Developing graduates with capabilities in complex problem-solving for the 21st Century

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Abstract

The United Nations Sustainable Development Goals (UNSDGs) are challenging decision-makers to think beyond conventional methodologies and materials, and models for development. Higher Education Institutions, particularly in engineering and built environment studies, have identified that students want 'to make a difference'. However, there are significant challenges in embedding improved problem-solving within curriculum that builds capacity for students to undertake complex, system thinking and address unconscious-bias. This leads to the lived reality of programs that are for the most-part unchanged in their content and approach, with short-falls in graduate capabilities to fulfil on the aspirations of agendas such as the UNSDGs.

This paper draws on the lived experiences of the authors in the geospatial industry, and piloting coursework and student engagement with a collaborating research partner in Nagoya, Japan. Specifically, the authors present findings from two years of enquiry into transforming student perspectives on their discipline and career opportunities, through an international collaboration between an Australian and Japanese University. The authors present the model as a narrative for framing their appreciation of professional practice and career planning. The research approach to sensemaking consists of surveys, focus groups and mind-map comparisons at the commencement and conclusion of the studies. The findings provide rich insights on student experience on this transformative 'look to the horizon' experience, through a focus on one of the most densely populated regions of the world, on the central East Coast of Japan. Through a ten-day field trip to Nagoya and Tokyo, students visit sites including manufacturing, transportation, energy, retail, residential and academic facilities, considering each through the lens of the CDIO process (i.e. Conceive, Design, Implement, Operate) and lessons learned regarding future optimisation. Within this context, this paper introduces the potential for Cynefin theory to help understand why education for sustainable development is so challenging, through considering the differences between simple, complicated, complex and chaotic problems and their implications for learning design.

The research findings provide evidence of this learning experience transforming the thinking of early program students as they were able to immerse in real world examples are engineering solutions related to disaster management, resilience and adaptation. The findings also provide a reference point for embedding sustainability into engineering education, assisting colleagues globally in preparing the future workforce with the ability to look at global problems and develop context-specific, technically sound engineering solutions using their the 'hands-on', 'on-the-job' business skills. The study has immediate implications for embedding the UNSDGs within coursework across built environment programs, wherein the authors propose the criticality of enabling students with an appreciation of the importance of appreciating complexity and addressing unconscious bias, providing a robust scaffold to use their discipline skills to problem-solve.

Keywords: Higher Education Institutions, Sustainable development, Curriculum, Immersive experience, Cynefin theory

1. Introduction

In mainstream literature the often-cited world view is that by 2050 more than half of the world's population will live in 'mega-cities' comprising more than 10 million people, with a substantial proportion of this urban migration occurring in Asia (Okazawa & Murakami, 2019; Smith & Hargroves, 2005; Smith, Hargroves, & Desha, 2010). Such statements are then often followed by urgent calls-to-action regarding the priority problem to be solved, namely to create or redesign cities to accommodate this end state. However, connecting this decision on how to act with just one predicted population distribution scenario has limiting implications. For example, it limits being able to plan for the complexity of global population mobility, where a range of scenarios relating to sea level rise, extreme weather patterns, tectonic movements and pollution could result in different configurations of humanity around the planet. It also limits the exploration of other potential pathways for enabling the 'quality of life' for a steady-state global population of around 10-12 billion people and environmental stewardship towards sustainable development outcomes that decouple economic growth from environmental pressures (Smith et al., 2010).

The United Nations Sustainable Development Goals (UNSDGs, 2015) is challenging decision-makers to think beyond conventional methodologies and materials, and models for development. Within the engineering profession there are calls to take a holistic and inclusive approach to design (Vemury, Heidrich, Thorpe, & Crosbie, 2018), and to become aware of our own unconscious biases in designing 'solutions' for the diversity of challenges present in the 21st Century (Kirman, Simon, & Hays, 2019; Mohsen, Ismail, Parsaei, & Karwowski, 2019). In The Necessary Revolution (Senge, Smith, Kruschwitz, Laur, & Schley, 2008) and The Fifth Discipline, the authors present the critical need for 21st Century professions to appreciate what it means to live and work within a system-based appreciation of available resources, and an age of uncertainty, where past experiences - for example with climate - do not provide a reliable indication of future events and outcomes. Alongside such efforts, several seminal authors in decision-making warn of the limits of current thinking in a world that is information-rich yet knowledge-poor. In The Impact of the Highly Improbable (Taleb & Swan, 2008) and Antifragility (Taleb, 2012), the authors articulate the problems with making decisions in a vacuum of meaningful data on the range of risks and scenarios. Rosling, Rosling, and Ronnlund (2018) describe the severe lack of common knowledge regarding population demographics, culture, needs and desires, and the need for humanity to practice 'factfulness' towards making better decisions for planet and for humanity. Robson (2019) defines the 'Intelligence Trap', where intellectually intelligent and 'well trained' professionals can make decisions that are sub-optimal, if actual facts, contextual factors and unconscious biases are not addressed.

Fortunately, literature from the educational and psychology fields provide well-established guidance and support for engaging with current context, dealing with unconscious bias, failure and for making better decisions. Snowden uses the Cynefin Model to propose that 21st Century problem-solving requires practitioners who can distinguish between simple, complicated, complex and chaotic environments, and then to act accordingly (Snowden, 2000). Syed (2015) discusses avenues for enabling a culture that embraces risk and failure, and in Nudge, Thaler & Sunstein (2009) raise questions about the rationality of many judgments and decisions that people make, with predictable mistakes arising because of heuristics, fallacies, and the influences of social interactions. In Thinking, Fast and Slow, Nobel Laurette Kahneman explains the necessity of spending time 'thinking slow' to problem-solve effectively, creating time to do this up-front distinguishing before embarking on a course of action (Kahneman, 2011). Unfortunately, such thinking and systematic exploration of decision-making is not our natural tendency or desire, requiring shifts in behaviour to achieve. From childhood through to adulthood, it is essential to educate, train and remind ourselves of the fallibility of decisions, towards problem-solving that is accountable and defensible.

In the education sector, higher education provides an important pathway for developing critical thinking skills, building on secondary school experiences across a breadth of topic areas, to enquire into particular professional discipline contexts. Curriculum for professional specialisations such as engineering, design, planning and law have highly regulated curriculum that is often governed by external accreditation agencies (Desha, 2013). However, these are increasingly ‘outcomes focused’ rather than prescriptive, enabling consideration of different learning and teaching strategies to produce professionals who are cognizant of current reality, and who can think (Engineers Australia, 2011; Byrne, Desha, Fitzpatrick, & “Charlie” Hargroves, 2013; King, 2008). Furthermore international agencies are advocating progressive thinking to address 21st Century challenges, including for example the International Engineering Alliance (2019), and the World Federation of Engineering Organisations (2018). Within this context, a key challenge for educators is to first enable students to understand their contribution to reinforcing sub-optimal decision-making, and then to develop their capacity to contribute to designing and implementing robust evidence-based solutions – and faster than conventionally achieved, acknowledging the time-lag dilemma facing the higher education sector (Desha, Hargroves, & Smith, 2009). The challenge is twofold: firstly, the challenge of developing the ability to accurately distinguish context – the facts and trends – and secondly to distinguish perspective – the priority actions to take, as acknowledged in inclusive engineering (Alpay, Ahearn, Graham, & Bull, 2008; Jolly, Crosthwaite, Brodie, Kavanagh, and Buys, 2011), in intercultural competency (Goldfinch et al., 2012), first year curriculum (Crosthwaite & Kavanagh, 2012), and in education for sustainable development (Mulder, Desha, & Hargroves, 2013). Addressing this requires deliberate educational approaches to expand student capabilities in non-binary, circular thinking and problem-solving. It also requires gathering data to evaluate the success of developing such capabilities, through designing insightful assessment and evaluation.

