"Biggs + ACAD =?" Evaluating an international authentic learning pilot in education for sustainable development

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Introduction

In order to realise the United Nations Sustainable Development Goals (United Nations, 2015), there is a critical need to transform engineering curricula to develop requisite knowledge and skills across the 17 thematic areas. Many Higher Education Institutions (HEIs) speak to the importance of integrating sustainability knowledge and skills within curriculum (Byrne, Desha, Fitzpatrick, & "Charlie" Hargroves, 2013; Desha, Hargroves, Dawes, & Hargreaves, 2013), and efforts are underway to enable curriculum transformation through defining engineering competencies by agencies such as the International Engineering Alliance (IEA) and the World Federation of Engineering Organisations (WFEO) (Desha & Caldera, 2019). Over the last three years the co-authors have been exploring a 'missing link' in engineering competencies towards these end-goals, in the form of geospatial knowledge and skills (Desha et al, 2019). This coincides with the Federal Government's launch of *Digital Earth Australia* (Mohamed-Ghouse et al., 2019) to connect society with high quality current and historical data on a myriad of physical, environmental and social topic areas.

Focusing on the context of, *"Everything is connected, and where is critical"*, this paper explores the question of what it takes to imbue engineering students with geospatial knowledge and skills (Desha, Hargroves, & Smith, 2009) whereby education systems are not keeping pace with the rapidly emergent capability requirements of employers in government an industry. Specifically, the paper evaluates the international course-work (International Engineering Practice (2007ENG) course, 2017-2018) undertaken in collaboration with Chubu University (Nagoya, Japan). This course aimed to engage students in in learning activities to shift appreciation of career pathways in geospatial enquiry to assist in rapidly creating a transformed appreciation of context and perspective of engineering, to then apply throughout the remainder of studies and forward into their career. The documented case study is intended to be transferable and replicable by other academics in Australia and overseas.

The authors use two theories: *Biggs 3P* (Biggs, 1989) and *Activity-Centred Analysis and Design* (ACAD) (Carvalho & Goodyear, 2018) as theoretical lenses to evaluate the learning approaches (surface / deep learning) and the elements of the design (within a complex system) for learning used in selected learning and teaching activities in this course. The course is then mapped using both the Biggs' 3P model and ACAD framework and the authors discuss the iterative opportunities provided by ACAD which are not in the Biggs 3P model. Reflections are provided about observed shifts in student perceptions of the importance of geospatial within their engineering degree program, and opportunities to improve the course using the ACAD framework for guidance.

Creating a design for learning

This course aimed to engage students in in learning activities to shift appreciation of career pathways in geospatial enquiry and to emphasize the criticality of Digital Earth in education for sustainable development. The authors sought guidance in the form of Biggs' 3P model and ACAD framework as lenses of consideration. These are described in the following paragraphs.

Context – Bigg's 3P model

Learning and teaching revolves around complex concepts and principles. Biggs's 3P model consists of *Presage*, *Process* and *Product* which is an appropriate framework to evaluate the relations between the learner; the educator and learning environment; learning strategies and learning outcomes (Biggs, 1989). The presage focuses on factors that are established prior to student engagement with the learning experience. This includes student characteristics and teaching context and has the capacity to influence the other components in the model. The second component of process describes the specific mix of learning and teaching within a context. Lastly the third component of product explains the outcomes of the learning and teaching relationship (Biggs, 1989).

Biggs' 3 P model enables clear appreciation of the complexity of the learning process, albeit in a largely linear appreciation of how curriculum renewal is undertaken, which was popular in the late 1980s and 1990s. However, it is also recognised that the Biggs model evolved at a time when educational design processes were strong in emulating the pervasive linear manufacturing centric paradigm, where students are an end product of the educational manufacturing chain.

Context – ACAD framework

After two decades of Biggs learning and teaching inquiry, the Activity-centred analysis design (ACAD) framework emerged with an aim to understand the analysis of activity within complex learning situations and to identify the relationships between this learning activity and the tasks of design. The ACAD framework (Muñoz-Cristóbal et al., 2018) defines three elements including physical situation (set design), tasks (epistemic design) and social situation (social design). Learning tasks are generally offered by educators to students and these tasks could be created to disseminate key content (Muñoz-Cristóbal et al., 2018). The physical or set design consists of tools and artefacts primary or secondary artefacts) that are made available to learners (e.g.: chairs, laptops, iPads, pens, paper). The social situation focuses on the way that student will be involved for example to work in pairs, groups with pre-determined roles (Muñoz-Cristóbal et al., 2018).

