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Graduate Attributes for the Blue Economy

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ABSTRACT

CONTEXT

The *Blue Economy* brings together maritime engineering, renewable energy and aquaculture to solve global sustainability issues. As the research and industries associated with the Blue Economy Cooperative Research Centre (BECRC) continue to develop, greater clarity about the skill sets, (post)graduate attributes and employability skills required of graduates is needed to guide the development of this future workforce as they enter emerging industries.

PURPOSE OR GOAL

The study was conducted in order to determine PhD students' perceptions of the graduate attributes that they were developing as part of their studies with the BECRC. Surveys were conducted with the current BECRC doctoral student cohort. Survey questions included; demographics, motivations for studying a PhD, perceptions of industry connection, field of research (FoR) codes, graduate attributes, training needs and preferred avenues of work for future graduates. The study reported here focuses on PhD students' perceptions of the graduate attributes developed during their BECRC candidature and allows links to be made between other research in this space.

ACTUAL OR ANTICIPATED OUTCOMES

The study revealed that BECRC Students rated their development of specific graduate attributes more highly than others; for example, "willingness to learn" and "research skills, were rated at over 4.5 (on a 5-point scale), whereas "Academic rigour" and "Independent judgement" were rated around 4, and "Ethics" and "Teamwork", were rated at around 3.5.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

This research is the first phase of a planned longitudinal study and shows early promise in identifying how the BECRC PhD program is developing graduate attributes and employability skills for its students. Additional training may need to be undertaken to develop skills associated with teamwork, communication and leadership. The findings have impact on the additional training that may be required by PhD graduates in general and BECRC PhD students in particular.

KEYWORDS

Graduate attributes, employability, emerging industries, marine engineering

Introduction

The Blue Economy Cooperative Research Centre (BECRC) has brought the aquaculture and renewable energy sectors together to address the challenges of offshore seafood and renewable energy production. However, the offshore aquaculture and renewable energy industries are new and emerging sectors in the Blue Economy with still relatively under-developed training protocols and a limited skill base for future workforce development (Penesis & Whittington, 2021, Blue Economy CRC, 2023). One of the key goals of this large Industry – University partnership is to educate a new generation of engineers and scientists with detailed cross-disciplinary knowledge to work in emerging Blue Economy industries that include the sustainable aquaculture industry, offshore wind and wave energy industry, green hydrogen industry and remote and autonomous technology. The BECRC does this through provision of a diversified doctoral training program that provides links with industry.

Doctoral graduate attributes have been previously defined as “the qualities, skills and competencies that graduates possess, having completed their doctoral degree” (Senekal et al., 2022, p.10). There have been calls in the literature for greater recognition of the graduate attributes developed during doctoral candidature (Spronken-Smith et al., 2023). There has also been previous work investigating diversified research training through CRCs and requests for more evaluations of the outcomes and graduate attributes of these partnerships in terms of doctoral education (Manthunga et al., 2009). Platow (2012) found connections between self-perceptions of acquired graduate attributes and subsequent transitions to employment, signifying their importance in terms of employability, productivity and workforce transition.

This study expands on previously published literature (Cossu et al., 2023; MacKerarcher & Marsh 2019; Spronken-Smith, 2018; and Spronken-Smith et al., 2023) by adding a specific focus on the graduate attributes that doctoral students in engineering develop during their candidature. It does this by comparing this cohort to science doctoral students in a similar program (e.g. both cohorts from the BECRC). It also compares this cohort to the research data of Spronken-Smith et al. (2023). Prior research examined the differences between graduates in New Zealand, and the United States, and also between humanities and social science (HASS) and science doctoral candidates (Spronken-Smith et al., 2023).