In this paper, the authors present the ethnographic journey in exploring ways to cultivate a workforce that is capable of moving beyond these limiting design constraints towards complex problem-solving in the face of increasing expectations for rapid response. This has involved the first author, with the tutor assistance of the second author and advice from the third-author, running an international initiative that attempted to apply the above insights into a transformative experience for undergraduate engineering students. The authors were motivated to design a professional-behaviour intervention course “2007ENG International Engineering Practice” as to Japan (Nagoya) for undergraduate engineering students that aspired to shift attitudes on context and perspectives about the role of engineering for 21st Century society. The first author was keen to know whether Japan would be a good case study to provide students with a shift in appreciation of context and perspective, with areas of very high-density populations such as Tokyo and Osaka, interspersed with very low-density village living. Within the Asia-Pacific Region, there are many significant engineering lessons to be learned from Japan, spanning the last 200 years since the industrial revolution and including the country’s recent experiences in responding to and recovering from with the Great Eastern Japanese Earthquake, and preparations for the impending catastrophic Nankai earthquake. In addition, the first author is fluent in Japanese and Japan has the benefit of being within an eight-hour flight from Australia.

The paper outlines the experiences and evaluation findings from two years of implementation and maps the insights to existing literature that might help to explain the observations. Specifically, the authors consider, how do we embed the Cynefin way into formal education design (learning design), in an education environment where such literature does not necessarily turn up for educators looking for learning design assistance. The paper begins with a description of the initiative, followed by a summary of the research methods and discussion of the evaluation undertaken to date, connecting the findings to literature that discusses and guides interpretation of the experiences. The paper concludes with comments on other data to be gathered to evaluate the progress of the initiative, towards better informed graduates who can apply knowledge and skills in ways that foster improved problem-solving.

2. Description of the Initiative

In this section the authors describe the initial plans for the course, within the journey of developing a program for undergraduate students that could 'jolt' students into appreciating the need for whole-system design and committing to applying this design practice in their subsequent course-work. The initiative augmented an existing relationship between the first author and colleagues at Chubu University, who were working in the core research area of digital earth and green infrastructure exploring decision-making pathways for complex built environment challenges, towards nature loving, nature inspired and place-based solutions. Within this context Griffith University partnered with Chubu University (Nagoya, Japan) through the Institute for Advanced Studies, to create an intensive coursework experience for undergraduate engineering students.

After successfully completing this course it is anticipated that students should be able to describe the range of engineering design challenges and opportunities evident in mega-cities, drawing on the Japanese example; undertake carbon calculations for international travel and develop a strategy for offsetting these emissions; and evaluate the potential for Australian undergraduate engineers to develop capacity to address complex challenges in urban development. Students should become aware of the need to collect better data, organise the data to be meaningful, and to take time to consider the implications of alternative decisions, even if problems or situations appear 'urgent'. Furthermore, the course aims to expose students to similarities and differences in cultural contexts, influencing design constraints, opportunities and end-user dynamics. The course is offered at the end of first year engineering, following students completing: Engineering Materials, Engineering Design Practice, Creative Engineering, Engineering Mathematics 2, Engineering Maths, Numerical and Computing Skills, Engineering Science, Engineering Mechanics (Desha et al, 2019).

The first assessment for this course comprises a carbon offset report, which requires a mind map and analysis of the student's greenhouse gas emissions in preparing for, traveling to and from the field trip, and consideration of offset strategies over a 12-month period to counteract the emissions. The second item is a reflective video/photo presentation, which covers a reflection of the student's experiences in the study tour component of the course. The final item is a technical report, which requires students to reflect on their learning about context and shifts in perspectives about cities of the future, considering the topics addressed during the lectures, workshops and site visits.

The learning outcomes target context and perspective development (assessment shown in brackets):

1. Ability to describe the range of engineering design challenges and opportunities evident in mega-cities around the planet, referencing Japan (video and essay).
2. Ability to undertake carbon calculations for international travel and develop a strategy for offsetting these emissions (report).
3. Ability to evaluate the potential for Australian undergraduate engineers to develop capacity for working in urban mega-cities, through their engineering program (essay).
4. Ability to communicate the outcomes from the course in a range of ways including oral presentations (video production), and in written form (report and essay).

Current and future challenges and opportunities faced by Japan are highlighted through in-class lectures on innovation, sustainability and resilience. This is intended to provide an insight into the technical, social, environmental and economic issues facing the engineering discipline and the considerations of contextual factors impacting decision making and problem solving in complex environments. It is intended that within this experience the students would better understand the context, which would inform or even shift their perspectives on engineering practice.

3. Research Methods

A qualitative mixed-method evaluation approach was chosen by the authors at the commencement of the journey, comprising an in-country questionnaire and focus group discussion at the end of each in-country experience. Two years of data have been collected to date, with data collection and analysis methods described in the following paragraphs. The student cohort consists of students from a variety of engineering and built environment courses including civil engineering, electronic engineering, electronic and energy engineering, software engineering, environmental engineering, industrial design, urban and environmental planning. The majority of the students stated that it is their first visit to Japan. One student had not previously travelled abroad.

All students participated in the one-hour focus group in the classroom of Chubu University, as two discrete undergraduate cohorts (10 in 2017, comprising 4 females and 6 males, and 9 in 2018 comprising 4 females and 5 males). One focus group was considered appropriate for each cohort, given that the usual male/female biases identified in other studies (Kelley & Bryan, 2018) could be managed by the first-author. Table 1 presents summary pf the participant with the nomenclature used to support the focus group quotes.

The participants considered the following visioning 'blue sky' question*: How has your appreciation of Engineering Practice and International Engineering Practice shifted as a result of what you've experienced in-country?* Within each focus group, students were asked to identify any shift from previous appreciation of the Japanese context, and to reflect on new knowledge and competences gained to solve the problem. The focus groups were predominantly a self-directed process. Participants were encouraged to self-nominate their turn and invited to add additional reflections to build on what others said. To reduce the bias of responses motivated by students wanting to 'fit in', the first-author regularly interjected with counter-comments to those observed by the students and sought student input or thoughts on these comments. Furthermore, students were praised on their willingness to respond, not on what they said.

