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Large-industry partnerships: The interaction and impact on educational programs exemplified by the Blue Economy CRC

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CONTEXT

Traditionally the aquaculture and renewable energy sectors have operated independently and had limited interaction with experts in offshore engineering industry. The recently funded AUD$300M Blue Economy Cooperative Research Centre (BE CRC) in Australia has brought these three sectors together to address the challenges of offshore seafood and renewable energy production. The BE CRC exposes the benefits of offshore co-location of aquaculture and renewable energy farms by leveraging on shared infrastructure and services. Owing to a sustained 10-year research, the CRC will impact educational programs and transform the scope of traditional engineering training.

PURPOSE OR GOAL

One of the BE CRC key goals is to educate a new generation of engineers and scientists with detailed cross-disciplinary knowledge to work in future Blue Economy industries that include sustainable aquaculture industry, offshore wind and wave energy industry, green hydrogen industry and remote and autonomous technology. The objective of this paper is to analyse and qualify the impact on graduate attributes that arise from the Blue Economy research activities, educational and engagement programs for university students, researchers and practising engineers. While this work mainly focusses on postgraduate students, we also report short-term and likely long-term influence on the undergraduate engineering programs.

APPROACH OR METHODOLOGY/METHODS

Surveys of approximately 30 PhD students and 15 PhD supervisors have been conducted and analysed to reflect the perspective of pursuing novel research topics and cross-disciplinary approaches and their perception of career development opportunities. We compare data obtained from surveying students with and without an Engineering background within the BE CRC and we also draw a wider comparison with results taken by similar surveys in New Zealand and the United States of America. In addition, we give an overview and outlook based on academics' responses on how the Blue Economy is starting to be implemented in undergraduate engineering programs.

ACTUAL OR ANTICIPATED OUTCOMES

The offshore aquaculture and renewable energy industries are new and emerging sectors in the Australian economy with poorly developed training protocols and a limited skill base for future workforce development. Our results show that the creation of new knowledge, technologies and future leaders are underpinned by a cross-disciplinary approach which could be reflected more strongly in graduate attributes of Australian universities. The undergraduate

engineering curriculum will see some updates and adjustments to better equip students with knowledge, skill sets and interest in future careers in the Blue Economy.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

This work offers a first look on the potential impact of a large industry – university partnership in form of the Blue Economy CRC on engineering disciplines and curriculum. The new and emerging sectors of Australia's Blue Economy require an integrated understanding of technical, environmental and social aspects to support academic and industry career development which needs to be developed further at Australian universities.

KEYWORDS
Graduate attributes, Industry Partnerships, Curriculum design

Introduction

Traditionally the aquaculture and renewable energy sectors have operated independently and had limited interaction with experts in offshore engineering industry. The 2019 funded $300M Blue Economy Cooperative Research Centre (BE CRC) has brought these different 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 vectors 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 BE CRC key goals is to educate a new generation of engineers and scientists with detailed cross-disciplinary knowledge to work in future Blue Economy industries that include sustainable aquaculture industry, offshore wind and wave energy industry, green hydrogen industry and remote and autonomous technology. Currently, five Australian universities (University of Tasmania, University of Queensland, Griffith University, University of Western Australia, Macquarie University), CSIRO and Auckland University of Technology (NZ) are involved as (core) research partners along with 38 industry partners (10 of which are international). It is therefore expected that the BE CRC with its five research programmes (see Table 1), cross-disciplinary approach, active engagement with students (via regular webinars, zoom meetings with research teams, summer school, participants workshops and conferences) and 45 partners will impact educational programs at these universities and transform the scope of traditional engineering training.