The objective of this paper is to analyse the employability skills and graduate attributes needed by PhD graduates from Cooperative Research Centres (CRCs) and other disciplinary and institutional contexts. The focus will be on the differences in development of these skills between engineering doctoral candidates and other disciplines. This research contributes to the conceptualisation of graduate attributes at doctoral level. It highlights distinctions between different cohorts (Engineering, Science and HASS) and BECRC candidates in particular. It also adds to the emerging body of literature on the development of graduate attributes at postgraduate level through its focus on doctoral candidates and complements earlier work by placing attention on the Australian context. A potential impact of this research is to develop a set of postgraduate attributes statements tailored to the BECRC context that could influence further work in the areas of postgraduate attributes.

This work builds on existing research by McKeracher and Marsh (2019). The theoretical framework for this study is drawn from social cognitive career theory (SCCT) (Lent et al., 2002). SCCT offers a holistic framework from which to explore how people prepare for, choose, engage with and navigate their careers that recognises both the cognitive or individual differences, motivations and aspirations as well as the external environment that shapes access to and opportunities for careers. The study explored the acquisition of graduate attributes and the preparedness of BECRC PhD students for careers who were or currently are studying at BECRC partner universities. The research question addressed in this study is “What differences exist in the development of graduate attributes and employability skills between engineering and other disciplinary cohorts?”

Methods

Student survey

This study was conducted under human research ethics number 2024/HE000910. A comparative survey was designed based on a similar survey method reported in Spronken-Smith et al. (2023) and Cossu et al. (2023). The participants were all PhD students from the BECRC who are currently doing or have completed their PhD research. The cohort was surveyed at the BECRC Participants workshop (4-6 June 2024 in Kingscliff, NSW).

The survey was designed to include reflection on professional development and career development opportunities during their PhD study within the BECRC program. The survey collected both quantitative and qualitative data. For the purposes of this paper only the survey results comprised of the list of 20 attributes drawn from Spronken-Smith et al. (2023) will be reported. These attributes included knowledge, research, higher-order thinking, communication, interpersonal, organisational, and personal resourcefulness skills, as well as attributes relating to global citizenship. Respondents were asked to rate to what extent their BECRC PhD studies encouraged the development of graduate attributes. Ratings were on a 5-point Likert scale from 1 ‘never developed/applied’ to 5 ‘almost always developed/applied’. For questions generating Likert ratings, averages were calculated. Due to the nature of the data collected through the Likert scales, the range of scores goes from 1 to 5, not 0 to 5. For the purposes of comparison with previous research, subsequent figures maintain a similar style, without the 0 being represented (see Figures below).

Complete survey responses from 27 PhD candidates were obtained. The responses and ratings of the development and of graduate attributes are addressed in the following section. One student response was omitted from the analysis as there was only one student who had completed their PhD in the sample.

Results

In total, 26 BECRC student responses are included in the analysis. All surveys were de-identified. They are from two broad disciplines, *Engineering* and *non-Engineering (science),* representing 38.5 and 61.5% of students respectively (Table 1). Students were classified as either Engineering or non-Engineering based on the Field of Research codes that they selected when completing the survey. From the PhD students surveyed, 15.4% were in their first year of candidature, 46.2% were in their second year, 30.8% in their third year and 7.7% in their fourth year (Table 1). The gender ratio was in favour of males to females, resulting in 53.8 and 46.2% respectively (Table 1). International students made up 69.3% of PhD candidates, outweighing domestic students 2.25:1 (30.8%) (Table 1).

Table 1. Survey respondents and demographic details for Blue Economy CRC PhD candidates surveyed during the BECRC Participants Workshop in June 2024 (n=26).