Table 1: Summary of the two participant cohorts, their program details and analysis coding

Year	Gender	Course	Year	Code
2017	Female	Bachelor of Engineering (Civil)	1	S17-1
2017	Female	Bachelor of Engineering (Civil)	1	S17-2
2017	Male	Bachelor of Engineering (Electronic & Energy)	1	S17-3
2017	Male	Bachelor of Engineering (Mechanical)	1	S17-4
2017	Male	Bachelor of Engineering (Software)	1	S17-5
2017	Female	Bachelor of Engineering (Civil)	1	S17-9
2017	Male	Bachelor of Engineering (Civil)	1	S17-10
2017	Male	Bachelor of Engineering (Electronic)	2	S17-7
2017	Male	Bachelor of Engineering (Electronic)	2	S17-8
2017	Female	Master of Environmental Engineering and Pollution Control	2	S17-6
2018	Male	Bachelor of Engineering (Civil)/ Bachelor of Business	1	S18-7
2018	Female	Bachelor of Engineering (Mech)/ Bachelor Industrial Design	2	S18-6
2018	Male	Bachelor of Engineering (Mech)/ Bachelor Industrial Design	2	S18-2
2018	Male	Bachelor of Engineering (Civil)	3	S18-1
2018	Male	Bachelor of Engineering (Civil)	3	S18-3
2018	Male	Bachelor of Engineering (Civil)	3	S18-4
2018	Female	Bachelor of Engineering (Civil)	3	S18-5
2018	Female	Bachelor of Urban and Environmental Planning	4	S18-8
2018	Female	Bachelor of Urban and Environmental Planning	4	S18-9

A survey was administered at the end of each in-country experience on an individual basis. This tool gathers data on student appreciation of the value of the lectures and field trip elements, and cross-checks individual responses generated during the group discussions. Similar methodological approaches have been adopted in previous engineering education research with wider implications on engineering curricula (Byrne et al., 2013). The first in-country survey was undertaken on the last day of the students' time in Japan, online using the SurveyMonkey tool, and consisting of 5-point Likert scale questions in addition to open-ended questions.

An additional survey comprised the evaluation of course experience, administered as an end of trimester survey by the Griffith University central surveying unit. This provides a third-party indication of student appreciation and satisfaction of the course, undertaken in Week 11-12 of the trimester using the Griffith University survey tool. The survey comprised five pre-determined questions (Q1-Q5) in addition to two course-specific questions determined by the first-author.

In order to allow some comparisons to be made, the data was qualitatively analysed using a clustering method constructed from the key facets of the Cynefin framework, to visualise students' understanding of urban planning and design as containing simple, complicated, complex and chaotic components. In the following section the results of the focus groups and surveys are presented and then discussed in relation to the first author's aspirations for the course, mapped to key literature that supports and refutes the findings.

4. Results – Focus Groups

Findings are presented under several themes, including the role of factual and relevant information (context), the role of professional practitioners (context) and the importance of interdisciplinary teams (perspective). 3.1 Role of factual and relevant information (context). More than half of the students in each cohort reflected that opportunities will open up for 21st Century engineering if students develop capacity to "*correctly identify*" (S18-9) problems, and then create "*appropriate*" (S18-8) solutions for the problems. For example, "*I think when I've done a bit of work in property and buildings, I can see that engineering doesn't have to be on the side, be more corporate and what not, understanding that all the work that the professors here, and engineers in different parts of Japan. It highlights the breadth of opportunities in terms of career and impacts you can have, like working on global energy created, or to bring world peace, or advising government, or doing research, or working with NGOs, or working with the UN, lots of different avenues and opportunities, you don't even know what you can do*"(S17-10).

Many students noted the shift in their appreciation of the magnitude and significance of infrastructure resilience demonstrated in Japan. For example, "*Japan is an exemplification of the spirit of the SDGs through its resource management, disaster preparation and adaptation to the next stage of human society. From an engineering perspective, there are many challenges to overcome, however Japan presents a bright picture of what the future of the world may one day look like*" (S18-9).

Several students in both cohorts spoke to the importance of "*system things*" (S17-1) and "*ability to deeply understand the interconnections and interrelationship*" (S17-3) with regard to making informed decisions in micro and macro levels. For example, "*The connection between decision-making and implementation has to be there so that you can make good decisions that actually are sustainable and not just in a short-term perspective. And integrating that systems thinking, not just on a project, but on a macro policy and strategy level as well"* (S18-3).

Some students reflected on the difficulty of sense-making regarding the "*Japanese way*" (S18-2) of addressing some humanitarian challenges. For example, "*I really thought since the trip (about) the idea of fatalism that I definitely (see) persist(ing) in Japanese culture. They have this intense reference for spirituality, they take such measures in time to create shrines and go back there. If we knew that some things are going to happen why would they still live there? What else are they going to do? We face a lot of large-scale problems here. Oceans are rising, why aren't we taking measures?*" (S18-2).

4.1 Role of professional practitioners (perspective)

Several students in each cohort reflected on their appreciation of "*unprecedented global challenges*", "*requiring engineering graduate to be upskilled with 21st Century problem-solving*" (S18-7). Students discussed the emotional challenge of seeing the nuclear power plant and then visiting Hiroshima, reflecting "*that was hard*" (S18-1) and "*it was difficult*" (S18-9). They also spoke to feeling inspired to think creatively and apply their knowledge to real contexts. For example, "*Japan is so forward in being proactive, with engineering in every discipline. I think as engineers now our responsibility is to be, after this point, not to be the same. personally at least, I'll be a little more driven because I've seen a little bit more of the context*" (S17-2). In each cohort a student also noted that problem-solving from historic experiences is unlikely to meet expectations on suitable solutions (with much agreement via nodding in both cohorts) (S18-2, S18-9).

Student responses across both the 2017 and 2018 cohorts expressed their shift in appreciating the breadth of the practitioner role in city planning and engineering. For example, "*I think when we went to Hiroshima it made me realize that being an engineer is sort of being like a super power, in the size of the potential reaction and you* *have to decide what you stand for, what you want to create in this world, who you really are, sort of you are in a position to make whatever you want basically, and that's just remarkable*" (S17-7). Students pointed to improved understanding of phrases such as "*problem identification*" (S18-6), "*problem definition*" (S18-3) and "*assessing the severity to address the global sustainability*" (S17-1). For example, "*I realize that engineering isn't just another job, we actually play an important role in the direction society takes, in doing a job well or doing it badly has ramifications on the future of society*" (S17-5).

In the 2018 cohort, this was further augmented by students' referral to global applications of engineering practice that showed super conductor and the ability to transform the future energy. Several students indicated their shift in understanding regarding improved level of energy storage. For example, "when we were having a lecture about the power lines, it made me realize when they were talking about the almost global power grid, how engineering can be on the forefront of blurring the lines between countries so that each country isn't separated and self-sufficient… it makes the world look more globalized yeah…engineers may be able to do things politicians aren't able to, people like Donald Trump, if you have engineers making the infrastructure like global power grids it really opened my mind" (S17-8).

Some students struggled to understand the pedagogical approach and intended learning outcomes but were beginning to think beyond the conventional program deliverables of theories, equations and calculations, with conscious regard for the thinking process. For example, "*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 then 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)

4.2 Role of interdisciplinary teams (perspective)

All nineteen students in both cohorts mentioned their shift in appreciating the critical need for interdisciplinary teams collectively working solving problems, although there was limited reflection in what ways this could be possible. For example, "*it's amazing to see how even though environmental engineering and civil are different from each other we can work together in a team. That's been amazing. Actually, Australia has more to benefit and learn from Japan*" (S18-9).

