingly valued in many sectors (Lavoie & Finnie, 1998).

The confusion regarding who is an engineer results in part from the legal status of the occupational title in various jurisdictions. While there is legal protection for the occupational use of the title engineer in some countries, especially in Europe (European Council of Civil Engineers, 2005), in many other countries such protection is limited or non-existent. Spinden (2014) notes that while all states in the US require engineering practitioners to be licenced, around 80 per cent of those working in engineering roles do not pursue licencing, because they fall into one of the categories exempt from requiring a licence. Didier (1999) observes that in France, "The engineering profession itself is neither controlled nor regulated by French law." (p. 476) She also notes that those with a formal engineering education are only a subset of those working as engineers. In Australia, "… there is no legal ownership of the occupation title 'engineer'. Anyone can call themselves an engineer …" (Australian Workforce and Productivity Agency, 2014, p. 30) In many countries this results in an 'engineering workforce' composed of people with a range of qualifications, including non-STEM qualifications or none at all. In the US, in 1995, 400,000 of the 1.6 million people (approximately 25 per cent) employed in engineering occupations did not have an engineering degree (Lucena, 2003). In 1999 this proportion was still around 25 per cent (Parker, 2004). For all STEM workers in the US in 2011, around 30 per cent had less than a bachelor degree (Landivar, 2013).

Many people completing undergraduate engineering studies and qualified to enter the professional engineering workforce do not, or if they do, leave it after a short time, i.e., many 'engineers' work out of their field. In many countries, qualified engineers make up only a proportion of the professional engineering workforce. The nature of engineering work and the engineering workforce is often much more complex than the view presented to students (both those considering engineering study, and those currently completing undergraduate studies), and that upon which undergraduate engineering curriculum design is typically based. To gain an 'authentic' overview of the Australian professional engineering workforce, and where graduates of Australian undergraduate engineering programs fit in, here we analyse the latest Australian national census data covering educational qualifications and occupational roles reported by the Australian population.

3 Methodology

To identify which occupations Australian engineering graduates are working in, the Australian Bureau of Statistics census online TableBuilder service (Australian Bureau of Statistics, 2015) was used to cross-tabulate those respondents in the most recent Australian national census (in 2011) that reported a bachelor-level degree in engineering versus the occupations reported by respondents. The census data include 477 occupational classifications. These occupational classifications clearly identify 11 groups related to professional engineering, those not working, and those whose occupation cannot be classified. The remaining 463 non-professional-engineering occupational classifications were clustered into broad occupational groups – IT, general management, technical, marketing, etc. A discussion of this data set, including its limitations has been reported previously (Palmer et al., in press). Similarly, to identify what qualifications those working in professional engineering occupations in Australia have, the ABS TableBuilder service was used to cross-tabulate those census respondents that reported working in a professional engineering occupation versus the highest educational qualifications reported by respondents. The census data include 120 educational qualifications, based on eight levels (advanced diploma, bachelor, graduate diploma, etc.) across 15 broad discipline areas (engineering and related technologies, health, education, creative arts, etc.). The occupational classifications used to identify the Australian professional engineering workforce were the same 11 groups noted above. These two sets of cross-tabulated data were charted together to map out the relationship between those who graduate from bachelor-level undergraduate engineering programs, and those who work in professional engineering occupations, in Australia. The results obtained and their implications are discussed.

4 Results

Table 1 presents the census occupational classifications used to identify respondents currently working in a professional engineering occupation. In the 2011 Australian census data, 200,356 respondents reported a bachelor-level engineering qualification. The left-hand column in Figure 1 presents the numbers and proportions of respondents who reported a bachelor-level engineering qualification, grouped by consolidated professional engineering occupations and the other principal broad occupational groups reported by respondents. In the 2011 Australian census data, 140,427 respondents reported working in a professional engineering occupation. The right-hand column in Figure 1 presents the numbers and proportions of respondents who reported working in a professional engineering occupation, grouped by the highest educational qualification reported by respondents. Australian census data reported publicly via the ABS TableBuilder service are subject to small random adjustments to avoid the possibility of categories with very small numbers of respondents possibly leading to the re-identification of individual respondents. Hence, the two lower column segments in Figure 1 (on the left - those bachelor of engineering graduates working in a professional engineering occupation, and on the right – those people working in a professional engineering occupation and holding a bachelor of engineering qualification) do not quite match in absolute numbers of respondents.

Table 1. Census occupational classifications relating to professional engineering.