In comparison to the Biggs model, the ACAD framework unpacks the presage with granular details of set design, physical and social designs. Furthermore, it explains learning activity to be dynamic and emergent, as well as physically, epistemically and socially situated. This means that learning activity cannot be designed but rather can be influenced through the designed tasks, physical and social contexts (Carvalho & Goodyear, 2018; Muñoz-Cristóbal et al., 2018). In essence, ACAD mapping presents a design with an iterative process that gets continually refined, enabling the authors to move towards the deeper learning experiences. Within this context, the rest of the paper predominantly relies on ACAD framework to evaluate the course opportunities for further improvement, evaluating contributions to the emergent activity while seeing a better level of granularity.

Context – Course design

In this paper, the co-authors report on a first-year engineering course unit that involves a 12-day field trip in Japan. This course is offered at the School of Engineering and Built Environment, Griffith University in Australia. International Engineering Practice (2007ENG) course aims to provide an intensive experience of how the engineering profession delivers goods and services in densely populated urban environments, considering the international directives and aspirations in relation to the UN SDGs. It also exposes students to diverse cultural contexts. The course aimed to achieve the following learning outcomes.

1. Describe the range of engineering design challenges and opportunities evident in mega-cities around the planet, drawing on the Japanese example.
2. Undertake carbon calculations for international travel and develop a strategy for offsetting these emissions.

3. Evaluate the potential for Australian undergraduate engineers to develop capacity for working in urban mega-cities, through their engineering program.
4. Communicate the outcomes from the course in a range of ways including oral presentations (video production), and in written form (short report and essay).

Table 1 presents a summary of learning activities and assessment takes in its relation to the above-mentioned learning outcomes. This summary also indicates the constructive alignment of intended leaning outcomes in relation to learning activities and assessment tasks.

Table 1: Leaning activities, assessment task vs learning outcomes matrix (Adapted from International Engineering Practice course profile, Griffith University, 2018)

Learning Activities	Learning Outcomes			
	1	2	3	4
Japanese Cultural Orientation (Lecture Series)			•	
Pre-Departure Briefing (1 day): Overview (Workshop)	•	•		
Study Tour (Field Trip) (Field Work)	•		•	•
Study Tour "Hapyookai' Seminar (Seminar)	•	•	•	•
Assessment Tasks				
Carbon Offset Strategy	•	•		•
Reflective Video Production & Submission	•		•	•
Technical Report	•	•	•	•

A course summary of experiences is provided in Table 2. Throughout the workshops, lectures and field trips on the tour, insightful knowledge was gained about engineering practice in Japan and a problem-based learning technique were used for to explore about how Japan is using the Digital Earth knowledge to drive their research agendas, projects and industry practices at improving life on land for planetary wellbeing.

Table 2. Course components by itinerary

Timing	Lecture/ Activity
Week 1	Pre-Departure Day
Week 1-3	Japanese Cultural and Language Immersion (three 2-hour sessions) **Assessment: Carbon Offset Report**
Week 4-5	**In-Country Experience (Day 0 & 12 are Transit days – BNE-NRT-Nagoya)**
- Day 1	Chubu University: Welcome Speech & Introduction; Evening Networking Function
- Day 2	Toyota Manufacturing Plant Tour; Toyota Museum
- Day 3	Nagoya local tour
- Day 4	Chubu University: Smart and resilient agriculture; Waste and Resource Recovery; English Cultural Session
- Day 5	SCMAGLEV & Railway Park; Nagoya Port & Aquarium; Nagoya Castle
- Day 6	Hamaoka Nuclear Facility
- Day 7	Hiroshima Peace Museum; Miyajima Island Village and Gates; Overnight Ryokan Accommodation
- Day 8	Kyoto sight-seeing
- Day 9	Chubu University: Introduction of Smart Grid System on Campus (Shimizu Corporation); Transportation; Health GIS; Super Conductors: The future of energy
- Day 10	Chubu University: Coastal Cities Resilience
- Day 11	Kyobashi Station and Circular Garden; Trade Investment Queensland; Tokyo Tower
- Day 12	Miraikan Science Museum
Week 7	Happyoukai (Presentation Afternoon) – On Campus **Assessment: Video Reflection**
Week 11	**Assessment: Essay (Online submission)**

The teaching team was deliberately designed the learning activities and assessment tasks to ensure the constructive alignment of learning outcomes as it is critical for delivering a

scaffolded, learning experience for students (Biggs, 2014).Keeping the course context in mind the next section describes the evaluation approach adopted in this study.