Students of both cohorts also commented repeatedly on their newfound appreciation of links between disciplines like engineering, agriculture and geo-spatial technologies. For example, "*before coming here I kind of had an idea of what software engineers do, but I realize 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. 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*" (S17-10).

The majority of students in both cohorts were able to speak to the opportunity for them to apply best practices and technologies from Japan to other global contexts if it could be adapted to local conditions. For example, "*And I think there are examples of that here, done well and done poorly, and I think it's important globally to look at those examples, learn lessons and build upon that and not make the same mistakes again*" (S17-3). In particular students commented on their shift in understanding how much of Japan's story could be learned from, relating to innovation in technology, knowledge, and ambition and commitment (S17-6, S18-1, S18-6, S18-7). This extended to students commenting on Japanese companies aligning their practices with UN Sustainable Development Goals has inspired the students. For example, "*I now understand the need to learn of different ways of thinking and deciding in order achieve the planning competencies and have a better way of responding to the sustainable development goals. By understanding how Japan responds in the face of great uncertainty, I can now put this theory into practice and work towards succeeding in my field*." (S18-9).

5. Results - Surveys

In addition to the focus group discussion two surveys were used to evaluate the students' perceived satisfaction regarding the value of various components of the field trip, and the course as a whole. As student comments in the open-ended questions were anonymously provided, the quotes are given without direct reference to the individual student.

5.1 Evaluation of in-country lectures and field visits

In total there were 17 respondents, including 9 from 2018 (90 per cent response rate) and 8 respondents from 2017 (72 per cent response rate). Results are discussed in relation to feedback regarding students' satisfaction with the value of the nine in-country lectures, and with the 13 in-country field visits.

5.1.1 In-country lectures

The majority of students reported being satisfied or very satisfied about the lectures delivered during the field trip (Table 2). This was further supported by the open-ended question responses where students provided a number of specific examples on key lectures from the students' perspectives, described below.

Table 2: *Survey results - student satisfaction (Lectures)**

Lecture Description	Not at all	Unsatisfied	Neutral	Satisfied	Very satisfied	Respondents (out of total)
Welcome Speech	1	-	2	8	6	17/19
Introduction	2	-	1	9	5	17/19
Smart and resilient agriculture	1	-	3	5	8	17/19
Waste and Resource Recovery	1	2	5	7	2	17/19
Introduction of Smart Grid System	1	-	2	7	5	15/19
Transportation	2	-	2	5	2	11/19
Health GIS	1	-	2	6	7	16/19
Super Conductors: The future of energy	1	-	2	7	8	18/19
Coastal Cities Resilience	1	-	-	6	9	16/19

* Number of participants who selected that level of satisfaction. Note some students did not respond to some questions "N/a"

The use of multiple pedagogical techniques to offer a meaningful learning experience for students was appreciated through the student comments. For example, "*YouTube videos, simulations, paper handouts which made it feel varied, and when lecturers brought in hands-on stuff to interact with after the lecture (e.g. Prof Ito standards games, Prof Izutsu liquefaction demonstration using the beads & paper model, Prof Fukui UAV). It was also really helpful to have the physical/digital lecture slides afterwards to help us with the pebble pad reflections, save writing in the moment.*" The structure of the content was also commended, "*I think the range of topics covered was extensive and well structured. Especially with solar/nuclear energy being put together with the Hamaoka* *power plant visit, the standards lecture close to Eco conference etc. Topics in Digital Earth and the Agriculture IoT talk were particularly interesting to me as a software engineering student*". Some students highlighted few obstructions they faced during the lectures which include the clarity and language factors. For example, "*There were some slide that had not been translated to English which made it hard to concentrate and know what was going on*".

They also highlighted the shift in perspective during this immersive experience, "*Being immersed in another culture. Going to a Japanese university and getting lectures from Japanese professors on what they do and research. Meeting other students. Eating different foods and trying everything. Experiencing different events such as the Nabana no Sato or site visits such as the Hamaoka Nuclear Power Plant were very interesting and should be kept as a staple depending on the dynamic of the tour. Meeting other Griffith students who are working for companies in Japan was also insightful*."

5.1.2 In-Country field visits

The following figure shows the student satisfaction levels on the field visits made during the in-country intensive. In particular, students were very satisfied with the Toyota manufacturing facility, Hiroshima Peace museum, and the Scmaglev and Railway Park.

Table 3: *Survey results - student satisfaction (Field Visits)**

Field Visits	Not at all	Unsatisfied	Neutral	Satisfied	Very satisfied	Respondents (out of total)
Toyota Manufacturing Plant Tour	1	-	-	1	13	15/19
SCMAGLEV & Railway Park	-	-	2	4	6	12/19
Nagoya Port & Aquarium	-	-	4	5	6	15/19
Nagoya Castle	-	-	5	5	3	13/19
Hamaoka Nuclear Facility	1	2	2	5	5	15/19
Hiroshima Peace Museum	-	-	2	6	7	15/19
Miyajima Island Village and Gates	-	-	-	5	10	15/19
Kyoto (place of choice)	-	-	3	5	9	17/19
Kyobashi Station and Circular Garden	-	-	3	7	1	11/19
Trade Investment Queensland	-	-	2	5	8	15/19
Tokyo Tower	-	-	5	7	3	15/19
EcoProducts Exhibition (Tokyo Big Sight)	-	-	-	3	3	6/19
Shiodome City Centre (Tokyo Lendlease)	-	-	1	3	2	6/19

* Number of participants who selected that level of satisfaction. Some students did not respond to some items, indicated by N/a

While the majority of the student cohort was satisfied or very satisfied with the field trips there were number of students who commented on challenges with the experiences. One student reflected, "*that gave us good background cultural context & experience of engineering practice for all different types of engineering and how they relate together. Well placed with the lecture's topic-wise. Probably the range of areas and things we got to see and experience. Good mix of education and fun, the variety and getting access to some of them such as the*

Hamaoka Nuclear Power Plant is what really made some of them impressive and I think even the revisit value is quite high. I would like to go on them again".

Students reflected on their challenges in the open-ended responses as follows, "*For most of them the trouble was insufficient time, but I guess that's just more of a personal issue since I'm a slow guy. For instance, 1h at the Hiroshima peace park was way too little, you barely get to take anything in before you realise you have to go back out. The devastation is just intense, and you shouldn't rush that sort of thing. I almost feel as if it should be made to have just one field trip/site visit a day, two max, as squeezing them all in just takes away most of the individual experience of each and I really felt that was a shame for a lot of them*". Another student commented, "*One thing that was difficult was time. If we could have spent some more time at places would have been nice. Like Hiroshima it would have been nice if we could have spent more time looking at the area. Other than that, it was done well*".

5.2 Evaluation of course experience

In 2017 45.5 per cent of the student cohort responded to the survey while in 2018 this improved to 80 per cent of the student cohort responded to the survey. Results are presented in Table 4 for both cohorts and discussed below.