Table 1: Research Programmes of the BE CRC (Blue Economy CRC, 2023)

Research Program	**Description**
RP 1 Offshore Engineering and Technology	Design of stand-alone and/or integrated offshore aquaculture and renewable energy infrastructure
RP 2 Seafood and Marine Products	Developing offshore aquaculture systems that provide viable and sustainable growth opportunities
RP 3 Offshore Renewable Energy Systems	Building Australia's offshore renewable energy opportunities with technologies to assist the decarbonisation of offshore industries
RP 4 Environment and Ecosystem	Managing the environmental footprint of the infrastructure, culture systems and energy generating devices used by offshore industries
RP 5 Sustainable Offshore Developments	Developing regulatory frameworks and ensuring operations at highest environmental standard for sustainability and ecosystem integrity

Apart from the new research programmes that could - at least partially - be integrated in existing engineering curricula, the Universities' curricula are often guided by the outcomes achieved by graduate students, with the main goals to enhance employability and ensure curricula are relevant to meet the needs of industry. This is embedded in the framework of graduate attributes and while this is mostly relevant to undergraduate levels, similar expectations to attain graduate attributes also exist for doctoral graduates, albeit at a higher level of ability (Spronken-Smith et al., 2018). Recently, Senekal, et al (2022), defined doctoral graduate attributes as "the qualities, skills, and competencies that graduates possess, having completed their doctorate degree". These recent studies used quantitative approaches to analyse the development of skills and attributes in their workplace. Findings demonstrated a high level of consistency for the following attributes: knowledge, research, communication, scholarship and higher-order thinking skills. Furthermore, they found a lower development of organisational and personal resourcefulness qualities and reported poorly developed research management and interpersonal skills. A new framework for graduate attributes with the main domains: Knowledge, Research, Communication, Interpersonal skills, Higher order thinking skills, Personal resourcefulness, and Global Citizenship was synthesized from these findings (see Table 5 in Spronken-Smith et al. 2023, for detailed information and subdomains).

The objective of this paper is to analyse the impact on graduate attributes that arise from a large industry-university collaborations using the BE CRC as an example. We aim to add to the literature on the development of doctoral graduate attributes and we compare the findings to a holistic set of graduate attributes derived mainly from Humanities, Arts and Social Sciences (HASS) and Sciences students to the Engineering discipline. While this work mainly focusses on postgraduate students, we also summarize the immediate impact the BE CRC has already had on undergraduate engineering programs at some of the core research partner institutions.

Methods

Student survey

The study explores the acquisition of graduate attributes and the preparedness of BE CRC PhD students for careers who were or currently are studying at BE CRC partner universities: University of Tasmania, The University of Queensland, Griffith University, Macquarie University, Auckland University of Technology (AUT) (NZ) as well as University of Technology Sydney (UTS) (although not a BE CRC partner but two PhD students have moved from AUT to UTS during the time of study). The graduate profile from participating universities from the BE CRC training and education program specifies highly developed research skills and specialist knowledge, alongside several other attributes.

A comparative survey was used which was designed based on a similar survey method reported in Spronken-Smith et al (2023). The participants were all PhD students from the Blue Economy CRC who are currently doing or have completed their PhD research. The cohort was surveyed in the first half of 2023 (until early June 2023). Approximately 32 students were contacted with 28 complete survey responses obtained (87.5% response rate).

The survey was designed to include reflection on professional development and career development opportunities during their PhD study within the BE CRC program. The survey collected both quantitative and qualitative data. The first section of the survey asked for consent (all respondents gave informed consent), confirmed the anonymity/confidentiality of the results and categorised the cohort in "Non Engineering" and "Engineering related" doctoral studies. The second part of the survey used questions to obtain information on professional development opportunities. Importantly, it comprised a list of 20 attributes drawn from Spronken-Smith et al. (2023) for graduates including 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 BE CRC PhD studies encouraged the development of graduate attributes, and to

what extent they felt they applied each of these in their studies (application is not discussed hereafter). 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. The third part of the survey was designed to obtain information about the students’ perception of the adequacy of Professional and Career Development opportunities during their doctoral studies (1 = inadequate to 5 = very adequate). This information was designed to investigate the perception of the impact of BE CRC PhD research on employability. The last section of the survey related to the educational programme at individual universities with respect to BE CRC topics. Students were asked whether undergraduate programmes already include courses relevant to BE CRC topics and whether they thought this new research field should have more weight in their curriculum.

