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Future Engineering Graduate Skills for the Australian Department of Defence

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ABSTRACT

CONTEXT

The Department of Defence (DoD, also known as 'Defence') is one of the biggest drivers for the recruitment of skilled engineers in Australia. Amidst the current shortage of skilled engineering labour, the Defence industry is booming with hundreds of billions of dollars invested by government over the next ten years to improve military capabilities (DoD, 2020). It is critical for Defence to build a capable workforce to handle the increased workload, and who understand how military systems are designed and employed. Available literature highlights that engineering graduates that enter the workforce in Australia have perceived shortfalls from their employers and are lacking the skills and attributes required of the practice (Nair et al, 2009).

PURPOSE OR GOAL

Defence has an obligation to the people of Australia to provide the systems and workforce that can defend its national interests. This paper investigates the skills and attributes that graduate engineers require to effectively support Defence projects and compares this data to previous literature from the general engineering industry. It also highlights the main engineering demands required by Defence beyond 2028 to better inform how tertiary institutions can prepare graduates for its workforce.

APPROACH OR METHODOLOGY/METHODS

A survey was used to capture the data to fill the gaps in literature for this project. This data included the perceived performance of graduate engineers working on Defence projects as well as opinions on the future needs of Defence. The survey was targeted at professional engineers working in the industry and was distributed through several networks. The survey had some limitations, and all attempts to remove bias was made to preserve the validity of the results.

ACTUAL OR ANTICIPATED OUTCOMES

The results of the survey demonstrated that graduates in Defence are falling behind in satisfaction levels compared to the general industry in attributes and skills. It was identified that graduates need to be able to better demonstrate co-operation and teamwork as well as learn new skills to be able to work within multi-disciplinary teams. There was also a clear shortage of information and telecommunications engineers which is considered a critical trade for Defence.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

The evidence shown in this paper demonstrates that there is a shortfall in the performance of engineering graduates who begin their careers in Defence. It is critical that graduates improve their skills in systems engineering processes and expand their understanding of how Defence conducts its operations. Improved relations between Defence and academia through workplace experiences would see graduates better prepared for the multidisciplinary problems they will face in industry.

KEYWORDS

Defence Department, Graduate, Skillsets, Engineering Education

Introduction

Defence is experiencing rapid growth within its workforce in order to meet the future security demands of Australia (DoD, 2020). Amidst this demand, Australia is experiencing a shortfall of engineering graduates from tertiary institutions with recent statistics showing 8,444 graduates of engineering in 2020, with more than half coming from international students (EA, 2020). Those graduates that enter the workforce have perceived shortfalls from their employers such as communication and interpersonal skills and are lacking the attributes required of the practice (Nair et al, 2009).

Amidst this growth, the Australian Defence organisation as a whole is facing unprecedented challenges in the ability to acquire new and emerging technologies to deal with changing strategic circumstances (Cook, 2004). In order to posture as a viable military among deteriorating international relations, a surge in demand for engineers who have the necessary skills and understanding of the organisation has been created (DoD, 2019). One of the key problems Defence and private industry is experiencing is the recruitment and retainment of skilled engineers amidst a current nationwide shortage (Parliament of Australia, 2012). This shortage is defined as the situation where there are more engineering vacancies than there are prospective employees. The education of engineers in Australia is not a perfect process, and the few graduates that do enter the workforce generally have skill gaps reported by their employers (Palmer and Ferguson, 2008).

Literature Review

Growth in Defence

The 2020 Defence Strategic Update warns of a lack of strategic warning, where previously Australia would have a ten-year window to prepare for a major conventional attack. This is no longer the case, and Australia needs to develop its military capability among current ‘grey-zone’ warfare activities occurring against the country’s national interests (DoD, 2020). In 2019, a census was conducted on the Defence workforce which found that there is approximately 100,000 uniformed military members and 10,000 civilian public servants (DoD, 2019).

These figures however do not include private contractors from industry who support Defence, and for all intents and purposes, form part of their workforce. Statistics show that the public service portion of Defence has been steadily growing at 3% per year, however the required growth rates to meet the demands of the 2020 Defence Strategic Update are still unknown (DoD, 2020).