Demographic details	Characteristic	Number	Total (%)
Responses completed		26	100
Discipline area	Engineering	10	38.5
	Non-engineering	16	61.5
Candidature year	Year 1	4	15.4
	Year 2	12	46.2
	Year 3	8	30.8
	Year 4	2	7.7
Gender	Female	12	46.2
	Male	14	53.8
Citizenship	Domestic	8	30.8
	International	18	69.2

The development of 20 graduate attributes perceived by PhD students varied based on the year of candidature (Figure 1). While there was a clear separation in the perceived development of some attributes by year of candidature, some responses were well aligned, regardless of candidature year. The top 10 highest scored perceived developed attributes across all years were *willingness to learn* (mean 4.65), *research skills* (4.63), *solve problems* (4.50), *plan own work* (4.38), *written communication* (4.33), *flexibility/adaptability* (4.33), *oral communication* (4.26), *information literacy* (4.20), *analytical skills* (4.19) and *independent judgement* (4.19).

The 10 graduate attributes that students determined were less developed were *cultural understanding* (mean 3.51), *awareness of ethical issues* (3.63), *collaboration and teamwork* (3.70), *environmental literacy* (3.98), *global perspective* (4.00), *skills to implement change* (4.01), *creativity* (4.04), *academic rigour* (4.04), *ability to integrate knowledge* (4.15) and *self-confidence* (4.16).

Figure 1 summarises the mean responses for developed graduates by year of candidature. In general, student responses indicate a similar trend where early year candidature students' perception of developed attributes fall within the inner rings of the radar plot and later candidature students reside more frequently on the outer rings (Figure 1). On average the largest mean increase (>0.74) of pooled attribute response was from students in their first year first compared to students in their fourth year, followed by third year students (>0.61). For students in their second and third year of candidature, there is an increased frequency of overlapping responses. Interesting, third year students scored on average 0.02 lower (mean 4.01) than second year students (mean 4.04).

The largest change in developed attributes was *awareness of ethical issues* (>1.75) recorded by students in fourth year, in comparison to first year students, followed by *skills to implement change* (>1.58) as perceived from second year students in comparison to fourth year students (Figure 1). Students in their first and third year responded to having low development in *environmental literacy* (3.5) although by fourth year students perceived they had higher development (5) *environmental literacy* (>1.5).

Students perceived a decrease in development for *self-confidence* after their first year (4.5), scoring 3.8 in years 2 and 3 respectively, before enhancing their development by fourth year (4.5). Similarly, first year students responded to have a high level of development for *creativity* and *academic rigour* (4) respectively, while *student* perception decreased marginally in their

second year (<0.08) then increasing in third year (>0.33) scoring a mean of 4.25 respectively and decreasing again in fourth year (4).

