ISBN number for CSE 2021 is: 978-1-925627-55-8

Integrating Sustainability into Higher Education Curricula

Rajabifard, A.[1], Lumantarna, E.[1], Herath, N.[1], Hui, F.K.P.[1], Currie, G.[1], Kahalimoghadam, M.[1]

Department of Infrastructure Engineering, The University of Melbourne, Parkville, 3010, Australia

Corresponding author: elu@unimelb.edu.au

ABSTRACT

Education has been widely recognised as a key instrument to achieve sustainability. Integrating sustainability knowledge, skills and values are considered paramount to enable individuals to contribute to sustainable development. The paper presents a pilot study conducted at the University of Melbourne to investigate the links between the subjects offered by the University and sustainability. The pilot study is a part of the Sustainability in the Curriculum program, which addresses the Sustainability Plan Teaching and Learning Target 1, aimed to incorporate sustainability knowledge and values in the University's curricula.

The 17 Sustainability Development Goals have been used as a framework to measure how well the curricula are linked to sustainability. A study first undertaken to establish the link between subjects and the Sustainability Development Goals is presented. The study involved data collection through published literature on Sustainable Development Goals and the University's subject handbook, followed by a survey involving the subject coordinators. The findings of the study show that the strength of linkages between subjects with sustainability varies, highlighting the challenge in some technical subjects in linking their contents with sustainability. Approaches adopted in the Faculty of Engineering and Information Technology in embedding sustainability in the curriculum are presented with some examples and discussions for the next steps.

INTRODUCTION

The United Nations World Commission provides the most quoted definition of sustainable development in the 1987 Bruntland Commission Report (Brundlant 1987) as a "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". The 1987 Bruntland report has recognised sustainability as a global challenge that encompasses four dimensions, society, environment, culture and economy, that are intertwined and cannot be treated in isolation one from another.

To address the global challenge, the UN General Assembly adopted the 2030 Agenda for Sustainable Development. This agenda includes a global framework centred around 17 Sustainable Development

Goals (SDGs). The SDGs address social needs such as food, education, health and wellbeing and employment opportunities while tackling environmental issues and climate change (United Nations Economic and Social Council 2016). In order to achieve the goals, everyone needs to contribute, including governments, private sectors, universities, and all individuals across the world. Education has been recognised to play a central role in achieving the SDGs (Rieckman 2017). It has been explicitly addressed by SDG 4 "ensuring inclusive and equitable quality education and promoting lifelong learning opportunities for all" (United Nations DESA 2016). Clearly, universities have a vital role in addressing the global challenges and achieving the SDGs through their teaching, research and operation.

This paper presents interim findings of a study conducted at the University of Melbourne to establish the extent of sustainability knowledge embedded in the University's curricula using the UN SDGs to measure how the subjects are linked with sustainability. The UN SDGs were selected as a measure in view of the UN 2030 Agenda to achieve the SDGs target by 2030. Embedding sustainable learning principles provide opportunities for young people to learn and practise critical, holistic and systemic thinking and apply it to real-life situations, enhance lifelong learning, responsible decision-making and professional practice (Guerra 2017). Addressing the SDGs in education will equip graduates with knowledge and skills that make them capable of making environmentally and socially responsible decisions in their professional practice and contribute in achieving the SDGs.

There has been a vast amount of literature on the teaching of sustainability in tertiary education, especially on how sustainability knowledge have been embedded into specific courses at universities (e.g., Peet et al. 2004; Boks and Diehl 2006; Palacin-Silva et al. 2018) and on the appropriate teaching pedagogies for the teaching of sustainability (e.g., Guerra 2017; Leal Filho et al. 2016). However, there are limited studies on how well subjects within the universities' curricula address sustainability knowledge. To the best of the authors' knowledge, no studies currently use the SDGs to measure how sustainability is embedded in the curricula.

The paper presents a pilot study at the University of Melbourne to evaluate the extent to which sustainability knowledge is embedded within its curricula. The pilot study is a part of a university-wide initiative at the University of Melbourne "the Sustainability in the Curriculum program", aimed to embed sustainability knowledge and values in all University's curricula. Data collection is presented with the interim findings and discussion of our progress and future works.

MAPPING OF THE SUBJECTS AGAINST THE SDGS

The data collection involves a desktop review of published data on the 17 Sustainable Develop Goals and the University of Melbourne's subject handbook. Two key resources on the UN SDGs, the Inter-Agency and Expert Group on Sustainable Development Goal Indicators (United Nations Economic and Social Council 2017) and The 2030 Agenda for Sustainable Development (United Nations DESA 2016), were reviewed, and the targets and indicators for each SDG were extracted. The information on the subjects' content and intended learning outcomes were obtained from the University's subject handbook (https://handbook.unimelb.edu.au/search). In this pilot project, data was collected for six schools at the University of Melbourne, School of Computing and Information Systems (CIS), School of Electrical, Mechanical and Infrastructure Engineering (EMI), School of Chemical and Biomedical Engineering (CBS), Melbourne Law School (MLS), Melbourne School of Design (MSD), and Faculty of Science (SCI). These schools have a total of 15 departments offering 162 majors and 2157 subjects.

