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From Thesis to Tap: Navigating the PhD Pipeline to the Water Industry

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ABSTRACT

CONTEXT

In Australia, more than half of PhD students in STEM fields are hoping to work in industry (McCarthy and Wienk, 2019). This is within a context of the number of international PhD students increasing and now exceeding domestic students, particularly in engineering and information technology (Larkins, 2019). To avoid the loss of the generated new knowledge and higher level skills obtained during doctoral studies, efforts should be made to retain graduates and encourage pathways to industry.

GOAL

Our research investigates the experiences of both domestic and international PhD graduates, examining how perceptions of their employability capital are shaped by factors such as prior industry experience, or exposure to industry throughout their candidature.

APPROACH

This study investigated current PhD students directly or indirectly associated with the water industry (as a case study), as well as former students who hold a PhD and are currently working in the Australian water industry. Surveys were used to gather information regarding perceptions of their capitals as defined by the Graduate Capital Model developed by Tomlinson (2017). Experiences with the water industry during as well as prior to their candidature, networking frequency and approaches, as well as identification of skills participants believe are important to develop were also reported.

FINDINGS

Respondents with prior industry experience and domestic PhD candidates demonstrated higher knowledge of the water industry compared to candidates who had no industry experience and international students respectively. When evaluating graduate capitals, prior industry experience was a stronger predictor of higher capitals than other factors (such as domestic versus international student). Notably, similar levels of knowledge of the water industry, and graduate capitals were reported between PhD graduates currently working in the water industry and PhD candidates with prior industry experience. Additionally, differences in networking frequency and approaches were observed across different cohorts and may identify potential areas for change.

CONCLUSIONS AND RECOMMENDATIONS

This study confirms the inherent value of prior industry experience, and our findings show that prior industry experience was a more significant factor than others we investigated for PhD candidates aiming to work in non-academic fields like the water industry. Industry exposure enhanced both industry-specific knowledge and graduate capitals, particularly human and social capital. Yet, both domestic and international cohorts could benefit from increased engagement, and key training areas identified by respondents include technical skills related to industry-specific technologies, collaboration, communication, language proficiency, and building networks beyond academia to

facilitate a successful transition to the water industry.

KEYWORDS

Graduate outcomes, Water Industry, Higher Degree Research

Introduction

A PhD allows the development of deep knowledge into a specific area, in doing so it promotes critical thinking and innovation, demonstrating perseverance and creativity. Globally, increasing numbers of PhD graduates have exceeded available academic positions (OECD, 2014). However, there is a large demand in the private and public sector for deep knowledge, sound research and analytical skills, that can be gained from advanced research degrees (Garcia-Quevedo et al., 2012; McCarthy & Wienk, 2019). In Australia, more than half of PhD students in STEM fields (science, technology, engineering, and maths) were hoping to work in industry (McCarthy & Wienk, 2019). The number of international PhD students have increased and now exceeds domestic equivalents, particularly in fields of engineering and information technology (Larkins, 2019). As an internationally recognised qualification, completing a PhD overseas can benefit from diverse perspectives and international collaborations. However, to avoid the loss of the generated new knowledge and higher levels skills obtained during doctoral studies, efforts should be made to retain graduates in Australia and encourage pathways to industry.

Prior experience or even knowledge of an industry can enhance employability and facilitate finding employment, by providing practical skills, industry knowledge and an understanding of workplace dynamics (Barry et al., 2016; Murray et al., 2015). However, for international PhD candidates, it is unclear how important are domestic compared to international experiences in terms of knowledge of the local industry or perceptions of their own employability. The graduate employability capital model, developed by Tomlinson (2017), emphasizes different forms of capital, namely human, social, cultural, identity, and psychological which graduates can hold that may impact their preparedness for employment.