On top of the investment in the workforce, the DoD intends to inject an additional $270 billion AUD over the next ten years to invest in Defence capability, bringing the total budget to $575 billion AUD (DoD, 2020). Achieving these outcomes requires Defence to rapidly expand its workforce, including engineers, to ensure that they can be self-sufficient in the sustainment and operation of these assets (EA, 2020). Engineers Australia (EA) Defence spokesperson Greg Walters has expressed concern about the increase in the Defence budget. He cited that the “boom/bust cycle in Defence acquisition is incompatible with consistent employment” and when making long-term decisions, they need to consider the skilled labour required to achieve those outcomes (EA, 2020).

Issues with Engineering Education and Frameworks

Despite an evolution in engineering education that has been designed to improve the readiness of graduates for the 21st century, there are still fundamental problems that require change. Investigations by Litzinger et al (2013) showed that engineering education did not allow students to construct deep conceptual knowledge. A recommendation of this study was that students need to be given the opportunity to ‘develop the ability to apply key technical and professional skills fluently, and to engage in a number of authentic engineering projects’ (Litzinger et al, 2013).

“When trust is unconscious, it’s even more important to protect the integrity of engineering practice” (EA, 2020). When society uses systems designed by engineers, they trust that they work in a safe and effective manner. A key issue in Australia is that engineers do not need to be registered to practice, nor is their practice governed by any regulatory bodies. A comprehensive case study for the statutory registration of all engineers was published by EA in 2020, however it is yet to be reviewed and approved by the Government.

It is also well known that there is an extreme gender imbalance within the engineering profession in Australia, with females representing only 11% of the workforce in 2017 (Professionals Australia, 2017). Among this 11%, there are reports of wage disparities between men and women, sexism and bullying that ultimately leads to a large portion of females leaving the profession before they are 40 years old. The profession of engineering and its education are lacking flexibility and humanisation, both which are vital components to improving the perceived image to future students. When the perceived image is improved, only then can society begin to see a more diverse student body within tertiary engineering education (Darvall, 1991).

Supply and Demand of Skilled Labour

Qualified engineers provide a critical capability to an economy with rapid growth, particularly in areas such as exportation of commodities including energy and minerals (Dowd, 2010). In Australia, the demand for engineers is higher than the current supply from universities. The four biggest drivers for engineers are the resources sector, DoD, the National Broadband Network, and major infrastructure projects (Parliament of Australia, 2012). With a wealth of projects within these sectors, it is expected that the number of vacancies will rise by 7.9% within the next 12 months (Matthews, 2021).

Without proper supply of engineers educated within Australia, industries have to look elsewhere for employees, with migration providing roughly half of the current skilled engineering workforce (Parliament of Australia, 2012). Recent reporting from EA recorded 57% of the engineers in Australia come from overseas, compared to an average of 40% in other professions (EA, 2020). Figure 1 below highlights the trends in the supply of engineering graduates between 2001 and 2018. These graduates are classed as engineers who are 3 years or less into the profession in the workforce (EA, 2022).

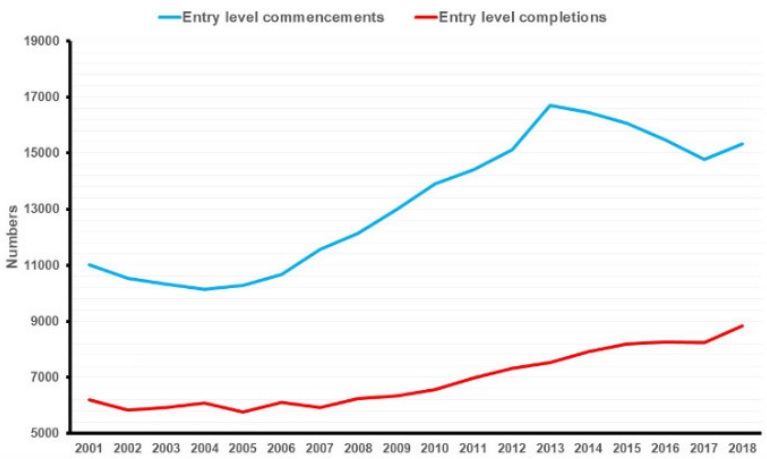

Figure 1: Supply of Engineering graduates from Australian universities (EA, 2020)

Despite a steady decline in the commencement of engineering students from 2013-17, Australia saw a 6.6% rise in university enrolments in 2018. This spike saw 8,444 new engineering graduates; however, this number includes international students who potentially travel home after their studies. One of the big unknowns will be the effect on supply of engineering graduates due to COVID-19

given that new international students have not been able to enrol in courses. In 2018, 4850 of these graduates comprised of international student which made up 57.4% of all graduates for that year.