The data were analysed using a qualitative approach. The framework analysis method was used to define the linkages between the subjects' content (and intended learning outcomes) and the targets and indicators of the SDGs. The framework analysis method identifies similarities and differences between qualitative data, and based on the identified similarities and differences, determine linkages between two sets of data (Gale et al. 2013). The method involves coding keywords and phrases extracted from targets and indicators for the SDG. The coding summarises the broad range of words and phrases to a limited number of words representing specific concepts. The codes were compared and matched with those extracted from the subjects' content and intended learning outcomes to establish the link between the SDGs and the subjects. The method is shown in Figures 1 to 4 for an example subject Water Sensitive Urban Design. The keywords and phrases extracted from SDG 6 are presented in Figure 1 in bold (e.g., "access to safe and affordable drinking and water). Figure 2

presents a part of the intended learning outcomes of the subject with the extracted phrases highlighted in bold. Figure 3 presents the keywords and phrases from the SDG mapped with those of the subject. The process was repeated for other SDGs to establish if there are linkages between the SDGs and the subject. The result for subject Water Sensitive Urban Design is presented in Figure 4, showing a link with SDGs 6, 11, 13, 14, 15.

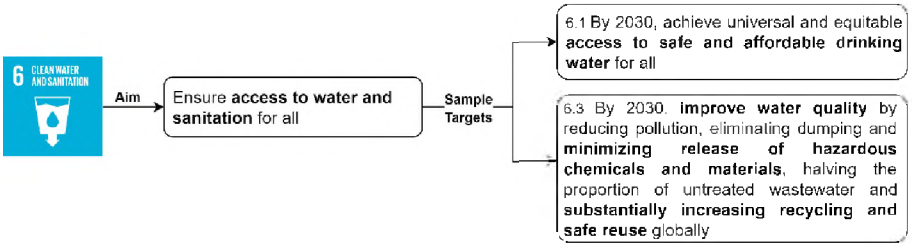


Figure 1. Keywords and phrases for SDG 6 (shown in bold).

Intended learning outcomes

To give students expertise in the concepts and techniques of **water sensitive urban design** (WSUD) and to allow them to apply these techniques to integrate **the management of water into the urban landscape**. The subject thus aims to benefit students across a broad range of disciplines, including **environmental science, landscape architecture, architecture, urban planning, geography, urban horticulture, forest science and ecology**.

On successful completion of this subject, students should be able to understand and analyse water in the urban landscape and the various components of the **urban water cycle**, including their interactions.

Figure 2. Parts of a sample subject's (EVCS90025 Water Sensitive Urban Design) intended learning outcome, with keywords and phrases related to SDG 6 highlighted in bold.

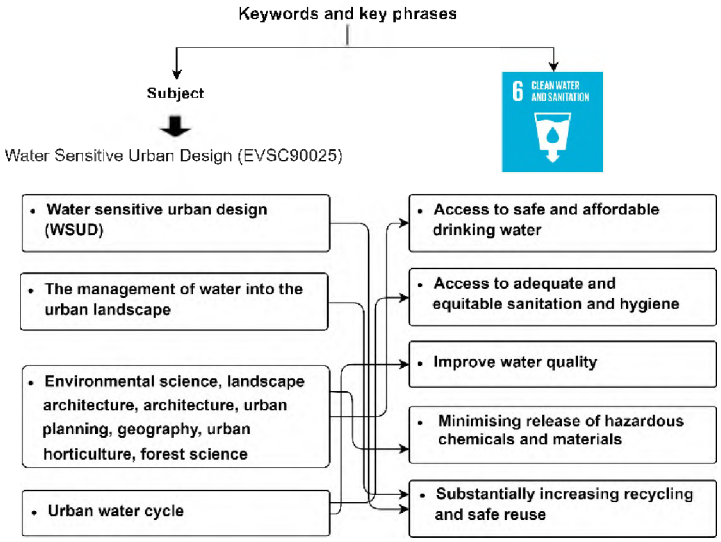


Figure 3. Defining the connections between SDGs' and a sample subject (EVCS90025).

Figure 4. Mapping of a sample subject EVCS90025 with SDGs based on the method.

The analyses were performed on the 2157 subjects offered by the six Schools at the University of Melbourne. Results from the analyses are presented in Figure 5 illustrating the number of subjects against the SDGs in a radial plot. The numbers of subjects linked to the SDGs, presented in terms of the percentage of a total number of subjects offered by the Schools, are presented in Figure 6. Perhaps expectedly, it was found that a subject can be linked to more than one SDGs. However, not all subjects are linked to SDGs. Some schools can have more subjects linked with SDGs, such as School of Mechanical, Electrical and Infrastructure Engineering and Faculty of Science. The stronger link can be caused the Schools offering a wide range of majors directly relevant to sustainability, for example, energy specialisation in Master of Civil Engineering, Environmental Science major in Bachelor of Science. However, it should be noted that the links between the subjects and the SDGs can only be identified if the subjects' contents and intended learning outcomes have words and phrases that have links to the SDGs. This approach may pose difficulties in identifying the links between theoretical and technical subjects and sustainability. The links between subjects and SDGs can also exist through examples, practice questions and assessments demonstrating the application of the theoretical knowledge, which may not necessarily be reflected in the subjects' content.