Research on the transition to industry for those PhD holders suggest that they may feel overqualified for industry jobs and anticipate difficulties in adjusting to the business environment (Cabral-Cardoso, 2001). In many countries, there has been a focus on integrating industry preparedness into PhD programs with programs focusing on professional development such as communications, grant writing, teaching internships and public speaking (Heflinger & Doykos, 2016). Nevertheless, many are still reporting poor preparation from their PhD program for careers outside of academia despite this trend (Manathunga et al., 2009; Mitic & Okahana, 2021).

Research skills as well as communicating with non-technical audiences have been positively linked with job preparation (Mitic & Okahana, 2021), as have the ability to collaborate with industry, established connectivity and completion of industry-based employment (Beasy et al., 2022). The importance of personal networking and mentoring in finding non-academic jobs (Purcell et al., 2013), and smoothly transitioning into a career (Choudhary & Jesiek, 2015; Heflinger & Doykos, 2016) is also emphasized in the literature.

Our research investigates the experiences of both domestic and international PhD candidates and graduates, examining how perceptions of their employability capital are shaped by factors such as prior industry experience, or exposure to industry through collaborative research projects. The water industry employs graduates from a range of disciplines, education levels and cultural backgrounds. This has been chosen as a case study due to its breadth and the study authors partnering with the Australian Water Association (AWA). The study includes an analysis of participants declared knowledge of the water industry and their perceived graduate capitals. Participants included both current PhD candidates as well as PhD graduates working in the water industry.

The research aims to:

- Identify differences between the domestic and international PhD cohorts regarding their perceptions of graduate capital and knowledge of the water industry.
- Determine the importance of industry experience, or knowledge of the water industry on

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perceptions of graduate capital and knowledge of the water industry.

Outcomes of this research aim to identify areas to be targeted in graduate training programs to support PhD transitions to industry, ultimately providing better knowledge transfer and support of innovation.

Method

Approach

Surveys were developed for PhD candidates as well as doctoral graduates in areas relevant to the water industry. Questions focused on perceptions of graduate capital attainment, knowledge of the water industry, prior industry experience as well as demographic information such as age, academic level, and enrolment as domestic or international candidates. Questions build on those previously defined studies (Mosyjowski et al., 2013; Tomlinson, 2017). The surveys were conducted anonymously according to ethics approval (iRECS 5147) using the Qualtrics platform.

The two survey structures are presented in Figures 1 and 2. The current PhD candidate survey was distributed through the UNSW Engineering faculty mailing list, relevant schools in the Faculty of Science, as well as water engineering research centres in other universities on behalf of the research team. The survey completed by doctoral graduates currently working in the water industry was distributed on behalf of the research team by the Australian Water Association (AWA) in the Source magazine, as well as targeted emails from their mailing lists. Data was gathered over the period of March to May 2024.

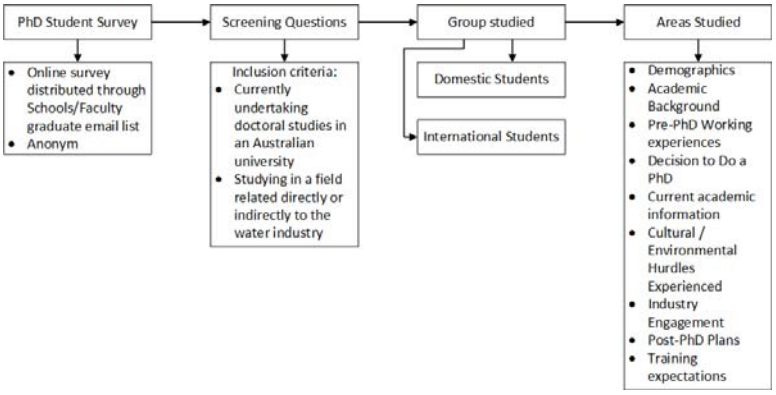

Figure 1. Survey structure and flow for current PhD candidates.