Evaluation approach

The paper draws on two years of data gathered from 21 Griffith University students who participated in the course. This research adopted a qualitative mixed-method which consists a survey and a focus group discussion and analysed the course design through the lens of two theories. Data was collected from two student cohorts in 2017 and 2018. The survey was administered using an online platform and ensuring the anonymity of the participants. After the field excursion all students participated in the one-hour focus group considering the following visioning 'blue sky' question: *How has your appreciation of Engineering Practice shifted as a result of what you've experienced in-country?*

This course provided a couple of key opportunities to enquire into teaching and learning practices, considering deep learning opportunities as presented in this paper, in addition to complexity (discussed in Desha et al, 2019). Both enquiries relied on the same data collection methods but have explored the data in different ways: The first paper to be presented at the European Roundtable for Sustainable Consumption and Production (ERSCP) 2019 analyses the complexity of 21st Century engineering problems and how this course enabled the undergraduate to understand the problem using the Cynefin framework. This paper takes a different perspective with the aim of analysing the learner ecology and design for learning evaluation using the Biggs 3P model and ACAD framework.

Findings and discussion

Findings are presented under two key themes, including connecting the two theories and moving toward deeper learning experiences. The authors attempt to map the course activities and outcomes using the Biggs's 3P model and ACAD framework as theoretical foundations.

Course reflections using the Biggs 3P model

Biggs 3P model enabled the authors to evaluate the complex nature of the learning and teaching process in relation to presage, process and product. The course-specific findings (blue text) were mapped out in the base of Biggs 3P model (Figure 1) to better understand these elements and its interactions. Further details are supported by focus group findings are presented in Table 3 below. This course aimed to offer a deep learning experience enabling students to immerse in real world engineering challenges and improve their problem solving, and critical thinking skills. Figure 1 presents the 3P model map demonstrating how the course was designed using the component of presage process and learning outcomes.

By evaluating the Biggs' 3P model initially, it is clear that it demonstrates a logical structure which reflects the university course profiling system works. This captures key areas such as '*what do they bring in to the course*', '*what is the teaching context for the design*', '*how we are going to do that*', '*whether it's a broad- shallow interaction or deep- immersive interaction*', and '*what we are going to get as learning outcomes*'? .
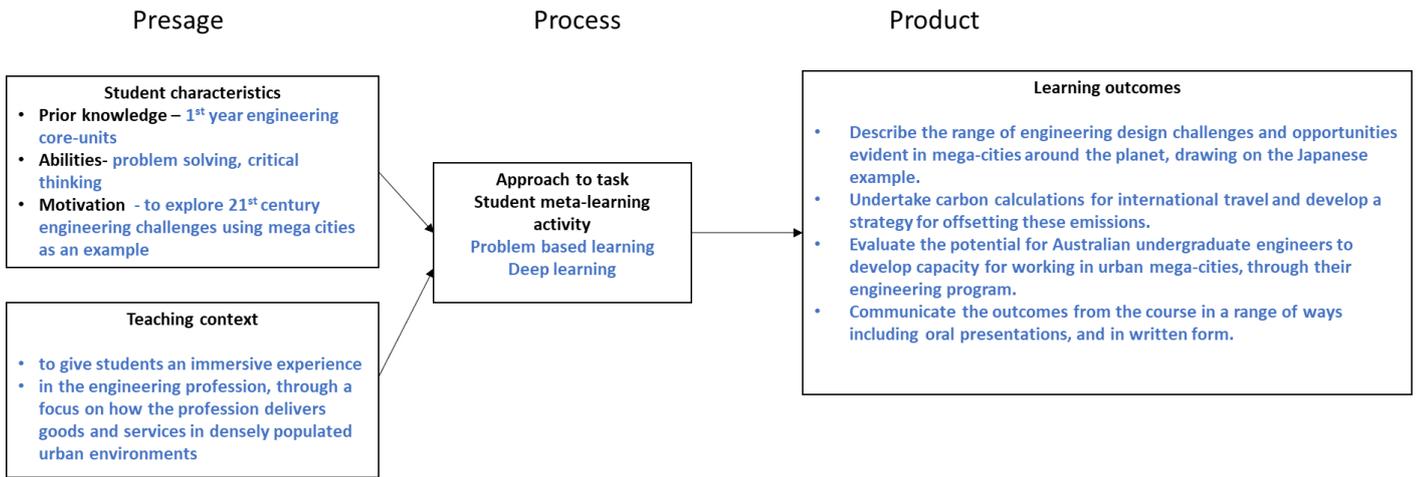
Figure 1: Course design through the lens of the Bigg's 3P model (Base model was adapted from J. B. Biggs (1989))