Gaps between Education and Industry

Analysis of available literature shows that academics who teach engineering at the tertiary level rarely understand the practice of the profession beyond design and technical problem-solving (Trevelyan, 2010). This is consistent with industry feedback within Australia where graduates lack appreciation of fundamental knowledge along with a misalignment between courses taught and requirements of the workplace.

Educators of engineering have been cited as seeing the profession as ‘problem-solving’ in which an engineer performs solitary technical work to produce design outcomes. While reports from employers say that having ‘problem-solving’ skills is important, engineers do not often perform their specialised skills to solve problems in solidarity. On the contrary, the practice requires an ability to achieve results through others, the sharing of knowledge to achieve multi-disciplinary outcomes, a level of tacit ingenuity and the application of engineering science as well as rules of thumb (Trevelyan, 2010).

A study done in 2009 looked at a gap analysis between the top ten engineering graduate attributes as rated by employers and their general satisfaction with those skills shown in Table 1 (Nair et al, 2009). A total of 109 different employers of engineering graduates, specifically from Monash University, participated in the study. Respondents were asked to rate graduates on their performance using a 5-point Likert as well as the importance of a variety of attributes. The top ten attributes are shown in the table below.

Table 1: Gap analysis of engineering employer' perception of Monash University graduate attributes (Nair et al, 2009)

		Mean		
Rank	Attributes	Importance (I)	Satisfaction (S)	Gap (I – S)
1	Oral communication skills	4.57	3.92	0.65
2	Interpersonal skills with colleagues and clients	4.56	3.99	0.57
3	Written communication skills	4.38	3.83	0.55
4	Capacity to analyse and solve problems	4.58	4.04	0.54
5	Ability to develop new or innovative ideas, directions, opportunities or improvements	4.17	3.72	0.45
6	Time management skills	4.07	3.62	0.45
7	Capacity for co-operation and teamwork	4.60	4.16	0.44
8	Ability to apply knowledge in the workplace	4.33	3.91	0.42
9	Ability to cope with work pressure and stress	4.03	3.63	0.40
10	Capacity to learn new skills	4.60	4.22	0.38

The results give tangible evidence to an underperformance of engineering graduates once they enter the workforce. Generic feedback that was consistent among all the employers was that requirements of industry need to be aligned to educational programmes and there should be a closer relationship between industry and tertiary educators.

Plans to Remediate

There are a number of studies that point towards key regulation and accreditation issues with the engineering education sector in Australia that were previously touched on, however is out of scope for this paper. Research conducted in Australia demonstrated that students at University who understood globalisation, including political and societal issues around the world would be better prepared to tackle the problems expected of them in the workforce (Nair et al, 2009).

The introduction of work experience has had positive effects for both students and employers. Research conducted in 2016 from a sample of 240 undergraduate engineering students demonstrated that those who completed work placements were achieving higher grades than those

who had not. Additionally, students who performed well during work experience programs were often offered full time employment after graduation, reducing the recruitment burdens on the employer (Blicblau et al, 2016).

Issues with Current Defence Engineers

Engineer shortages are considered a significant problem for Australia, but for Defence it is critical. Thales Australia's Chief Executive Officer (CEO) Chris Jenkins pleaded with the New South Wales (NSW) legislative council that state governments must act to rectify Science Technology Engineering and Mathematics (STEM) issues in schools so that more graduates emerge out of universities. Unless Australia fixes the shortage, industries that support Defence will have to export projects or import additional engineers from overseas (Defence Connect, 2017).

Defence systems are becoming increasingly more expensive and usually encompass multi-role military platforms, which means that products cannot be replaced 'like for like' anymore (Smith and Oosthuizen, 2012). An emergent problem that the DoD is having is that the curriculums taught at university do not include the requisite skills, particularly in systems engineering, that are required of future graduates to meet their demands (Beven et al, 2019).