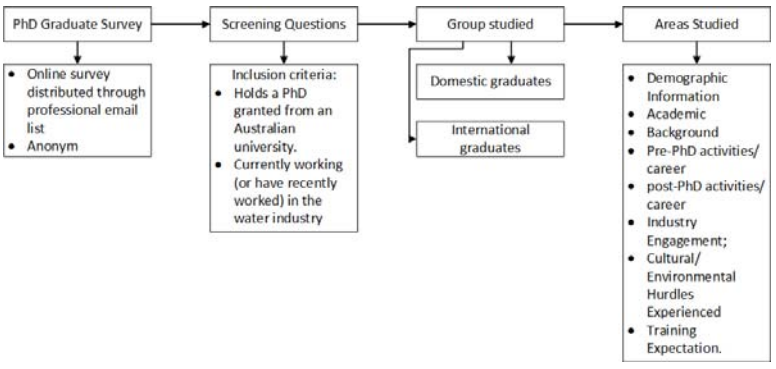

Figure 2. Survey structure and flow for PhD graduates currently working in the water industry.

Data Analysis

Descriptive statistics were used to explore the responses from both surveys. Likert scales were used, such as where participants were asked to rank each graduate capital on a scale ranging from 1 (not at all confident) to 5 (Highly confident). The scale was coded as follows: 1 = Not at all

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confident, 2 = Slightly confident, 3 = Somewhat confident, 4 = Moderately confident, and 5 = Highly confident. Where numerical scales were coded, independent-sample t-tests were used to compare different groups (α = .05), such as students with and without previous industry experience.

Findings

Summary of survey data

PhD candidate survey: Descriptive statistic overall

A hundred and thirty PhD candidates participated in the survey. The initial screening questions (Are you currently enrolled in a PhD program in an Australian University? and is your doctoral research topic relevant or aligned to the water industry in Australia?) were passed by 77 respondents.

In terms of gender identity, 51 % (n = 38) declared to be male, 41% (n = 31) declared to be female, while 1% (n = 1) declared to be non-binary. The participants were divided into the following age brackets: 18-25 years (n = 8, 11%), 25-29 years (n = 24, 32%), 29-34 years (n = 26, 35%), 35-39 years (n = 9, 12%), 40-44 years (n = 1, 1%), 45 years and above (n = 3, 4%), missing (n = 5, 7%). Regarding their academic background, 48 (64%) of them declared to have majored in engineering, 18 (24%) declared to have majored in science, while 3 (4%) declared to have majored in other fields. Fifty-two (69%) of the participants declared to have completed a master's degree.

To examine differences between domestic and international candidates the data was split into domestic (n = 18) and international (n = 50) cohorts, the modal class for ages were 25-29 years for domestic and 30-34 years for international candidates. The cohorts exhibited a nearly balanced gender distribution, with both male and female declarations approaching parity.

Regarding the work/no prior industry experience, 14 (21%) of the respondents had declared to work in the water industry prior their commencement of their PhD, with a higher representation of males (64 % of "Yes" responses). Sixty-four percent of those with water industry experience had a bachelor's degree in engineering, 36% had a science major, and none had a major in other fields. Of those without water industry experience, 71% had an engineering major, 25% had a science major, and 4% had a major in other fields. A single respondent who preferred not to disclose their industry experience had an engineering major.

PhD graduates working in the water industry survey: Descriptive statistic overall

Fifteen responses were obtained and 13 of those passed the screening process (Do you hold a PhD from an Australian University? And are you currently working (or have previously worked) in the Water Industry?). Due to the small size of the cohort, it was not split into further groups and was analysed as a whole. Demographics show a 54% to 46 % female to male ratio. In terms of their academic background, only 31% of the graduates had a master's degrees, while 69% of the respondents reported to be from Australia.

Knowledge of the Water Industry

The surveyed students were asked to rank their knowledge of the Australian water industry on a scale 1 to 10, gave a mean score of 3.75 (SD = 2.25). It was found that domestic students had higher knowledge of the Australian water industry (M = 4.73, SD = 2.46) than international students (M = 3.37, SD = 2.10), $t(58) = 2.07$, $p = .043$. While those with previous experience in the water industry also had higher levels of knowledge in the Australian water industry (M = 4.85, SD = 2.58) than those who didn't have previous industry experience in the water industry (M = 3.43, SD = 2.10), $t(58) = 2.05$, $p = .04$. Those with PhDs currently working in the Australian water industry were also asked to rank their knowledge of the industry, from when they were completing their PhDs.