Table 4: *Survey results - student satisfaction (Field Visits) **

Survey Questions*	Cohort Year	SD (%)	D (%)	N (%)	A (%)	SA (%)	Respondents (out of total)
This course was well-organised	2017	-	-	20	40	40	5/10
	2018	-	-	-	50	50	8/9
The assessment was clear and fair	2017	-	-	-	40	60	5/10
	2018	-	-	50	12.5	37.5	8/9
I received helpful feedback on my assessment work	2017	-	-	-	-	100	5/10
	2018	-	-	12.5	12.5	75	8/9
This course engaged me in learning	2017	-	-	-	40	60	5/10
	2018	-	-	12.5	37.5	50	8/9
The teaching on this course was effective in helping me to learn	2017	-	-	-	-	100	5/10
	2018	-	-	-	37.5	62.5	8/9
Overall I am satisfied with the quality of this course	2017	-	-	-	60	40	5/10
	2018	-	-	-	25	75	8/9
Overall this course was effective in developing my ability to think globally and to consider issues from a variety of perspectives	2017	-	-	-	-	100	5/10
	2018	-	-	-	25	75	8/9

* SA Very Satisfied; A Satisfied; N Neutral; D Dissatisfied; DS Very dissatisfied

In 2017 40 per cent strongly agreed and 60 per cent agreed to the statement of "*Overall I am satisfied with the quality of the course*". In 2018 this improved to 75 per cent strongly agreeing and 25 per cent agreeing to the same statement.

In 2017 students added substantial comments that enabled insights on student engagement and the experience they gained through this course. This included for example one student reflecting, "*The experiential component was the best part- being able to observe and interact (by learning & questioning about) examples of engineering in Japan. The activities were spread across all disciplines of engineering and all really interesting and engaging.*

Site visits and lectures relating to other topics e.g. Toyota Factory opened up learning about things I wouldn't have learnt otherwise, and I can see how all the disciplines interact to solve main issues: resilience, sustainable infrastructure, energy, transport etc."

Students also highlighted areas they thought that could be improved. For example, another student reflected, "*Giving the students a better idea of what the trip includes and is about beforehand will definitely help. Itinerary and transport routes (how to get somewhere, where we're staying) will help give a better idea of the trip to students interested or looking into it. The more details early pre-trip information encompasses, the more likely the student can come to a comfortable decision in whether they want to go on the trip and take the course. Also, an intensive Japanese course would be helpful for those wishing to understand the language and not feel so alienated in a foreign country. Simple words/phrases and sentences can go a long way as well as possibly learning Hiragana and Katakana, Kanji would be too much. More importantly though I believe learning Japanese etiquette is more of a priority for those coming into Japan with no experience of the culture. Simple things like how the Japanese use escalators, line up for trains, greet each other, and so on. Also help to prepare for the culture shock, show students just how crammed train carriages can be and what to expect when everyone has to get in one. Communication is a big one and getting lost is a no, so letting everyone know which station everyone is stopping at and/or going will help get everyone on the same page in terms of travel*".

This comment from the 2017 student cohort was then addressed in 2018 by offering a Japanese cultural session before departure to teach students about basic etiquette and language used in Japan. In 2018 the students pointed out additional areas for improvement including clarity in assessment task and time management, "*the assessment task sheets did not provide enough/specific information in writing. The requirements were discussed verbally but they were not documented on the task sheets. Secondly time management was also highlighted as a challenge during the course, "better time management in Japan as sometimes we were late and missed doing things in Japan*".

6. Theoretical Mapping

This paper documents an initiative that began with the aim of finding alternative ways to embed the principles of the UNSDGs into engineering education. The hypothesis could be stated as: Exposing Australian engineering students to existing complex engineering solutions for sustainability challenges (in Japan) would "jolt" students into awareness of the need for system of systems approaches in engineering. The early sections of the paper describe the authors' rationale for pursuing this inquiry, the process followed and the results. In the implementation of this initiative, and subsequent reflection, several linked hypotheses – or assumptions – became apparent:

- The UNSDGs represent 'wicked' problems and their solutions are inherently complex.
- Disasters are chaotic and the limitations of known solutions are being increasingly identified.
- Engineering graduates may not be sufficiently trained in the identification and execution of complex problem solving at the level required for UNSDG implementation.
- Education design (how the content is delivered) plays an equally important role as the content in engineering courses.

- There is scope to enhance the design of engineering courses to facilitate the development of complex problem-solving skills in graduates.

The themes of complexity and chaos and their relationship to best practice, order and expertise led the authors to a more in-depth review of the Cynefin framework, first published in a seminal knowledge management paper by Snowden (1999).

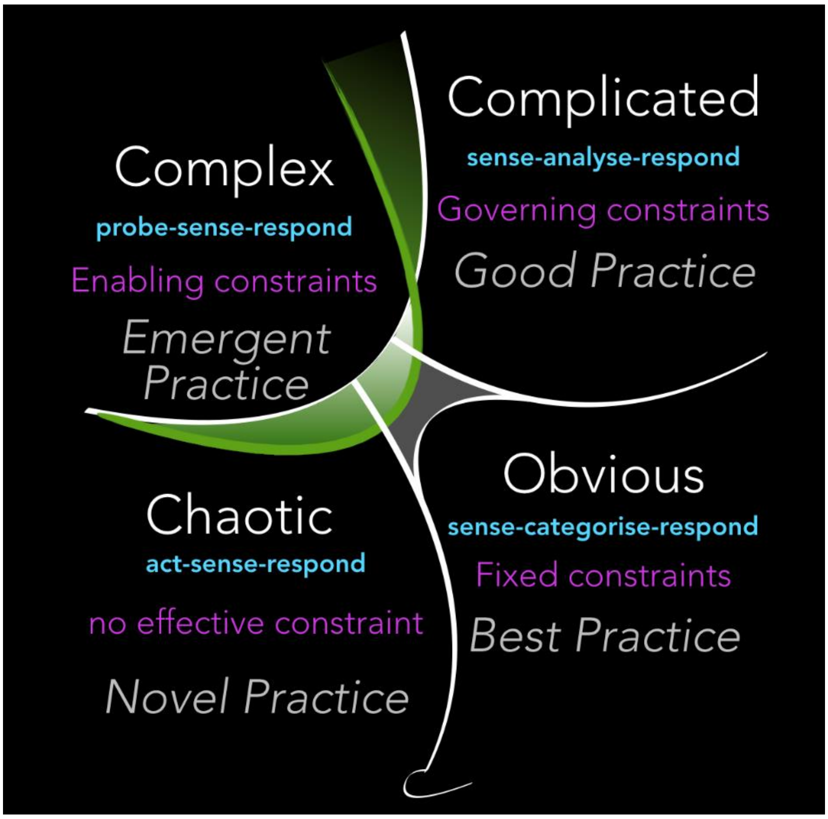

Figure 1. *Cynefin Framework (Source: Snowden, 2017)*

As shown in an updated liminal model of the Cynefin diagram, Snowden (2009; 2017) proposes that knowledge exists in four primary, related, domains: Obvious, Complicated, Complex, Chaotic. These are categorised according to availability of data and effectiveness of constraints in the organisation and application of the knowledge. Snowden argues that knowledge is either ordered or unordered, and when the relationship between cause and effect is known in the data, and constraints can be applied to influence this relationship, the degree to which this is true affects the rigour of systems thinking approaches that can be applied to successfully manage the context. "Very true" implies highly ordered, often practiced approaches, very untrue implies chaos, or highly unordered and no known approaches. Further, the role of "experts" or those who can advise on systems when one is not obvious, is limited to knowledge that is ordered and inherently known. Beyond this, the knowledge is yet to be ordered (unordered), and must be discovered using probes, or safe-to-fail experiments. Significantly, Snowden proposes that failure to correctly categorise the context in which one is working (or problem solving) is likely to result in dysfunction (or disorder).