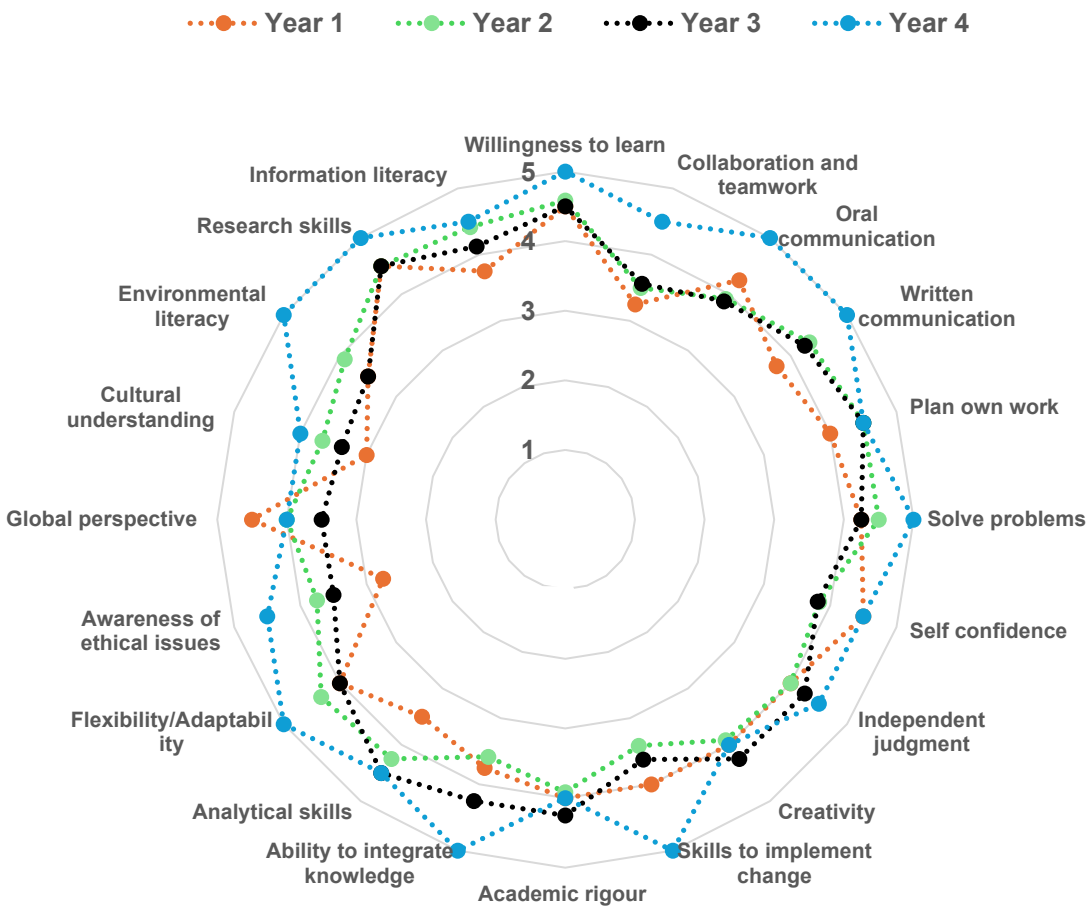

Figure 1. Developed attributes for Blue Economy PhD students surveyed in 2024, expressed by year of candidature. Orange dots/lines (year 1, n=4), green dots/lines (year 2, n=12), black dots/lines (year 3, n=8), and blue dots/lines (year 4, n=2). Data are mean values.

Figure 2 summarises the developed attributes from the 2024 BECRC workshop, pooled by discipline (i.e. *Engineers* and *non-Engineers*) for respondents surveyed in 2024, data were compared with BECRC participant workshop data from Cossu et al. (2023). In 2024, *non-Engineers* made up the majority of respondents at 61.5% (Figure 2). Overall, *Engineering* students scored 0.11 (pooled across 20 developed attributes) lower on the Likert scale when compared to *non-Engineering* students. The highest developed attributes scored by Engineers were *skills to implement change* (>0.50), *oral communication* (>0.43), *self-confidence* (>0.36), *global perspective* (>0.29), *collaboration and teamwork* (>0.23) and *environmental literacy* (>0.15) (Figure 2). In comparison, *non-Engineers* responded to have better developed skills across *analytical skills* (>0.70), *academic rigour* (>0.55), *plan own work* (>0.51), *creativity* (>0.39), *flexibility/adaptability* (>0.38), *information literacy* (>0.38), *cultural understanding* (>0.33), *written communication* (>0.28), *research skills* (>0.23) and *solve problems* (>0.20) (Figure 2).