Especially Part 2 (graduate attributes) and Part 3 (career opportunities/employability) were designed intentionally similar to previous surveys to allow a direct comparison of the Engineering / Non-Engineering BE CRC cohort with results obtained by Spronken-Smith et al. (2023) who surveyed >130 former PhD students from mainly HASS & Sciences disciplines at 2 US universities and 1 NZ university. The average ratings of the development and of graduate attributes and Career Development opportunities were plotted on radar graphs.

Academic survey

Another survey was undertaken to target academics and PhD supervisors who work at one of the partnering universities and also supervise (or co-supervise) one of the current or completed doctoral study within the BE CRC project. The academics were asked a similar set of questions related to graduate attributes taught at the universities and attributes developed during the PhD studies. Ratings were also on a 5-point Likert scale from 1 ‘never developed’ to 5 ‘almost always developed’. For questions generating Likert ratings, averages were calculated. The second part of the survey also asked about the undergraduate program and whether if should include (more) subjects relevant to the Blue Economy. The last question aimed to gain insight into the employability of doctoral students and whether the BE CRC academics perceived research and likewise industry placements as beneficial. Approximately 40 academics (working and/or supervising in the BE CRC) were contacted with 15 complete survey responses obtained (37.5% response rate).

Results

Out of the current 32 BE CRC student cohort, 13 were related to Engineering, whilst the slightly larger fraction respondents (15) did not have an engineering topic within the BE CRC.

Figure 1 summarizes the responses from the BE CRC Engineering (red diamonds), the BE CRC Non – Engineering (blue circles) and the HASS/Science comparison cohort (black squares) with respect to the development of graduate attributes. It is evident that in almost all categories, the engineering students build the envelope of all cohorts, meaning that they reported to have developed stronger graduate attribute skills. The comparison between BE CRC Engineering and BE CRC Non-Engineering students shows a significantly better perception (>0.5) of developed attributes such as Creativity, Skills to implement change, Academic rigour, Ability to integrate knowledge, Analytical skills, Teamwork and Research skills. Slightly better values (> 0.25 – 0.5) are perceived in attributes such as self-confidence, independent judgement, environmental literacy, awareness of ethical issues, global perspective and willingness to learn. In turn, the Non-Engineering students responded to have slightly better developed skills in cultural understanding and the ability to plan their own work.

The comparison between BE CRC Engineering to the Non-CRC comparison cohort is varied and even more significant. There are large differences (>1) in the perception of willingness to learn and environmental literacy, and quite prominent differences in self- confidence, skills to implement change, ability to integrate knowledge, awareness of ethical issues and cultural understanding (all > 0.5). In contrast, the Non BE CRC cohort perceives attributes such as written communication, academic rigour and analytical skills to be better developed (>0.15 -

0.25) and has marginally a better perception of problem solving (0.03). However, in all other categories the BE CRC Engineering cohort has a slightly better perception of developed attributes.