6.1 Sense-Making Theory – dealing with Unorder

The first and second authors became aware of the Cynefin model early in this project, at the time the third author was working with this theory in a related engineering discipline. Having then viewed the project through the Cynefin lens (consciously and otherwise), the authors were expecting to find a direct correlation between Cynefin and their observations. Interestingly, this lens is what led to the later articulation of some previously "unconscious" hypotheses.

It is clear in Cynefin terms that the project itself was operating in the complex domain: the development of engineering courses specifically designed to teach students how to unpack and implement the SDGs within engineering solutions is emerging (Byrne et al., 2013). There is no existing best practice model, nor any specialist expert (solutions continue to require high levels of interdisciplinarity, which as the student feedback shows is not common practice or expectation for engineering graduates). The authors therefore began to probe more broadly into this challenge within the education literature, specifically seeking examples of action learning, behaviour change and complex problem solving. They first examined the course materials with a Cynefin lens, interested in understanding the proportion of course content that students were being exposed to unordered knowledge, either by experiencing knowledge in an unordered way, or by learning about the ways people in Japan had responded to situations that could be described as complex or chaotic. Table 5 presents a matrix of teaching intentions (shaded), documenting where students could identify the influence of one or more Cynefin quadrants in relation to the course modules. Several examples are provided below the table.

Lecture examples include:

- Smart agriculture: farmers in Japan collect data using remote sensor networks and satellites and share it on an open database, allowing them to make real time and informed decisions in the face of unprecedented weather conditions or natural disasters as well as optimise irrigation and fertilising systems. Technology is answering the questions, '*What day should I sow for an optimized yield', 'Where and when do I need water and fertilizer and how much', 'In the occurrence of this weather event when should I plant my crop and what is its probability of success*?'
- Disaster resilience: Subway stations are equipped with automatic flood gates to prevent water flooding the underground network and Shinkansen (high-speed trains) have an automatic stop feature which is activated after ground tremors are picked up by remote sensors and activate the automatic stopping of trains in the area. Supply services such as water, electricity and sewage are anchored to bedrock in disaster prone areas to reduce outages in the aftermath of a natural disaster. US$1 billion has been invested to equip residents and visitors with the knowledge to help themselves and others to survive an earthquake and resulting tsunami.

Table 5. *Coursework outline International Engineering Practice Source (Desha and Caldera, 2019)*

Timing	**Lecture/ Activity**	**Cynefin Quadrant of Consideration**			
		Simple	**Complicated**	**Complex**	**Chaotic**
Week 1-3	Japanese Cultural and Language Immersion				
Week 3	*Assessment: Carbon Offset Report*				
Week 4-5	*In-Country Experience*				
- Day 1	Evening Networking Function (Chubu)				
- Day 2	**Toyota Manufacturing Plant Tour**				
- Day 3	Nagoya local tour				
- Day 4	Smart and resilient agriculture (Chubu)				
	Waste and Resource Recovery (Chubu)				
	English Cultural Session (Chubu)				
- 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				
- Day 8	Kyoto temples and built environment touring				
- Day 9	Introduction of Smart Grid System on Campus				
	Transportation in Japan (Chubu)				
	Health GIS in Japan (Chubu)				
	Super Conductors: The future of energy (Chubu)				
- Day 10	Coastal Cities Resilience				
- Day 11	Kyobashi Station and Circular Garden				
	Trade Investment Queensland				
	Tokyo Tower				
- Day 12	Miraikan Science Museum				
Week 7	*Assessment: Video Reflection*				
Week 11	*Assessment: Essay (Online submission)*				

Field trip examples include:

- Toyota Factory was highlighted as one of the richest learning experiences of the study tour. The company is a world leader in lean and green manufacturing or using a systematic and continuous approach to eliminate waste from the system and improve operational performance. Toyota isn't working to only reduce physical waste but also wasted time, energy and resources, while also focusing on how its employees work. There is adjusted work environments and rolling work stations, focused on the comfort and improved productivity of the technician, situating everything in the right place to allow the employee to work more efficiently. Employees are also encouraged to contribute to the improvement of work stations and the flow of work, with daily meetings held on the factory floor, encouraging employees to raise concerns or suggestions to improve the process.

- The Hamaoka nuclear power plant showed an incomparable level of proactiveness with over seven countermeasures. This was influenced by a past traumatic event, the Fukushima accident, which enforced them to prepare for the worst circumstances.
- The 'Shinkansen' or bullet train is inspired by nature, where its aerodynamic shape is modelled on patterns observed in nature to reduce friction and sound losses. The modern Shinkansen also operates with an auto braking feature, which activates braking and demobilizes acceleration when two Shinkansen's are detected to be within a certain distance of each other, before the driver would be aware. Japan Rail's latest project is the MAGLEV, a Shinkansen which runs on superconducting magnetic levitation technology, which has been in development since 1962 and is planned to be in operation by 2027, featuring a top speed of 505km/h.
- This exercise confirmed the authors' emerging belief that the course design was contributing to the preference for ordered thinking in engineering design. To test the validity of this theory, the authors next reviewed the literature on learning theory and considered the thematic development of theoretical approaches to professional education. This exercise highlighted a subsequent challenge as discussed in the following section.

6.2 Learning and Teaching Theory ('How')

Knowing what to apply (what principles and insights), how to integrate the critical knowledge and skills arising from sense-making and behaviour change theories, and when within the engineering curriculum is central to educational practice. Caldera et al (2019) discuss this opportunity within a conference paper presented to the Australasian Association of Engineering Education (AAEE) conference (Brisbane, 2019), on "*Biggs + ACAD = ?" Documenting an international pilot to address the 'Time Lag Dilemma' in education for sustainable development*". Reflecting on the last two decades of key literature on engineering education and behavioural sciences it is evident that there is a wide range of perspectives across engineering disciplines regarding what sustainability is and what urgent need for engineers to be skills with relevant competencies (Desha, 2013; C. Desha, Hargroves, Dawes, & Hargreaves, 2013). The first author has previously written that resource management, digital technology, values, ethics, transdiscplinarity and systems-and-complex thinking are critical competencies for 21st century engineers if the UNSDGs are to be implemented (Byrne et al., 2013).

There are a number of researchers exploring the realm of behaviour change which can readily be considered within the context of professional practice – and in this case within the context of engineering practice. Behaviour change occurs as a result of many factors converging to support the development of knowledge and skills; shaping and strengthening habits in accordance with "how, when and where it was learned". These ideas of building on prior knowledge, embedding new knowledge into practice, authentic problem solving, impact of knowledge sequencing, and metacognition are central to constructivist learning theory (Kolb, 1984; Krathwohl & Anderson, 2009; Merrill, 2002; Mezirow, 1981; Thorndike, 1927)

The challenge appears to be applying these theoretical foundations in the context of university education, where the time-lag dilemma for engineering education is well known (Desha, 2013). The first author has also written extensively on the challenges for designing curriculum to support the development of graduate skills relevant to solving climate change and sustainable development, looking at strategies including peer learning, fostering interdisciplinary networks, intensive experiences and study tours (complementary 'flagship' activities), information portals, and multidisciplinary projects.