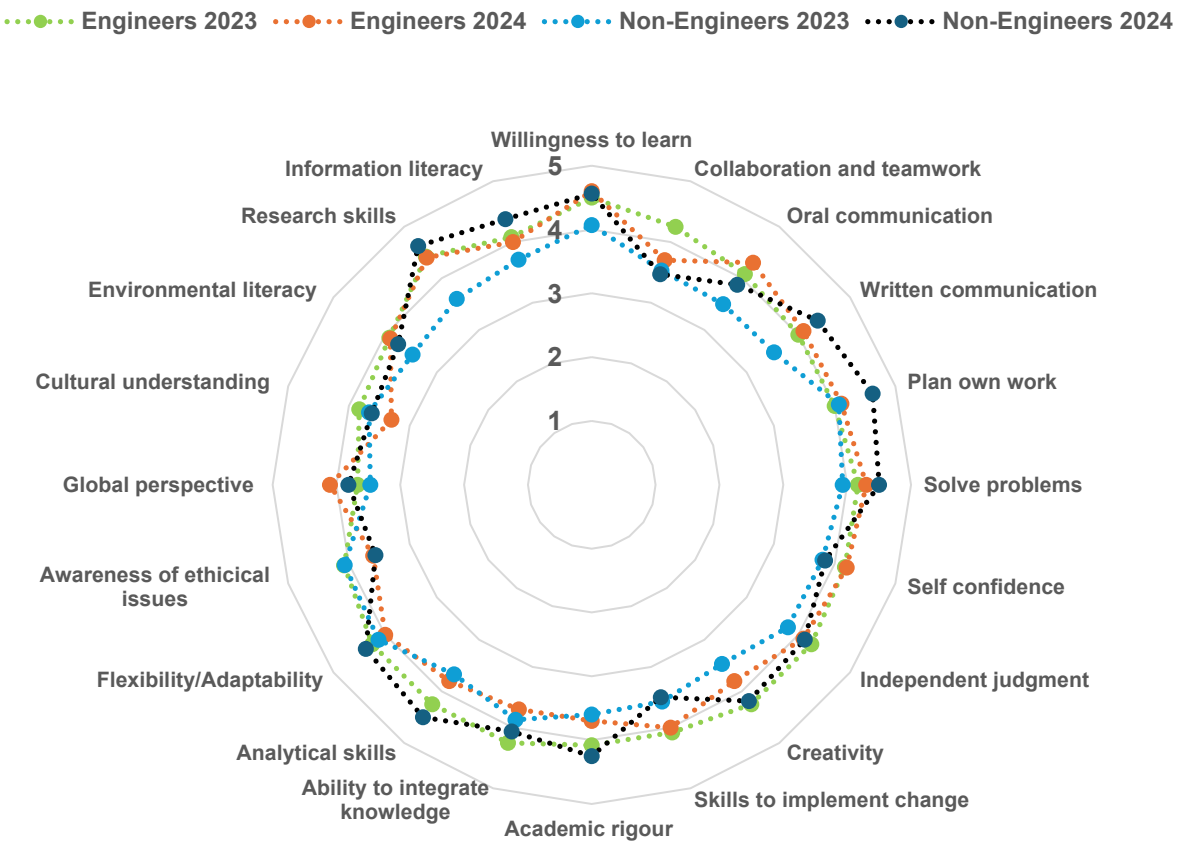

Figure 2. Developed attributes for Blue Economy PhD students surveyed in 2023 and 2024 Participants workshop (data pooled by discipline). Green dots/lines (Engineers 2023, n=12), orange dots/lines (Engineers, 2024, n=10), blue dots/lines (non-Engineers 2023, n=15) and black dotes/lines (non-Engineers 2024, n=16). Data are mean values.

The perception of developed attributes of PhD students (pooled by discipline) in the BECRC program surveyed in 2023 and 2024 scored higher across 14 and 18 developed attributes respectively, when compared to non-CRC programs surveyed by Spronken-Smith et al. (2023) (Figure 3). In contrast, non-CRC NZ/US PhD students responded to have developed stronger skills in *academic rigour* (>0.54), *global perspective* (>0.45), *awareness of ethical issues* (>0.45), *self-confidence* (>0.40), *creativity* (>0.20) and *willingness to learn* (>0.09), compared to BECRC students surveyed in 2023. The higher developed skills of the non-CRC NZ/US PhD students in comparison to BECRC 2023 students were less marked compared to the BECRC students surveyed in 2024; resulting in only *academic rigour* (>0.26) and *awareness of ethical issues* (>0.21) being higher in the non-CRC students in comparison to BECRC 2024 students (Figure 3).