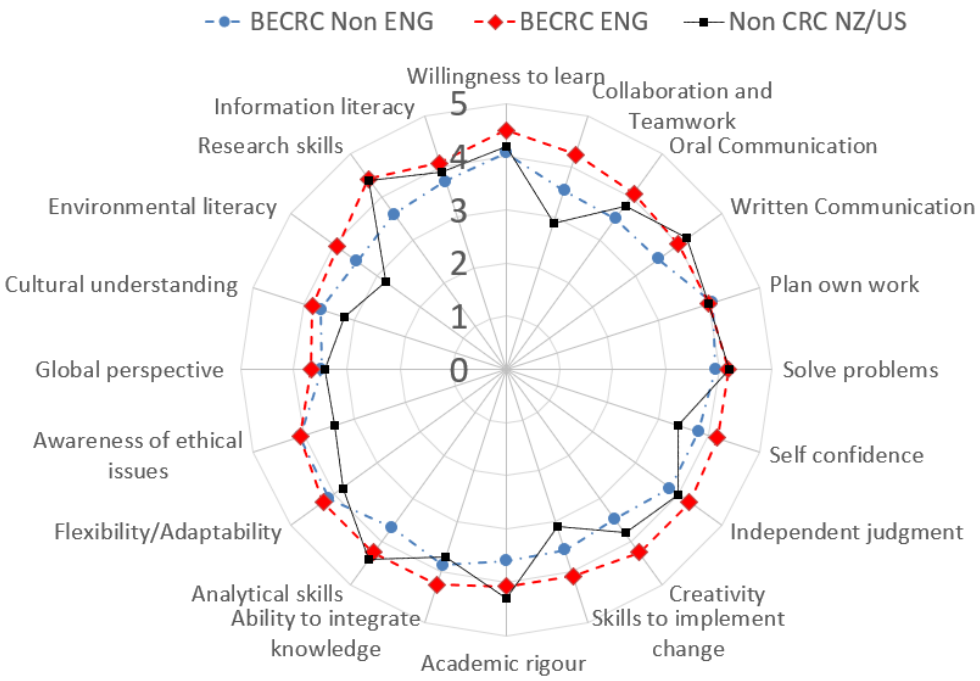

Figure 1: Developed Attributes Engineers vs Non Engineers (BECRC), Data Spronken-Smith (NZ, US studies)

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The BE CRC students reported positively undertaking professional development opportunities as part of their doctoral studies with the BE CRC Engineering cohort averaging around 4.18 and the Non-Engineering cohort about 3.86 respectively (1-5 Likert scale) for 8 different categories as depicted in Figure 2. The most noteworthy distinction between the CRC students is the better rating for Leadership and Teaching development (both >0.5) and project management (0.45) by the BE CRC Engineering students.

However, again the more remarkable difference can be seen when comparing the BE CRC Engineering students to the Non-CRC cohort: activities like Teaching development (4 to 2.9), Working in teams (4.36 to 3.2) and especially Research skill development (4.45 to 2.45) are significantly better rated. In addition, Networking, Leadership development and Project management received also much better feedback (>0.5). In contrast, the professional development activity Entrepreneurship & Commercialization has a much better rating from the NZ/US non CRC cohort.