The mean score was 6.08 (SD = 2.27). When compared to the current PhD candidates, the graduate group (M = 6.08, SD =2.27) showed higher perceived knowledge of the industry compared to the student group (M = 3.75, SD = 2.25), $t(71) = 3.26$, $p = .002$. It should be noted that graduates were asked to recall their level of knowledge, which may result in biased recall.

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The same statistical tests were used to compare the graduate cohorts with the student: domestic/international and student: experience/no experience groups. It found no significant differences between the reported knowledge of the water industry from the graduates and domestic students, as well as the graduates and students who had prior experience. Significant differences were noted between graduates and the general student population, international students, and students without industry experience. Although the study did not test the causal relationship between industry knowledge and future employment, the observed differences suggest potential areas for further investigation. This includes efforts by universities and industries to increase awareness of various industries among HDR candidates, especially those with no prior experience or who are international students.

Graduate Capitals

While knowledge of an industry is important to initially identify it as a future carer option, the Graduate Capital Model developed by (Tomlinson, 2017) is another way to explore employability. The model is based around five key capitals:

Human capital reflects skills acquired through formal education, which can also be referred to as graduates' hard skills. This would include the specialised knowledge and advanced research abilities acquired during a PhD that would be relevant to water-related fields.

Social capital consists of building connections through previous job experiences, networking with industry professionals, attending conferences or collaborating on relevant projects.

Cultural capital is knowledge beyond technical skills of behaviours with organisations, such as industry specific practices, normal and challenges. For example, awareness of water-related awards and regulations may consist of cultural capitals.

Identity capital involved shaping one's professional identify and aligning present actions with future aspirations. Previous or current involvement in water-related professions, research, conference, or events can help shape the self-image for PhD graduates seeking water industry roles.

Psychological capital refers to the resilience and adaptability, which is needed not only for seeking employment – but also through a PhD. This also involves maintaining confidence, managing stress, and staying motivated during the transition to water industry careers.

Surveyed students were asked to rate their confidence in the five graduate capital dimensions. Responses were typically 'somewhat confident' which was Level 3 in the five level Likert scale and was coded as three for the statistical evaluation. Variations between the different graduate capital dimensions and the different cohorts are presented in Table 1. For the PhD candidates, the highest average confidence reported in psychological capital and the lowest in social capital.

When comparing the effect of domestic and international cohorts, the results showed no significant differences on any of the graduate capitals among the two groups. More variability in the dataset could be attributed to factors such as industry experience in the water industry and its influence on graduate skills, specifically for the following areas:

- **Social capital:** Students who had previous experience in the water industry had higher confidence levels of social capital, than those who didn't have previous experience, $t(58) = 2.31$, $p = .024$.
- **Identity capital**: Students who had previous experience in the water industry had higher confidence levels of Identity capital, than those who didn't have previous experience, $t(58) = 2.06$, $p = .044$.
- **Psychological capital**: Students who had previous experience in the water industry had higher confidence levels of psychological capital, than those who didn't have previous experience, $t(58) = 2.64$, $p = .010$.

Graduates ($n = 12$) had the highest confidence in human capital and lowest in cultural capital. Compared to PhD candidates group, graduates had significantly higher confidence in their human capital $t(71) = 2.69$, $p = .008$ and social capital $t(71) = 3.07$, $p = .003$. Both these dimensions were also significantly different for all groups except those with previous industry experience. This

highlights the importance of exposure to, and understanding of, specific industries, as it helps in building relevant knowledge, skills (human capital) and networks (social capital).