Aim of the Research

The overall aim of conducting this research is to identify where there are shortfalls in engineering graduates working for Defence. A summary of the key project aims include:

- Capture the opinions of professionals in the industry of what the future engineering demands of Defence are and compare these to available literature;
- Understand the perceived shortfalls of engineering graduate skills and attributes;
- Compare research data to previous literature on the attributes of graduate engineers; and
- Provide recommendations for future research to address the issues highlighted in this report.

Methodology

A survey was used to capture the data for this project. This data included the perceived performance of graduate engineers working on Defence projects as well as opinions on the future needs of Defence. The survey targeted professional engineers working in the industry and was distributed through several networks. The following sections provide more details to the methodology for data collection.

Survey Development

The survey included seven multiple choice questions, six free responses, and two Likert scale questions, which provided a mix of quantitative and qualitative data. The perceived performance of graduate skills and attributes was captured using a 5-point Likert-scale which enabled a comparison study to previous research conducted by Nair et al (2009). In addition, Paradis et al (2016) noted that Likert-type questions do not always allow for individuals to fully respond to what they know about a problem. This is where capturing qualitative data is useful as it aids in formulating responses to problems with no clear solution (Paradis et al, 2016).

It was important to differentiate the definition of 'skill' verse 'attribute'. For the purposes of this report, the definition of attribute will remain the same as the study done by Nair et al (2009). In short terms, this includes 'soft skills' or qualities that a person may naturally possess, such as the ability to easily relate to others. A skill on the other hand will be considered as a technical quality that has been taught through tangible qualifications.

Target Audience

The targeted criteria for respondents included engineers who met the following; degree qualified engineer (Bachelor or higher), worked for any length of time on a Defence project, and either been a graduate or worked with/managed engineering graduates.

Limitations and Bias

A key limitation of this project was the use of personal connections rather than a full sample of randomly selected engineers across the industry. This tied a small level of bias to the project that could not reasonably be removed by using known contacts. An attempt to remove this personal connection was made by creating the survey as a public link. Google forms enabled anyone with the link to take the survey. This allowed snowball sampling of contacts to share the survey. Additionally, by using known connections, the qualifications of respondents did not encapsulate all disciplines of engineering. for example, an area that is severely lacking in this survey is within construction services (i.e., geotechnical, civil, structural, environmental). This is however due to the location of different Defence project offices and the fact that the survey was largely distributed around the Canberra market.

Results

In summary, the survey was open to market for nine weeks with a total respondent pool of 43 people. This was comprised of a wide variety of engineers from across all sectors of Defence. The results and analysis of the survey is shown in the sections below.

Respondent Analysis

Respondents were asked to indicate their highest level of engineering qualification, with the majority of the respondents holding a Bachelor of engineering with honours (72%). A notable number of respondents held a Masters' degree (18%), with the remainder holding a Bachelor (5%) and Doctoral (5%) degrees. The disciplines of engineering of respondents are illustrated in Figure 2.

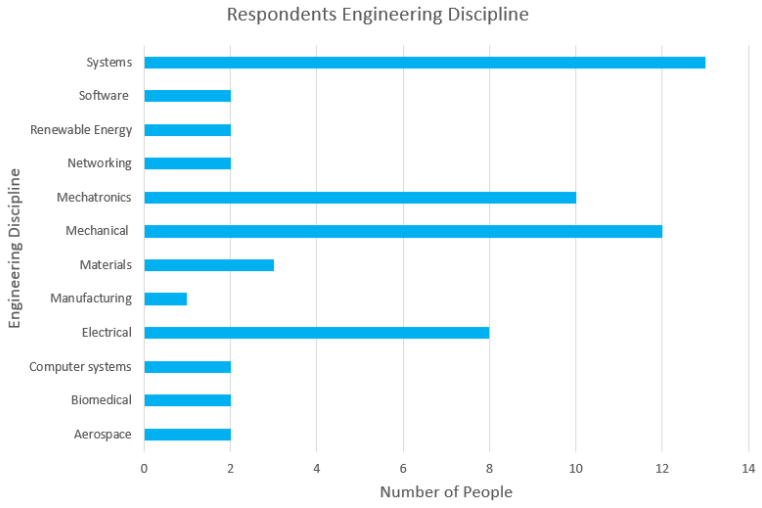

Figure 2: Breakdown of various disciplines the respondents are qualified in.