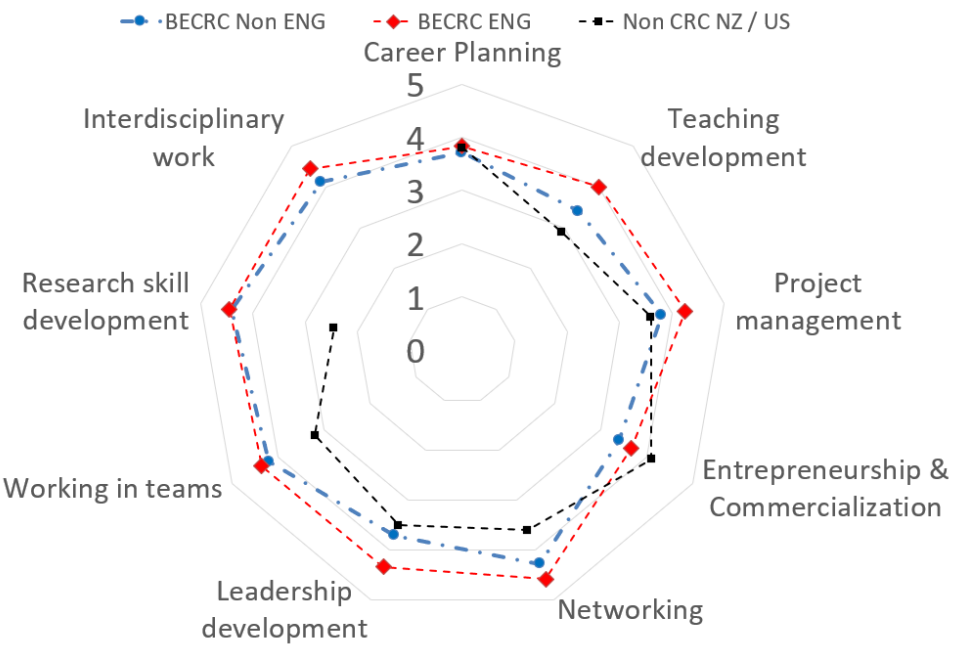

Figure 2: Professional Development opportunities

Another category that has been investigated - but that could not be found from the Non-CRC cohort - is interdisciplinary work which received very high rating from the BE CRC cohort (4.45 Engineering and 4.13 Non-Engineering). This can be attributed to the structure of the BE CRC as research projects are usually of cross-disciplinary nature and aim to achieve milestones in more than one research programme. Thus, doctoral research studies can carry various research questions and are often - at least partially - driven by multi-disciplinary research goals. This trend is also corroborated by the supervisor survey no details shown here) which revealed that thought this attribute (interdisciplinary work) was better developed in the BE CRC cohort than in regular PhD studies at universities.

Another important outcome was the expectations that respondents (both students and supervisors) had towards the importance of industry placements for developing professional attributes and employability. More than 90% of Engineering, Non-engineering and also supervisors agreed or strongly agreed that internships with a CRC industry partner would be very beneficial for career development and positively impact employability after graduating.

Undergraduate curriculum

When asked about the education and training that RHD students had received during their undergraduate degree with respect to Blue Economy topics, the responses were mixed both for the Engineering and Non-Engineering cohort (Figure 3a). There is no clear trend as almost the same amount reported to have little or none training compared to the fraction that answered, “a lot” or a “great deal”. This disparate response could be attributed to different curricula of individual institutions as many of the CRC students have studied overseas and have very diverse backgrounds. In contrast, the majority reported that they would support a better representation of BE CRC topics in the undergraduate degree and that it would help

their career development in this industry sector (Figure 3b)..

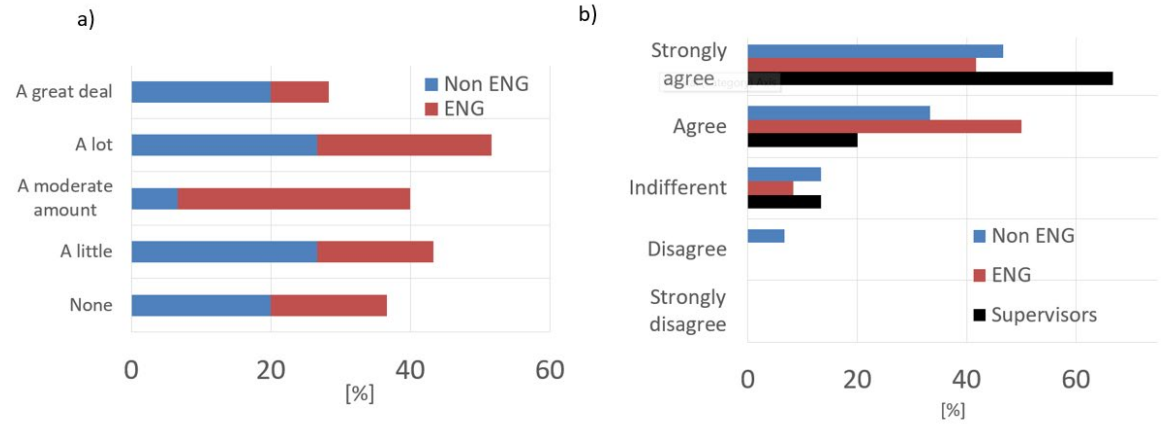

Figure 3: BE CRC subjects in undergraduate curriculum a) Experience of education and training in Blue Economy relevant subjects b) Support of better representation of Blue Economy relevant subjects in the undergraduate curriculum. This perception also includes the responses from academic supervisors at Australian / NZ universities (black)