Course reflections using the ACAD framework

Figure 2 illustrates the key levers of this design for learning plan, inspired by designing with ACAD framework. In the figure, the text below the arrows presents the contextual information related to International Engineering Practice course. Exploring the course for improvement opportunities within the ACAD framework context allowed the authors to split out the teaching context primarily into the set design, physical and social designs so inside these elements the value of a number of initiatives embedded are acknowledged.
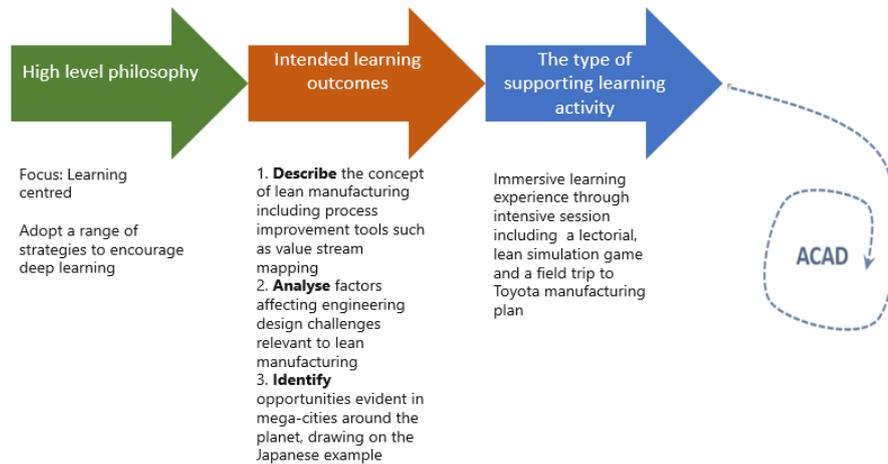
Figure 2: Illustration of key levers of the design for learning using ACAD framework

In contrast, in Biggs' 3P model the teaching context was rationed as being an immersive experience opportunity to give them an engineering professional context. When the ACAD lens was added, the authors were able to look at the physical and social situations where the immersive experience in Japan has value in the context of providing a physical situation rather than being in a class room in Australia. In Table 3 and in Figure 3, the authors acknowledge the physical contribution of field trips, and the tools used to include online calculators and mind mapping software. All contribute to striving above and beyond the broad context that Biggs encourages. The ACAD framework has significant contribution in unpacking the teaching context. For example, students will be engaged through individual reflections as oppose to

group work. They are looking at the roles required by professional engineer but their roles inside their learning is actually based on reflections amongst peers. They are also being split during the experience of international peers through the English language class.

These types of experiences provide a much more holistic evaluation opportunity for how the course is contributing to learning outcomes. Through ACAD mapping the authors see a clearer pathway / clear rationale for meta-learning activities in a deep, problem-based learning. ACAD mapping can be seen as a furthering of the Biggs 3P model. ACAD is not so linear/sequential like the Biggs' 3P model and instead of saying the outcomes are the most important element, this focus on the emergent activity. In essence, ACAD does not focus on what is being attempted to achieve because the activity will lead to emergent outcomes. All these three are informing the emergent activity, linked in a triangular way.

Table 3: Summary of the course performance, considering the ACAD model (quotes identified using "SYear-Student" nomenclature for anonymity)