The majority of respondents identified as having worked within Defence between three to eight years (51%), followed by the next closest breakdown of zero to three years (23%). There was also a notable 12% of respondents who had worked over 20 years in Defence. Over this time period, 55% of respondents stated that they had completed a graduate program, and coincidently 55% had also been a manager of graduates.

Graduate Skill Analysis

A series of proposed critical skills needed for Defence work derived from both the literature review and consultation with current senior Defence engineers, were presented (S1-S5 in Table 1). The respondents were asked to rate their satisfaction with the performance of graduates on a five point Likert scale. The average result of these responses is shown at . Table 2. Additionally, respondents were asked to rate which of these skills they deemed most important for graduates to have. The indicated priority show how many respondents (and %) indicated that the skill was what they thought was most important.

. Table 2: Analysis of Defence engineers' perception of graduate skills

Item	Graduate Skill	Satisfaction	Indicated Priority	
S.1	Project management	3.00	5	11.60%
S.2	Requirements management	2.98	14	32.60%
S.3	Verification and validation activities	2.93	3	7.00%
S.4	ICT skills within employed engineering discipline	3.23	5	11.60%
S.5	Understanding of the Defence operating environment	2.30	16	37.20%

The results demonstrated that there was a very low perceived satisfaction with graduate specific skills that were presented within the survey. These skills that had low satisfaction levels are largely related to the discipline of systems engineering, which is a critical trade within Defence (Beven et al, 2019).

Perception of Graduate Attributes

The graduate attributes that respondents were asked to rate on a scale of one to five are shown below in Table 3. These attributes were presented from one to ten, which non-defence employers perceived priority based on the study done by Nair et al (2009). As part of this study, respondents were asked to rate the top attribute, which is most pertinent to working in Defence. This is shown in the ‘Indicated Priority’ column.

Table 3: Analysis of Defence engineers’ perception of graduate attributes

Item	Graduate attribute	Satisfaction	Indicated Priority	
A.1	Oral communications skills	3.47	5	11.60%
A.2	Interpersonal skills with colleagues and clients	3.56	7	16.30%
A.3	Written communications skills	3.30	1	2.30%
A.4	Capacity to analyse and solve problems	3.77	2	4.70%
A.5	Ability to develop new or innovative ideas, directions, opportunities, or improvements	3.56	0	0%
A.6	Time management skills	3.40	1	2.30%
A.7	Capacity for co-operation and teamwork	3.91	13	30.20%
A.8	Ability to apply knowledge in the workplace	3.30	2	4.70%
A.9	Ability to cope with work pressure and stress	3.40	1	2.30%
A.10	Capacity to learn new skills	4.12	11	25.60%

‘Capacity for co-operation and teamwork’ deemed the most important, followed by “Capacity for co-operation and teamwork’ and ‘Capacity to analyse and solve problems’. It should be noted that comparing the satisfaction levels of graduate skills to attributes demonstrated that there is a clear issue with skills in the Defence workplace. The highest satisfaction level of graduate skills (3.23) was less than the lowest satisfaction level of graduate attributes (3.30).

Case Study on graduate Attributes: Comparison to Previous Australian Study

Part of the survey was used to capture the perceived satisfaction of graduate attributes displayed within Defence, with the intent to compare these results to those captured previously by Nair et al (2009). All efforts were made to replicate this study in terms of the questions asked and the Likert scale that was presented to the respondents. A key difference however is the number of respondents to form the mean values of satisfaction. The study done by Nair et al (2009) captured the opinions of 109 engineering-related employers, whereas this study only achieved 43 individual Defence engineers' responses. Despite the difference in numbers, there is a clear trend in values as shown below in the comparison graph in Figure 3.

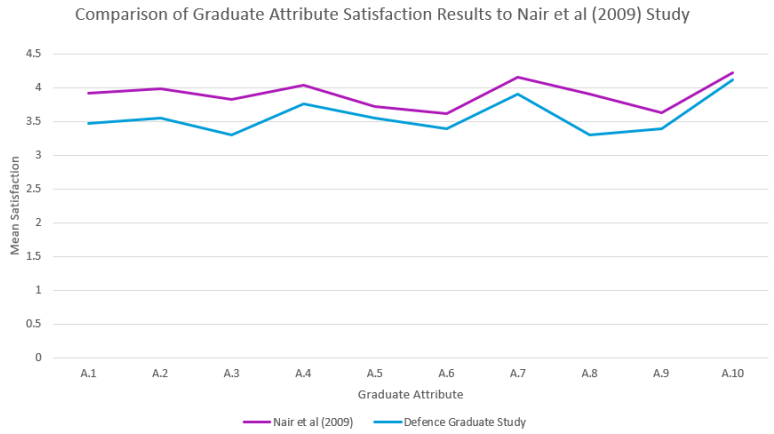

Figure 3: Comparison of graduate attribute satisfaction levels to the Nair et al (2009) study