This trend is also confirmed by the feedback from the academic supervisors (black columns) where the majority was very supportive of a modified curriculum that incorporates all research programs displayed in Table 1. For the Engineering curriculum potential subjects that were considered in the responses were: Maritime and Offshore Engineering, (marine) Renewable Energy systems, Environmental Engineering and Monitoring

Discussion and outlook

Graduate attributes and employability

Training programmes at universities are designed to promote a holistic development of desirable skills and attributes. The main focus is usually on the undergraduate degree, but similarly doctoral studies have an underlying framework of skills that foster career development and increase employability. One goal of this study was to identify attributes and test their development in a cohort of students that undertake their studies in a large industry-university collaboration – the Australian CRC program. We found that PhD graduates from the Blue Economy CRC, and especially from Engineering disciplines rated their developed skills consistently higher than students from Non-Engineering studies. This trend is further corroborated when including data from a wider-reaching study which includes international HASS and Sciences students that were not involved in CRC programs. For instance, attributes like Creativity, Skills to implement change, Academic rigour and Ability to integrate knowledge seemed to be developed better in Engineering studies. A large difference between CRC students and Non-CRC students was found in the career opportunities suggesting that industry focussed research had a positive impact on how RHD students perceived their professional development which resonates with an earlier study (Harman (2002) reported that CRC can play a significant role in research training in Australia and that CRC students higher levels of satisfaction compared to RHD students in regular university departments. The vast majority of RHD students and academic supervisors thought that BE CRC studies have a direct positive impact on employability. Likewise, both academics and student were highly favourable of an industry placement and that this would be further beneficial to the doctoral studies but also the career development. Thus, industry programs such as the CRC program could be advantageous as they could offer a streamlined process for internships and industry placements thanks to already-established collaborations between the companies and the research institutions. It is also worthwhile to track and monitor the perception and employment experiences of students during an industry placement or even after their graduation as

recommended by Manathunga et al. (2009) to help re-evaluating and improving PhD training programmes. Furthermore, doctoral students have also been found to positively influence knowledge transfer and knowledge sharing in university- industry collaborations (Santos et al, 2021).

Undergraduate curriculum

An interesting outcome was the perception that students had about their education and training they received prior to starting the doctoral studies. Although the responses were mixed ranging from poor knowledge to having a great understanding of the Blue Economy subjects, there is a clear support of a stronger representation of Blue Economy relevant subjects in the undergraduate curriculum. This is favoured by all cohorts, e.g., Engineering students, Non-Engineering students and also very strongly from the supervisors. With a large amount of academics being involved in Blue Economy research projects, it is likely that this research interest and subsequent need to train in Blue Economy subjects will be reflected in the undergraduate engineering curriculum. For instance, examples from Macquarie University, the University of Queensland, the University of Tasmania, Griffith University and University of Western Australia demonstrate that most institutions have already implemented some changes in the undergraduate engineering curriculum:

Macquarie University's research benefits greatly from projects within the BE CRC (Risk and Reliability projects) and has incorporated the outcomes and use of case studies into several units of study, such as "Health and Safety in Construction", and "Safety and Risk Engineering". These units are presented to students pursuing a Bachelor of Civil and a Master of Engineering Management. In addition, several undergraduate honour projects are also based on the research activities carried out in the BE CRC.