Chemical and Materials Engineers	Civil Engineering Professionals
Electrical Engineers	Electronics Engineers
Industrial, Mechanical and Production Engineers	Mining Engineers
Other Engineering Professionals	Engineering Managers
Engineering Professionals (not further defined)	ICT Support and Test Engineers
Telecommunications Engineering Professionals	

5 Discussion

Figure 1 indicates that approximately half of all engineering bachelor graduates are not working in professional engineering occupations. Nearly 20 per cent of the balance are not working, and overall, about one third of all Australian engineering bachelor graduates reported working in a professional engineering occupation. A separate analysis of this data that considered respondents aged 20-24 years old (i.e., the age range covering most recent graduates from undergraduate programs) found that, even immediately post-graduation, less than half of Australian engineering graduates were working in a professional engineering occupation (Palmer et al., in press). In addition to the occupational groups explicitly identified in the left column of Figure 1, the 'All other occupations' group was made up of: marketing 3.1 per cent; construction 2.3 per cent; other professional 1.9 per cent; finance 1.6 per cent; science 1.1 per cent, unknown 1.0 per cent; education 0.9 per cent; and health 0.3 per cent. The related literature was examined for similar results. In a longitudinal investigation of US bachelor graduates, Choy and Bradburn (2008) found that, ten years post-graduation, only about half of engineering majors were still working in a related field. Using earlier Australian census data, Trevelyan and Tilli (2010) found that across the period 2001-2006, about half of all bachelor or higher engineering graduates aged 25-55 years were not working in engineering-related jobs. When census data for higher degree graduates were included in the analysis here for comparison, the total number of engineering graduates increased by about 25 per cent, but the proportions in Figure 1 did not significantly change.

Figure 1 indicates that bachelor of engineering graduates make up less than half of all Australians who reported working in a professional engineering occupation. An additional 11.6 per cent of respondents had a postgraduate engineering qualification (master or PhD level), so, slightly more than half of those in a professional engineering occupations had a bachelor degree or higher in engineering. However, the curriculum design of postgraduate engineering studies is typically very different to that of undergraduate programs – the latter being of principal interest here. Another 16.2 per cent of respondents reported sub-professional technical and trade engineering qualifications (certificate and advanced diploma). 6.5 percent of respondents reported no post-secondary school qualification at all. 2.4 per cent of respondents reported a postgraduate qualification in management. In addition to the educational qualifications explicitly identified in the right column of Figure 1, the 'All other qualifications' group was made up of: information technology 4.4 per cent; other management and commerce 2.6 per cent; architecture and building 2.4 per cent; other engineering and related technologies 2.3 per cent; natural and physical sciences 1.9 per cent; unknown 1.3 per cent; and a number of others all less than 1 per cent each, totalling to 2.6 per cent.