It should be noted that the level of psychological capital for those with previous industry experience was also higher than their reported human capital, and indeed higher than all other cohorts. This was also significantly higher than that reported by graduates ($t(23) = -2.99$, $p = .006$). Whether this is a result of having industry experience, or having the drive to complete it in the first place is unclear.

Table 1. Compilation of graduate capital dimension scores, Mean (SD), for different surveyed cohorts. Note: numerical scores from 5 level Likert scale ranging from 1 (not at all confident) to 5 (Highly confident). Note: numbers are reported in terms of those who answered this question.

Dimension	PhD candidates (whole cohort) n = 61	PhD candidates – previous industry experience (n = 13)	PhD candidates – no previous experience (n = 47)	PhD candidates – domestic (n = 18)	PhD candidates – international (n = 45)	Graduates (n = 12)
Human capital	3.51 (1.01)	3.85 (.98)	3.38 (.99)	3.36 (.93)	3.53 (1.06)	4.33 (.65)
Social capital	3.08 (1.05)	3.62 (1.04)	2.89 (.98)	2.93 (1.21)	3.16 (.98)	4.08 (.90)
Cultural capital	3.25 (1.17)	3.62 (1.26)	3.13 (1.15)	3.36 (1.21)	3.24 (1.15)	2.92 (.79)
Identity capital	3.39 (.93)	3.85 (.80)	3.26 (.94)	3.14 (.94)	3.51 (.86)	3.17 (1.19)
Psychological capital	3.54 (1.12)	4.23 (.93)	3.34 (1.11)	3.36 (1.08)	3.64 (1.09)	3.17 (.83)

Influence of PhD training on graduate capitals

In addition to asking the PhD graduates to rate their confidence in their graduate capitals on graduation, they were also asked ‘How did your PhD education/training contribute to improving your abilities in each graduate capital?.’ The answers were on a 5-point scale ranging from 1 (Not applicable) to 5 (Significantly improved). The strongest effect is observed in human capital ($M = 4.5$, $SD = .67$), while the least impact is seen in cultural capital ($M = 2.83$, $SD = .94$). Social, identity, and psychological capitals fall in between, with mean scores of 3.25 ($SD = 1.06$), 3.42 ($SD = 1.31$), and 3.75 ($SD = 1.22$), respectively. This strong effect on human capital is expected as completing a PhD would equip individuals with specialized knowledge and advanced skills which would be highly valuable, not only to industry but also academia and other sectors. The low score on cultural capital, could be targeted by specific programs or liaisons with the water industry, through exchanges, mentoring or other mechanisms by which the working structure of the industry could be explored.

Types of involvements with the industry

Graduate capital findings suggest that employability confidence is strongly linked to prior industry experience, though there are also ample opportunities for PhD students to engage with the industry during their candidature. Surveyed students reported that the most common forms of engagement with the Australian water industry were through collaborative research projects (54% with prior experience, 42% without) and attending industry conferences or workshops (39% with experience, 32% without). International students were more likely to engage in collaborative research projects and internships compared to domestic students (48% vs 25%), while domestic students more frequently attended industry conferences or workshops (50% vs 28%). Interestingly, a higher percentage of domestic students reported no involvement with industry (31%) compared to international students (17%), potentially due to the greater number of surveyed domestic students pursuing science degrees rather than engineering. The survey also revealed that 13% of respondents had no industry engagement before or during their PhD. While this may pose challenges for future transitions (Grande et al., 2014), it is important to acknowledge that not all graduate students will pursue industry careers.

Networking

Networking is crucial for employability, as it enhances social and identity capital by building connections and professional identity through industry exposure. Networking can also positively impact psychological capital by providing emotional support, encouragement, and a sense of belonging (Tomlinson, 2017). The benefits of networking to social capital are particularly important, as many surveyed PhD candidates were less confident in this area (Table 1).

PhD candidates were asked about the frequency that they network with professionals from the water industry. The answers were on a 6-point scale ranging from 1 (Never) to 6 (Very frequent - Daily). On average PhD candidates networked with professionals from the water industry occasionally, which was described as once every few months and represented by level 3 on the scale. No significant differences were found between students with or without prior industry experience or between domestic and international students.