At the University of Tasmania, in their maritime engineering final year capstone design units (across Naval Architecture, Ocean Engineering, Marine & Offshore Engineering) they have introduced complex multi-disciplinary projects adopted from BE CRC research initiatives. For example, in 2021 undergraduate students needed to design and assess the feasibility of an offshore seaweed (giant kelp) farming operation that aimed to have a low environmental impact. In this series of projects, the student cohort of 43 engineers (in smaller teams) came up with two innovative and technologically advanced offshore seaweed production and carbon capture infrastructure designs, and support vessel designs. Similarly in 2020, they designed an offshore fish farming operation co-located with offshore renewable energy production. Similarly, in the Bachelor of Marine and Antarctic Science, BE CRC has provided support for university-based work-integrated learning (WIL) placements on topics such as offshore renewable energy policy and regulation, social license in emerging offshore energy and aquaculture sectors, and transitioning decommissioned oil rigs to sustainable seaweed-centred offshore aquaculture facilities. In addition, annually several undergraduate honour research projects are carried out in relation to BE CRC research initiatives.

At the University of Queensland, some undergraduate courses have also adopted Blue Economy Research outcomes and even introduced new courses that have been specifically designed to train undergraduates in new emerging engineering disciplines. For instance, in 2023 the new course "Marine and Hydro Power structures" covers topics such as Offshore Wind, Offshore Wave and Tidal Energy systems and resource assessment and site selection procedures. As one underlying element of the Blue Economy is sustainability, subjects such as Environmental Engineering and Environmental Impact Assessment procedures will also gain more importance in the Civil Engineering undergraduate curriculum.

At Griffith University, the Industry Affiliates Program (IAP) 6002ENG is a final-year BEng capstone project. This program requires students to undertake an industry-engaged research project, showcasing their ability to work independently. Throughout the project, students receive guidance and assistance from both industry and academic supervisors, who provide support in the research's design and execution. One of the projects offered in 6002ENG focuses on the innovative design of fish pens within the Blue Economy sector. By participating

in these projects, students have the opportunity to enhance their technical skills and knowledge in a specific area of engineering while also developing critical thinking and judgment abilities. It is worth noting that Blue Economy projects will continue to be available in the upcoming years, ensuring ongoing opportunities for students.

At the University of Western Australia, BE CRC topics have been gradually introduced into the engineering undergraduate and Master degrees over the last 5 years. The final-year elective undergraduate units such as 'Coastal and Offshore Engineering' and 'Design of Offshore Energy Facilities' motivate much of the learning through application to offshore renewables and/or aquaculture. However, the fundamental knowledge of hydro-, structural and soil dynamics, for example, remain unchanged, ensuring lessons learnt from the traditional oil & gas offshore engineering are not lost. These two units alone expose on average 125 students per year to engineering challenges in the blue economy. Moreover, the compulsory final-year engineering undergraduate research project unit has run a multitude of offshore renewable energy projects since 2017, including design, build and test of wave energy converters and floating substructures for offshore wind turbines. So far, over 30 undergraduate students have conducted their research project on blue economy topics. Additionally, new Master degrees in 'Renewable and Future Energy', 'Ocean Leadership' and 'Offshore and Coastal Engineering' have been launched with the aim to equip graduates with in-depth, innovative and highly interdisciplinary skills preparing them for a wide range of ocean-related career pathways

At the time of writing the survey of academics of BE partnering institutions was not finished and therefore these two examples most likely under-represent the significance that the Blue Economy already has on the (engineering) curriculum. Nonetheless, we expect more adaptations to the educational program as the governmental goal to rely more heavily on seafood and marine energy production will reshape the economy and training programs of the future workforce. It is anticipated that the partnering Universities (and likely other education institutions could follow) will consider how their doctoral and undergraduate training programmes can promote the development of desirable skills and attributes of the Blue Economy. More generally, large industry-university collaborations such as the CRC program, have major benefits as outlined in the Allen Consulting Group Report (2012). As this program continues it will further refine this set of attributes and align it with industry needs which will increase employability. While this was a first step in identifying differences and changes in graduate attributes, the importance of industry partnerships with respect to education and career opportunity development, this survey should be extended (to other CRC programs) or repeated (track performance and success of currently surveyed BE RHD students) to increase the confidence of results.

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