6.3 Behaviour Change ('Why' and 'Who')

The experience of designing, delivering and evaluating this course has pushed the boundaries of rapid transformation curriculum renewal in terms of the expectations placed on both students and educators of sustainable engineering theory. A paper like this offers the opportunity to stand on the outside and critique the development of thought processes and responses in students, and also the degree to which the teaching embodies those very concepts – "do as I do". As highlighted in the introduction to this paper, the authors have focussed strongly on a range of ideas relevant to thinking differently about hard (wicked, complex) problems, including:

- Problem-solving strategy: Think Small (Gallagher, 2017)
- Prompting behaviour change: Nudge (Thaler & Sunstein, 2009)
- Dealing with risk: Black Box Thinking (Syed, 2015)
- Bigger Picture: Seeing what others don't (Klein, 2013)
- Knowing when to look up, and when to copy patterns: Thinking, Fast and Slow (Kahneman, 2011)
- Knowing when to lead autonomously and when to lead from the front: The Starfish and the Spider (Brafman & Beckstrom, 2006)

Very relevant to behaviour change is Kubler-Ross' stages of grief and dying which has been adopted by the management community as the "Change Curve". The first stages, denial and anger, can often be observed in the unlearning (Becker, 2007) process. Macdonald, Burke, and Stewart (2018) describe the shift from unconscious incompetence to conscious incompetence as dissonance "the point at which one recognises that their perception of reality and reality itself cannot be reconciled until they change behaviour". Gartner have also modelled Kubler-Ross' theory in their hype cycle, ascribing the values to technology waves and consumer acceptance (Hype Cycle Research Methodology, n.d.). This cycle of reaction to acceptance is visible in national approaches to climate change, peaks and troughs in popularity, periodic proliferation of related commercial activities, and the wholesale adoption of UNSDGs globally.

With reference to the World Engineers Convention paper by the same authors, on "*Foundations and Horizons: The Critical Role of International Coursework to Engage Students in Engineering for the 21st Century*" (Desha & Caldera et al., 2019), we find a useful point of reference for colleagues attempting to move beyond rhetoric and awareness, to develop engineering graduates who can deliver sustainable solutions towards the fulfilment of the UN SDGs.

A significant implication for urgent attention is that professional education psychologically anchors students in the domain of the expert – *Complicated* in Cynefin terms. When students experience contexts as the 'new and novel', without appreciating the Complex and Chaotic, there is potential for loss of identity and sense of belonging in the profession leading to shut-down on the further development of self (Maslow, 1943), and at the very least a dissonance trigger. If not well managed in the learning process, students (and later professionals) are apt to discard any knowledge further reinforcing this dissonance. Education programs that aim to prepare graduates for unexpected, unordered contexts – which the UNSDGs ask of engineers – must go sufficiently beyond declarative knowledge (Bloom, 1956), and recognition-primed decision making (Klein, 2013). This means going beyond exposing them to novel circumstances frequently such that that they might reproduce outcomes, to ensuring they are comfortable with uncertainty and lack of data. Further, *it requires reinforcing that such unorder is not a negative reflection on their professional capacity but a symptom of the ever-increasing complexity of our world, and the changing role of engineers and other professions in responding to it collectively*. The third author has previously written about the disruptive nature of this type of change in embedded education practice, arguing that it requires careful planning to ensure success (Hutchinson, 2013).

Students were particularly alert to the potential for conflict emerging from wicked problem solving. "*Without having the ability to resolve conflicts within any discipline, a simple situation could become a complicated one if it's not handled appropriately, as demonstrated in the Cynefin framework. Wide scale problem solving abilities within the transport sector require a multi-discipline approach across public, active and private model*" (S18-8).

The authors' conclusion is that development of complex decision-making capacity in undergraduate engineering students involves overlapping a number of theories as summarised in Table 6. This spans the theories of "how we learn" – sequencing and stages, learner maturity, structural rigour (Argyris, 1977; Becker, 2007; Bloom, 1956; Delahaye, 2004; Gagné, 1965; Kolb, 1984; Krathwohl & Anderson, 2009; Merrill, 2002; Snowden, 2000; Thorndike, 1927) "how we organise and apply what we have learnt" – knowledge (Kahneman, 2011; Klein, 2013; Snowden, 2000) and "how we manage our emotional/human responses to unexpected knowledge gaps and change" (Geels, 2011; Kotter, 2012; Macdonald et al., 2018; Maslow, 1943; Taleb, 2012).

Table 6: *A summary of developments in ontology and the impacts for teaching UNSDGs*

Developments (Key resaercher/s)	Emergence	Ontology	Impacts for teaching UNSDGs
Laws of Learning (Thorndike)	~1932 published in stages	Behaviourist theory	Adult learners bring experiences and perspectives to learning. These greatly influence how they process and construct knowledge. Different types of knowledge manifest in different processing skills (eg recall, discrimination, understanding concepts, applying rules, solving problems). Experiences and authentic (real life) problems provide efficient mechanisms for exposing adult learners to new concepts, developing deeper skills and metacognitive process and relating new knowledge to old. Denial and resistance are common reactions to new knowledge that acts in conflict with old knowledge. Experiences that include metacognitive processes (eg reflective journals) provide opportunities for the learner to construct new meaning and mental models. Relating UNSDGs and implementation approaches to undergraduate students in first world environments helps to minimise some of the conflict arising from authenticy ("relevance of this to me").
Hierarchy of Needs (Maslow)	1943	Psychological health	
Types of Knowledge (Bloom, Killen, Anderson and Krathwohl)	Developed as behaviorist theory by Bloom in 1950s, extended by Anderson and Krathwohl to cognition (2001) then by Killen to divergent thinking (2005)	Behaviourist theory Cognitive theory - knowledge Learning theory – instructional design	
Nine Events of Instruction (Gagne)	Developed in a military setting in 1962 and extended in 1987	Learning theory - Instructional design Workforce development	
Adult Learning Theory – Andragogy (Knowles)	Andragogy was first coined in 1833 by Kapp and developed by several authors before Knowles argued adults learn differently from children in1968	Adult Education theory Adult psychology Workforce development Experiential learning theory	
Stages of Grief (Kubler Ross)	1969, extended to change management, then Bridges published Managing Transitions in 1991. It is unclear who first brought Kubler Ross to change management.	Psychology theory – Grief and loss, Change management, Organisational Psychology, Leadership Cognitive theory - Reframing	
Double Loop Learning Theory (Argyris, Schon)	1974	Behavioural theory Cognitive theory – Experiential learning Organisational psychology	
Transformative learning (Mezirow)	1981	Cognitive theory – perspective	
Stages of Learning, Experiential Learning (Kolb, Delahaye et al)	First published by Kolb in 1984 and extended by Delahaye et al 1994	Cognitive theory – Experiential learning Andragogy/adult learning theory	In the 1980's education generally, and especially professional education, became more aligned with business needs to automate. Emergent theorists focussed on management systems to support these aims, and were less learner centric. This period delivered signifcant thinking on the interplay between systems engineering and management – how systems thinking, when applied to human captial, can reduce waste and improve performance, consistency and predictability. Out of this came deeper understanding about problem solving contexts (Cynefin), automatic reponses to problems
Recognition Primed Decision Making (Klein)	1993	Behavioural theory Cognitive theory – mental models Experiential learning theory	
Eight Stages of Change (Kotter)	1996	Leadership theory – Change management Organisational psychology	
Sensemaking, Cynefin (Snowden)	1999 with the liminal phase added in 2018	Systems theory – Complexity Cognitive theory – knowledge	
Five Principles of Instruction (for adult learners) (Merrill)	2001	Adult learning theory	
Unlearning (Becker)	2007	Cognitive theory - Experiential learning Behavioural theory – change Adult learning theory	