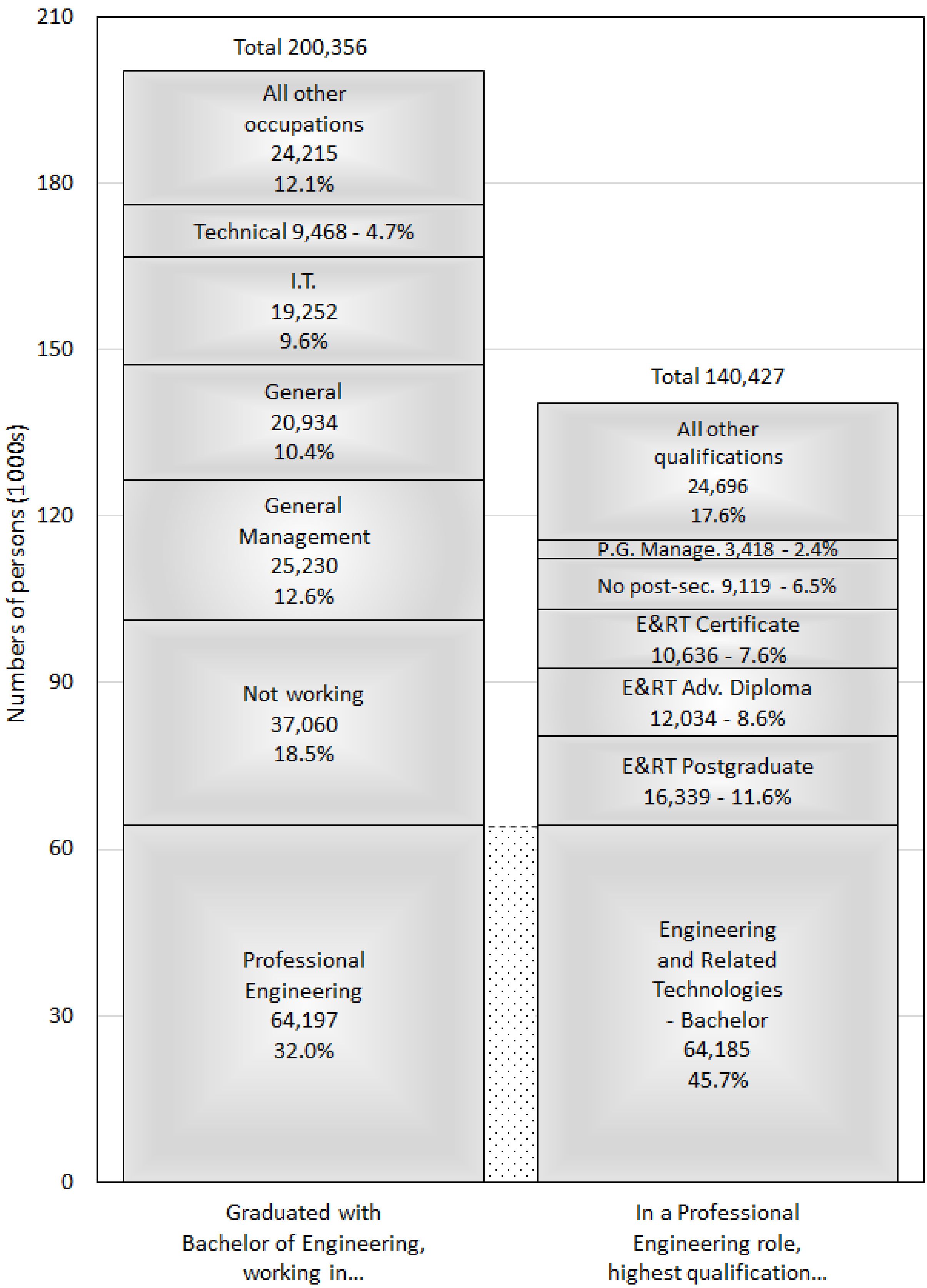

Figure 1. Summary of engineering qualification and occupation data from the 2011 Australian census.

In Australia, approximately 40 per cent of professional engineering roles are filled by people without at least a bachelor of engineering qualification. Lucena (2003) notes that perceived deficiencies in the management skills of some engineers may be responsible for non-engineers in engineering management roles. More generally, Lucena (2003) observes that, in the US, competition may drive organisations to recruit on the basis of demonstrated skills rather than formal qualifications. In jurisdictions where an engineering bachelor degree is not a mandatory requirement for working in a professional engineering occupation then this option is open to employers. In Australia, when demand for skilled professional engineering employees outstrips those locally available, skilled migration (both temporary and permanent) is often used to meet this demand (Australian Workforce and Productivity Agency, 2014). As in the US, it is also possible that demand and competition for engineering skills drives the employment of non-engineers in professional engineering occupations.

Figure 1 indicates that, even allowing for the significant group of graduates not currently working, the number of Australians holding a bachelor of engineering qualification exceeds the number of people reporting working in a professional engineering occupation. Once the significant proportion of non-engineers currently filling professional engineering roles is considered, it is clear that it is a fundamental structural feature of the Australian employment market that many bachelor of engineering graduates will have to find employment outside of engineering if they wish to have a job. As noted above, some investigations of the engineering workforce describe engineering graduates working out of field as problematic (Australian Workforce and Productivity Agency, 2014; Lavoie & Finnie, 1998; Roberts, 2002). Other investigations don't appear to even countenance the possibility of bachelor of engineering graduates working outside of engineering. Romer (2001) presents a detailed analysis of the US job market for engineers and scientists that includes a schematic model of education pathways and work types (p. 236), and which provides no options for completing undergraduates other than graduate studies or employment in private sector research and development. Such a view is congruent with the dominant 'pipeline' model of engineering workforce development (Australian Workforce and Productivity Agency, 2014; Bhattacharjee, 2009) – where students study STEM subjects in school, study engineering at university and then work in a professional engineering occupation. However, there is a growing view that the pipeline model doesn't represent the reality of engineering workforce development, and its assumptions about student intentions and where people enter and exit need to be re-thought (Lucena, 2003; Mellors-Bourne, Connor, & Jackson, 2011).

A number of investigations have found that many students are not presuming a long-term career in engineering, and may hold only vague, or even no specific, career plans. Mellors-Bourne et al. (2011) surveyed 7000 UK STEM students and found that only 63 per cent of final-year engineering students definitely wanted a career in engineering. A survey of Australian engineering graduates found that, "Given the opportunity, most respondents would choose engineering studies again, however many were equivocal about staying in engineering in the medium to long-term." (Department of Education Employment and Workplace Relations, 2009, p. 24) Nearly half of the respondents saw themselves remaining in engineering for less than ten years. Benderly (2015) reports that around 25 per cent of new US engineering graduates were considering careers outside of engineering. Investigating engineering graduate unemployment in the UK, Atkinson and Pennington (2012) noted the emerging view that not all students studying STEM intend to work in STEM, and their advice to universities from employers included "Developing curricula to better reflect the realities of an engineering career" (p 13).