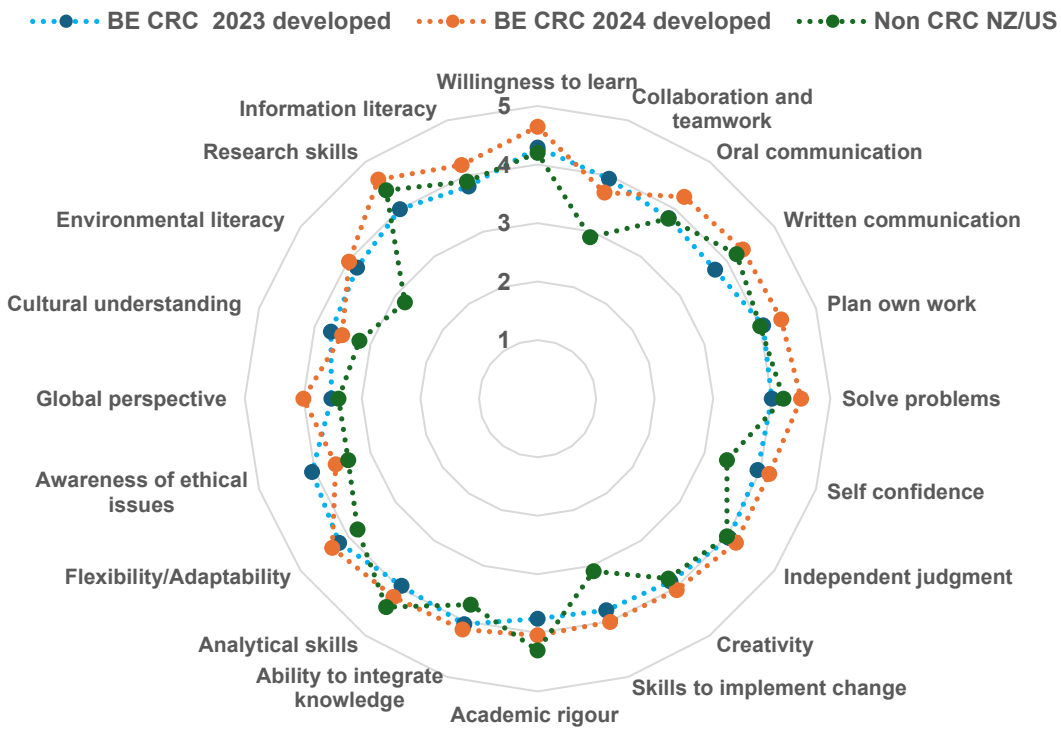

Figure 3. Developed attributes for Blue Economy PhD students, 2023 (blue dots, n=28) vs 2024 (orange dots, n=26) and NZ and US PhD graduate data (green dots, n=21) from Spronken-Smith et al. (2023). Data are mean values pooled by year.

Discussion and conclusions

The overall findings reveal some interesting patterns when it comes to the graduate attributes that students feel are most developed. In some ways it makes sense that *willingness to learn, research skills*, *solve problems*, *plan own work*, *written communication*, *flexibility/adaptability*, *oral communication*, *information literacy*, *analytical skills* and *independent judgement* are the top ten attributes developed as they may be considered hallmarks of the PhD and research experience. With the exception of *academic rigour* and *ability to integrate knowledge* the remaining eight graduate attributes that students perceived as less developed (*cultural understanding, awareness of ethical issues*, *collaboration and teamwork*, *environmental literacy*, *global perspective*, *skills to implement change*, *creativity* and *self-confidence)* could be thought of as relating to broader professional skills. They may also be areas that PhD candidates need to develop further; these attributes could also be less of a feature of doctoral study although they may still be required in the workplace.