| Key elements	Strengths	Weaknesses	Supporting quotes
Epistemic design	▪ Prior knowledge in Engineering Materials ▪ Creative Engineering, Engineering Maths ▪ Engineering Science enabled students to better understand the real-world problems ▪ Being physically present in Japan and seeing the real context motivated students to learn more about 21st Century engineering problems ▪ Students were given a range of opportunities to engage in deep learning including	▪ Some students were unable to identify or describe the grey areas of the problem and the learning process ▪ Some students were in the process of changing their study discipline and were not too motivated to see the engineering aspect of examples, but started focusing more on the human resources	▪ *"I guess for me – I am a very black and white thinker. And studying engineering we always learn a theory or a concept or how to calculate something in particular and we would work on that perfecting it. And the learn how to apply that in different situations. Being in Japan, I questioned myself where is the theory, where is the concept, what are we learning" (S18-5)* ▪ *"This is trying to work out future problems, learn on current knowledge and see how we could extrapolate into the future. That's not something we talk about that much in lot of courses".* (S18-6)
Social design	▪ Students in Japan are doing individual reflections amongst the peers rather than group work necessarily. ▪ Students are looking at the roles required by professional engineer but their roles inside their learning is actually based on reflections amongst peers.	▪ This social design was limited to individual and peer partners. ▪ This could be further improved through integrating more group work	▪ *"So, before coming here I kind of had an idea of what software engineers do, but I realise now that I didn't know exactly how they worked and intertwined with the other fields, like civil, etc and also combined with other industries, such as agriculture". (S17-2)* ▪ *"It's really interesting. It's always interesting to see how people who work in your future field, in that business, and really get a feel about what it involves. It's good to see that" (S17-2)*
Physical design	▪ The immersive experience in Japan has value in the context of providing a physical situation rather than being in a class room in Australia	▪ Not all students will have the capacity to participate in the international field trip	▪ *"For example, in Toyota, doesn't matter the spectrum of the problem it is a matter of identifying the complexity"* (S18-8)
Emergent activity	▪ Students had the opportunity to engage in deep, immersive observational learning experience	▪ Some students found it challenging to harness the best outcomes through the emergent learning experience	▪ *"I think I came into this subject to learn about environmental sustainability but coming out of it there was massive amount of knowledge, broad spectrum of ideas" (S18-4).*
Outcomes	▪ Students learned the detailed method of carbon calculations for international travel and developed a strategy for offsetting these emissions. ▪ Students learned to reflect and communicate their key learnings and its relationship to UNSDGs through oral presentations (video production), and in written form (short report and essay).	▪ Not all students were technologically competent with video production	▪ *"Opened my mind about seeing how things are done there, how to put things into place"* (S18-9) ▪ *"We use a lot of brain flip in learning. Lot of us are used for core- learning like look at literature, that very like this is the knowledge basin we have where we go". (S18-3)* ▪ *"This course is very- this is where we want to go, very future oriented" (S17-10)*
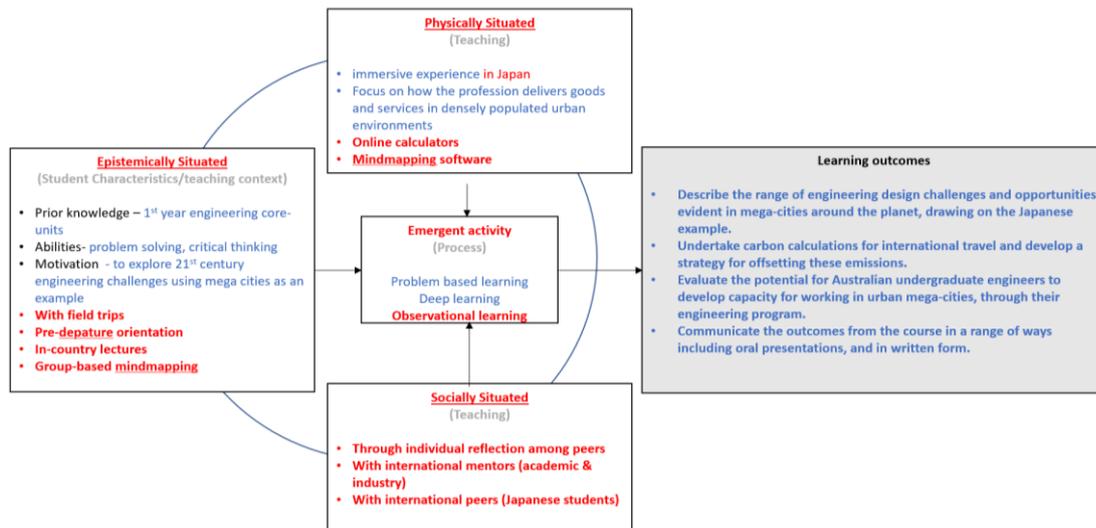
**Figure 3: ACAD mapping of the International Engineering Practice course
(ACAD elements are shown in red, course specific details are shown blue)**

Moving toward deeper learning experiences

One of the key outcomes of this paper is the authors have identified the iterative opportunities provided by the ACAD which are not in the Biggs 3P model. Biggs 3P model is similar to a sequential manufacturing process where a certain amount of input is processed to achieve a certain outcome. After 15 years of research progress through ACAD it was understood as a highly iterative process, with emergent direct benefits. As discussed, ACAD builds on Biggs in understanding the concurrent nature of the lived experience, which co-evolves according to three areas. Based on the awareness gained through this reflective process, the authors are planning the following adjustments to the curriculum going forward, in the next offering (T3, 2020):

- The opportunity to more explicitly inculcate the 'why' of the course itself, towards engineering practice that addresses needs based on locational context.
- The need to make the journey explicit for students, so that they are aware of 'why' they are having certain experiences relating to perceptions of 'confusion', 'unrest', 'excitement' etc.
- The opportunity to leverage the course further to motivate students, by creating a community of practice (with current students and alumni), online and in-person.