Participants were also asked about how they primarily networked with industry professionals. Those with prior industry experience used online platforms like LinkedIn more (83.3% vs. 46.7%). Similarly, involvement in industry conferences and seminars was slightly higher among those with prior industry experience in the water industry (58.3%) than those without (48.9%). Developing networks is a transferable skill and can also be applied to broader areas than the area of study (Germain-Alamartine et al., 2021), making it an important professional development process.

Domestic students favoured industry conferences and seminars (75% vs. 43.2%) compared to international students, while online networking was similar for both of these groups. Additionally, domestic respondents showed higher participation in personal contact and membership in professional bodies compared to international respondents (50% vs 18.2%).

These findings highlight distinct differences in networking approaches among various groups, though the effectiveness of these methods on employability was not assessed. The results underscore the importance of establishing mechanisms that expose all students, particularly international ones, to networking opportunities with industry professionals. Mentoring has been identified as a valuable mechanism through which capitals and experiences can be supported (Murray et al., 2015). Greater engagement with industry can also be achieved through active participation in professional bodies, attendance at industry conferences, and ensuring that students are not only aware of these opportunities but also supported in their efforts to engage with them—both by the universities and the industry itself.

Training for transitions

In the study, participants were asked about the types of training they received during their PhD. Crosstabulation between prior industry experience in the water industry and training/events showed that both groups (with and without prior industry experience) favoured networking events with local professionals (84.6% and 70.2%), research skills (76.9% and 66%), and academic conferences (61.5% and 55%). However, students with previous water industry experience had higher participation ratios overall.

When participation in training activities was evaluated for International vs. Domestic respondents, it was found that international respondents (75.6%) participated more in networking events with local professionals or students than domestic respondents (64.3%). While domestic respondents were more likely to engage in research skills training (85.7%) compared to international respondents (62.2%) and participation in academic conferences was slightly higher among domestic respondents (64.3%) than international respondents (51.1%). Possible causes for these may include disciplinary differences (more science degrees among domestic students) or greater experience among international respondents (higher levels of master's degrees and prior industry work).

Participants were asked to rank twelve different training areas regarding their importance for PhD researchers wanting to transition to the Australian water industry. When comparing each of the two study groups (domestic/international &with/without industry experience) no statistical differences were observed on the mean of each area.

On average, all the factors were considered moderately important, however the top four areas

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identified by current PhD candidates were:

- Effective collaboration and communication strategies with industry stakeholders and communities
- Language proficiency
- Technical training on prevalent water-related technologies in Australia
- Building networks outside of academia

The same question was asked to PhD graduates working in the water industry, with the top four from this group also identifying the same areas, albeit in a different order. This consensus identifies these as key areas that should be targeted both by universities and the water industry to aid the transition of PhDs into the water industry.

Conclusions

The study highlights the significance of industry exposure for PhD candidates aiming to work in non-academic fields like the water industry. This exposure enhances industry-specific knowledge and graduate capitals, particularly human and social capital. Based on both the knowledge of the water industry, as well as the graduate capitals, prior industry experience of PhD candidates gave these cohorts similar level as those reported on graduation by PhD graduates who are now part of the Australian water industry. This suggests that industry engagement prior or during a PhD can enhance industry specific knowledge and employability-related capital.

Participants with prior industry experience and international students were more actively engaged in various forms of industry involvement, particularly in collaborative research projects and internships. These differences may be influenced by discipline, with science students less involved in industry than engineering students. Regarding networking, no significant differences were found in networking frequency between participants with or without prior industry experience or between domestic and international students. However, preferences for networking methods varied, with those having industry experience favouring online platforms and domestic students preferring industry conferences. The findings reveal that both domestic and international cohorts benefit from increased engagement. Key training areas include technical skills related to industry-specific technologies, collaboration, communication, language proficiency, and building networks beyond academia to facilitate a successful transition to the water industry.

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