Developments (Key resaercher/s)	Emergence	Ontology	Impacts for teaching UNSDGs
Systems Leadership (McDonald et al)	2006	Complexity theory - Systems thinking Behavioural theory Organisational psychology	(based on experience) and working effectively with dissonance and resistance to learning. The relationship between systems (processes and procedures) and behaivor were laso under the spotlight.
Antifragility, Black Swan (Taleb)	2007 (Snowden and Taleb are currenlty engaged in Marx/Engels type conflict)	Systems theory – Complexity Cognitive theory – distortion, error	Simultaneous catastrophes in the western world (GFC, 9/11 etc) saw the concept of failure and how to treat it both in a risk management sense and a learning tool gain popularity in the early 2000's. The relationship between experience and systems were looked at closely. The emergent educational need was to prepare for the unknown and leverage small failures to devise solutions to wicked problems. This development highlights the need to change how we view the dynamics of professionalism, limitations of knoweldge and multidisciplinarity in the context of solving wicked problems. Students learning about UNSDGs must practice this way of working. Learning needs to include unsolvable or very difficult problems, where the assessment is focussed on the interpersonal skills and creative melding of divergent bodies of knowledge as well as the application of core course content.
Memory and experience (Kahneman)	2011	Cognitive theory – experiential learning Systems theory – Complexity	
Multi-level perspectives (Geels)	2011	Innovation theory Behavioural theory – change, cognitive dissonance	
Black Box Thinking (Syed)	2013	Cognitive theory – distortion, error	

The course employed a range of these strategies to create the conditions for behaviour evaluation in the students. Importantly, the authors note that reflection, review and metacognition are repeated themes in the literature in the context of bringing awareness to changed behaviour. The use of various reflective learning strategies during the course highlights this.

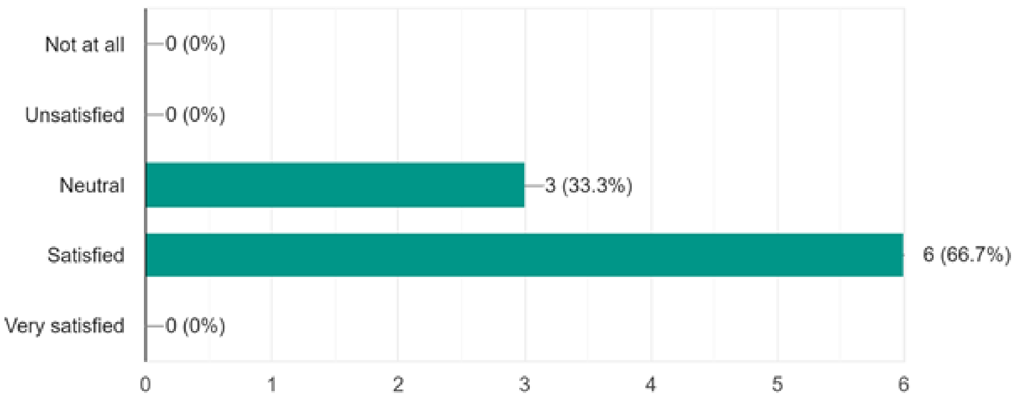

Figure 2. *An example of student satisfaction regarding the mind mapping exercise*

For example, to consolidate student perspectives, mind mapping exercises were adopted and feedback about their mind mapping experience was also gained through the survey. This tool demonstrated that the brain works by beginning with a central focal point and working outward in a random yet organized fashion. Mind mapping engages and focuses on using visuals along with the traditional verbiage from lectures and tests. Figure 2 shows that the majority of students were satisfied with the mind mapping exercise.

Figure 3. *An example of a consolidated mind map from the field trip*

Overall, students reported the value of these reflections toward their improved understanding of the need for multidisciplinary and novel approaches to embedding the UNSDGs in engineering practice. The students stated key benefits of mind mapping, such as "*everyone working together and hearing different opinion,*" "*drawing out knowledge and memories of the trip*," "*effective way to facilitate group discussion about complex topics*," and as "*a helpful tool in comprehending the whole scope of Japan and this trip*". "*Processing the information shown from the growing innovation and infrastructure in Japan, I was able to establish a connection between the UNSDGs, EA competencies and the complex innovation and infrastructure in Japan*" (S18-8, S18-9).

7. Conclusions

This paper has documented an ethnographic study into the use of an international intensive course on International Engineering Practice, including the analysis of data from two experiences of implementation, in 2017 and 2018 (Nagoya, Japan). The paper has explored the value of the course with respect to shifting student appreciation of context and shifting perspective towards re-engineering social and technical systems structures for thriving in the 21st Century. Several aspects of the course have been discussed in relation to the key intentions for shifting behaviour, including learning about advanced technologies, innovative processes, promotion of sustainable practices and the strong resilience demonstrated by the Japanese culture.

The skill-sets required to deal with future unknown problems are well-known, including interdisciplinarity. The challenge is maintaining disciplinary expertise while enabling team-play with a specialisation. This involves thinking less of self as the only expert in a problem-solving context, and more about recognising the futility of some disciplinary knowledge in certain contexts (i.e. this won't work here) - and replacing it with other expertise, or 'starting from scratch'. Inspiring the ability of graduating students to say, "*I learned how to do something once - I can do this again when needed*". Students are shifting in their self-awareness of the context for engineering challenges, and their perspectives for improving practices and outcomes for society.

The authors have documented an historical evolution of thinking about decision-making, with Cynefin concluded to be a useful tool for sense-making in relation to documenting coursework learning (see Table 6). Considering the experience through the lens of the Cynefin framework, it is concluded that the course is making progress in enabling undergraduates to develop practical skills to take challenges faced in the engineering discipline and create opportunities for the future. For the authors, the question herein concerns enabling more of the student cohort to develop a factfulness mindset that enables better decision-making. It was evident that this experience has enabled to broaden their horizons on international engineering practice and shift their perspective in role of engineering, importance of interdisciplinary teams, and resilient infrastructure. However future scholarship will need consider how these learnings from an international experience can be translated into a local or virtual experience that is more accessible for more students.

The findings of this paper have implications for entities accrediting undergraduate programs in universities, providing rationale for embedding context and perspective in the degree - as a motivational benefit and as a potential opportunity for transforming practice towards embracing complexity, failure and viewpoints of other culture. They provide a relevant and useful point of reference for colleagues attempting to move beyond rhetoric and awareness, to develop engineering graduates who can problem-solve towards delivering sustainable solutions. There are immediate implications for recruitment and retention strategies in developing tangible career-context and commitment to study from first year.

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