The development of graduate attributes over the different year levels of the PhD program shows a relatively consistent pattern. For almost all attributes average rating are high in year 4 of PhD candidature than they are in year 1. The attributes related to creativity, academic rigour and global perspective are exceptions. Nine of the attributes were near ceiling levels for PhD candidates in year 4 of their studies (*research skills, willingness to learn, oral communication, written communication, solve problems, skills to implement change*, *ability to integrate knowledge*, *flexibility/adaptability* and *environmental literacy*. The logical interpretation of these results is that the doctoral program within the BECRC is successful at developing these

attributes. Six of these attributes are in the top ten attributes listed in the previous paragraph. However, three of these attributes, notably *skills to implement change*, *ability to integrate knowledge* and *environmental literacy* are not in the top ten attributes. This may indicate that these three attributes in particular, are developed as students' progress through their doctoral studies (which is not surprising considering the scope of the BECRC) or that there is something specific to the PhD topics being followed by these students.

Comparing the graduate attributes development for BECRC students from 2023 to 2024 reveals some differences, as well as some stability of results. The results show the development of the students' perceptions of their graduate attributes from 2023 to 2024. For example, *ability to learn*, *global perspective* and *plan own work* have changed positively for the students in 2024 compared to 2023. Several graduate attributes have decreased over this time, and students now perceive their development as lower than in 2023. This is the case for *awareness of ethical issue*s, *cultural understanding*, and *collaboration and teamwork*. The remaining graduate attributes display stability over this time. Both the increases and decreases in students' perceptions of their development of graduate attributes could potentially be explained by the stage of candidature that candidates were at in 2023; for instance, it is possible that ethical issues were more pertinent at that time. Students could have been completing ethics applications, or they could have participated in some training on ethics as part of their induction process. It is also possible that the result is due to measurement error, or perceptions of salience of these attributes declining over time. Most attributes show little change in students' perceptions of their development.

There are also several differences in perceptions of development of graduate attributes for engineering and science of the BECRC PhD cohort. For example, the engineering students rate their development of oral communication skills more highly that the science students. However, the science students rate academic rigour and analytical skills more highly. Whether this finding will be replicated in future studies with similar cohorts remains to be seen. It may be an area of distinct difference between the engineering and science students that requires tailored training to develop further, or it could be related to disciplinary norms and the nature of the research projects that the students are completing.

What is perhaps more interesting, is the differences in perceptions of development of graduate attributes for BECRC students in comparison to the students surveyed in the study by Spronken-Smith et al. (2023). There are differences in students' perceptions of *their* development of *collaboration and teamwork*, *environmental literacy*, *skills to implement change, self-confidence* and *cultural understanding* Spronken-Smith et al. (2023) cohorts. Future studies should investigate this through recruitment and comparison with a similar cohort to the Spronken-Smith et al. (2023) cohorts. This will enable us to determine whether this is an anomalous finding or a genuine difference between BECRC students and other PhD disciplines.

There are however several limitations to this study. The first is that the sample size is relatively small (at under 30 students). The next phase of the study will be to track additional students over time and add to the sample size in future in order to overcome this. Another limitation is that many of the differences between cohorts are relatively small; for *instance*, 0.1 to 0.3 on a 5-point Likert scale. The focus on reporting differences between cohorts has been on differences of 0.5 to address this.

There are several implications for teaching and learning practice that arise from this study. PhD students could benefit from additional assistance to develop graduate attributes throughout the period of their candidature through provision of training, although in some instances this appears to be remedied by length of candidature. The BECRC doctoral program appears to make a unique contribution to the development of graduate attributes and employability skills, although this needs to be contextualised more within disciplinary norms, expectations and verified in focus groups with students, academics and industry. Developing standards of attainment for graduate attributes developed by PhD graduates in specific disciplines could assist graduate them to further identify their employability skills and is and long-term intention of this study. The study provides an insight into how industry partnerships, as is the case in the BECRC, may enable

students and graduates to develop skills that are different to those developed in other PhD programs.

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