Figure 3 demonstrates that the perception of graduate attributes within Defence is lower than those within the general engineering industry. The top three attributes with significant differences include; ability to apply knowledge in the workplace (Δ -0.61), written communication skills (Δ -0.53) and oral communication skills (Δ -0.45). Despite being the lowest rated attributes, they were not indicated as a high priority within Defence. Attributes such as capacity for co-operation and teamwork, capacity to learn new skills and interpersonal skills with colleagues and clients were rated as the highest priority attributes for Defence engineers.

These low rated attributes can however be traced to the graduate skills survey which helps explain the values. Understanding of the Defence operating environment was indicated as a top priority skill for graduates to hold, yet it had the lowest mean satisfaction of 2.30. It can be hypothesised that engineers who do not understand the work environment that they are performing their duties in will not be able to apply their core discipline effectively. Additionally, it can be deduced that if engineers cannot grasp the operating context of their solutions, they will not be able to effectively communicate this to their Defence clients and counterparts.

Defence is a unique industry that often requires engineers to perform multi-disciplinary roles. Based on the key themes raised by respondents for improvement to tertiary education, it is not unreasonable to see that the satisfaction of graduates is lower than other industries around Australia. Defence is a large part of Australian industry yet is still a niche career path for engineers. It is evident that there is not enough exposure for graduates to the Defence environment both through work experience and technical teaching, such as systems engineering.

Opinion of Future Needs

When asked to comment on which discipline of engineering was considered most critical to meeting Defence's needs in the next ten years. The top 3 results were information and telecommunications, systems, and software engineering, which align with the requirements highlighted in the *2020 Defence Strategic Update.*

When asked about the missing skills or attributes by graduates, only 17 of the 43 people provided a response. The top three common suggestions included:

- Skill – Understanding the Defence Capability Lifecycle and how systems engineering fits into that model;
- Skill – Having the ability to conduct change management for a system; and
- Attribute – Being able to adapt and switch focus in highly dynamic environments.

Conclusion

This paper has demonstrated through the use of a research survey that there is a clear shortfall in the performance of engineering graduates who begin their careers within Defence. Additionally, the main engineering demands of Defence for future operations has been validated and the survey demonstrated how these areas require more investment.

Research shows that graduates need to improve their skills in systems engineering processes and expand their understanding of how Defence conducts its operations within Australia and around the world. This is critical for future graduates to be able to provide more effective support to Defence projects and requires them to take a multi-disciplinary approach to solving complex problems.

Using a previous Australian study, this paper highlighted some of the key graduate attributes required by the general engineering industry which aligned to those required by Defence. It was perceived by the survey however that Defence graduate attributes were falling behind in satisfaction levels compared to those in the general industry. It was determined that graduates in Defence needed to be able to work with one another by demonstrating co-operation, teamwork and interpersonal skills with their colleagues as well as having capacity to learn new skills. This aligns with the required Defence skills as engineers need the capacity to work within multi-disciplinary teams, while also being able to learn and understand the work that each team can provide.

Lastly, the research used the opinions of respondents to determine what the future engineering needs of Defence were post 2028. It was found that the leading discipline required is information and telecommunications, along with systems and software engineering. This need was validated through commentary provided by the respondents and the *2020 Defence Strategic Update*. It was evident through the survey that the discipline of information and communications engineering has a significant shortage of qualified employees, something which the government has also acknowledges and plans to invest in.

Recommendations and Future Work

While the report focussed on all disciplines of engineering, further work should be done to identify how the information and telecommunications trade can be refined to meet Defence's future work force requirements. Lastly, more opportunities need to be made available to improve the engagement between Defence and tertiary institutions through workplace experience in order to enhance graduate understanding of the industry. Further work should be undertaken to investigate the success of these programs, and whether it assists in improving the quality of graduates who start their careers in Defence.

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