Robst (2007) observes that, while some view graduates working in jobs for which they are 'overeducated' as a labour market inefficiency, there is also a view that this is actually a feature of an efficient labour market, where the qualification plus, "[t]he training and experience gained through that position enables the person to find a better job." (p. 398) Submissions to a recent engineering workforce study in Australia noted that even where engineering graduates work out of their discipline, they, "… will continue to bring 'engineering perspectives and approaches to their work'."; that, "… the wide range of employment opportunities should be 'celebrated'."; and that, "… wherever they work, engineers will contribute their skills to benefit Australian business and the economy." (Australian Workforce and Productivity Agency, 2014, p. 94) Mellors-Bourne et al. (2011) observe that, in UK secondary education, the 'broadening' career benefit of studying STEM subjects is recognised in policy, and the full range of jobs open to STEM graduates, both in the STEM and non-STEM sectors, should be more widely acknowledged in higher education, and should be a key element of careers advice provided to students prior to higher and further education.

As noted above, industry advisory boards are generally viewed as an important mechanism for ensuring the relevance of engineering program curricula. Genheimer (2007) found limited research into the operation of engineering program IABs. Trevelyan and Tilli (2010) observe that the engineering school IABs that provide input to course curricula (and other matters) are typically comprised of representatives from traditional engineering industries. They note that the significant proportion of Australian engineering graduates employed outside of engineering has implications for the representation on IABs - "Given that so many graduates are employed outside engineering and related occupations, one can ask whether other employer groups should be represented …") (p. 114). If authenticity in undergraduate engineering curriculum is one of the goals of an IAB, then the authenticity of the representation on the IAB of likely industries in which graduates of the program will work should be considered.

Parker (2004) notes:

> At the end of the 20th century, engineering practice was challenged by a proliferation of occupations requiring technical education; by rapidly changing technological advances; and by a perennial—if not heightened—concern with the relationship between engineering degree programs and occupational outcomes. (p. xviii)

Historically, in many countries, a bachelor of engineering has been the foundation for a range of well-paid careers, both within and beyond professional engineering. However, engineering education is comparatively expensive (Beanland & Hadgraft, 2013), so a potentially inefficient way to prepare graduates for some careers outside of engineering. As long as there are professional engineering roles to fill, there will be demand for bachelor of engineering graduates. However, with increasing demand and competition for STEM expertise from the non-engineering and non-STEM sectors of the economy (Bhattacharjee, 2009; Mellors-Bourne et al., 2011), it is possible that some other existing or new technology-related undergraduate program(s) might challenge undergraduate engineering programs in these graduate employment markets. Perhaps there will be a shift to engineering science or engineering technology qualifications that provide graduates with the traditionally valued general engineering skillsets more efficiently to build expertise that can service the non-engineering market needs and prepare students for the full range of career possibilities.

6 Conclusion

In Australia, as in many other countries, the stock and flow of human resources in the professional engineering workforce is complex. Using Australian national census data we find that the majority of people holding a bachelor of engineering degree do not work in a professional engineering occupation, and, that more than 40 per cent of the people working in a professional engineering occupation do not hold a bachelor degree or higher in engineering. In Australia, both the attractiveness of career options outside of professional engineering that use and value engineering and STEM skills, and the lack of legal protection for the occupational title of engineer are likely to contribute to these findings. While there are often calls for undergraduate engineering curricula to more authentically reflect the real world of engineering practice, such conceptions of authenticity generally do not reflect a reality where graduates are as likely to work outside of professional engineering as in it. A key reference point for curriculum design is often an industry advisory board. However, the composition of IABs typically does not reflect the likely full range of employers of bachelor of engineering graduates.

It is apparent that existing models of engineering education actually suit many employers, both STEM and non-STEM, and wholesale curriculum change is likely to be a disproportionate response to acknowledging the full spectrum of engineering careers beyond the traditional confines of the profession – to employ the apocryphal engineering maxim, "if it ain't broke, don't fix it." Additionally, undergraduate bachelor of engineering programs are typically accredited by the national engineering professional body, and dramatic curriculum revisions are unlikely to be approved for re-accreditation. However, as well as traditional engineering employers and the professional body, engineering students are also important stakeholders in curriculum design and program employment outcomes. Students – both those considering engineering study, and those currently enrolled in undergraduate engineering programs – would be better informed about, and equipped for, the world of post-graduation work if they were exposed to the likely options for their career trajectory, as confirmed by this research. An authentic undergraduate curriculum would certainly incorporate and reflect the complex reality of the real world of professional engineering practice, the makeup of the engineering workforce, and the wide range of employment opportunities for engineering graduates in Australia.

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