Through the analysis it was understood that the narration of the course curriculum could be more explicit, so that students feel satisfied when dealing with uncertainty and complexity, rather than just the immediate feelings of elation or frustration.

Conclusions

The paper has concluded several opportunities to improve the course, highlighting the practicality of using this teaching strategy to motivate students, particularly in first year, and inculcate the necessary knowledge and skills within engineering education, towards engineering practice that addresses 21st Century needs. Beyond the course, these findings have implications for academics attempting rapid curriculum renewal, addressing the need for education for sustainable development to create graduates who are competent in delivering solutions that contribute to achieving the UN SDG ambitions. Considering the opportunities presented by theoretical constructs, the authors have reflected on the value of connecting two theories: *Biggs 3P* and *Activity-Centred Analysis and Design* (ACAD). These have been used to evaluate the learning approaches (surface / deep learning) and the elements of the design

(within a complex system) for learning used in selected learning and teaching activities in this course. The experience and results as a case study are transferable and replicable by other academics in Australia and overseas by using intensive field trips as a targeted approach.

References

Biggs, J. (2014). Constructive alignment in university teaching. *HERDSA Review of Higher Education, 1*(1), 5-22.

Biggs, J. B. (1989). Approaches to the enhancement of tertiary teaching. *Higher education research and development, 8*(1), 7-25.

Byrne, E. P., Desha, C. J., Fitzpatrick, J. J., & "Charlie" Hargroves, K. (2013). Exploring sustainability themes in engineering accreditation and curricula. *International Journal of Sustainability in Higher Education, 14*(4), 384-403.

Carvalho, L., & Goodyear, P. (2018). Design, learning networks and service innovation. *Design Studies, 55*, 27-53.

Desha, C., Hargroves, C., Dawes, L., & Hargreaves, D. (2013). *Collaborative resource development for energy efficiency education.* Paper presented at the Proceedings of 24th Annual Austalasian Association of Engineering Education Conference.

Desha, C. J., Hargroves, K., & Smith, M. H. (2009). Addressing the time lag dilemma in curriculum renewal towards engineering education for sustainable development. *International Journal of Sustainability in Higher Education, 10*(2), 184-199.

Desha, C, and Caldera, H.T.S (2019) *Foundations and Horizons: the critical role of international coursework to engage students in engineering for the 21st Century.* Paper to be presented at the World Engineers Convention, Melbourne, Australia (Accepted).

Desha, C., Perez-Mora, L., Caldera, S., Fukui, H., and Naidoo, C. (2019) *Innovation journey of the Digital Earth Node (DEN): Experiences, ideas and future opportunities.* In proceedings of International Society of Digital Earth Conference, Florence, Italy.

C. Desha, H.T.S Caldera, D. Hutchinson (2019) U*sing the Cynefin Model to develop built environment student capabilities in complex problem-solving for the 21st Century.* In Proceedings of the 19th European Roundtable of Sustainable Consumption and Production, October 2019, Spain (Accepted)

Mohamed-Ghouse Z, Desha C, Perez-Mora L 2019 Chapter 23: Digital Earth in Australia, in Guo H et al. Manual of Digital Earth, International Society of Digital Earth. London: Springer Nature.

Muñoz-Cristóbal, J. A., Hernández-Leo, D., Carvalho, L., Martinez-Maldonado, R., Thompson, K., Wardak, D., & Goodyear, P. (2018). 4FAD: A framework for mapping the evolution of artefacts in the learning design process. *Australasian Journal of Educational Technology, 34*(2).

United Nations. (2015). Transforming out world: The 2030 Agenda for SustainableDevelopment. Retrieved from https://sustainabledevelopment.un.org/sdgs

Acknowledgements

to making the experience a reality for staff and students. The authors also thank the Griffith School of Engineering and Built Environment for supporting the staff travel expenses.

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