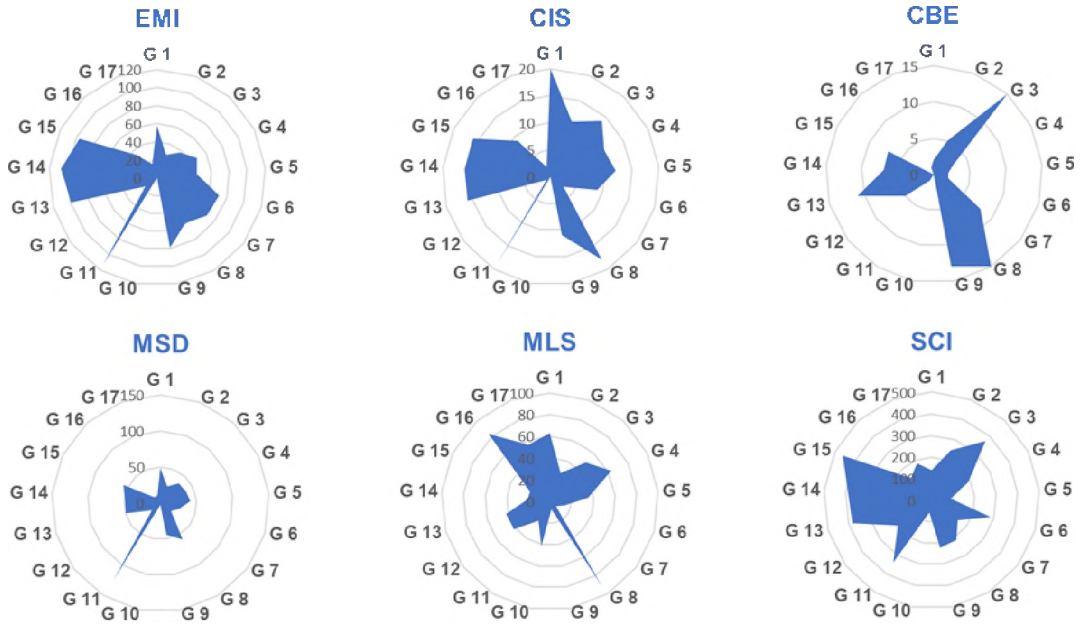
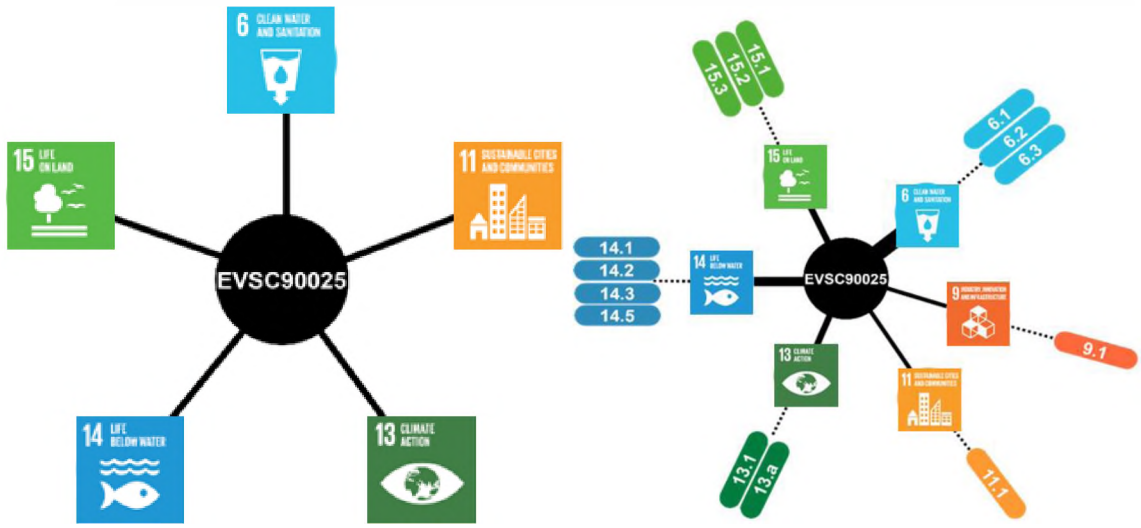


Figure 5. Number of subjects taught in the six schools that are connected to the 17 SDGs, CIS - School of Computing and Information Systems, EMI - School of Electrical, Mechanical and Infrastructure Engineering, CBS - School of Chemical and Biomedical Engineering, MLS - Melbourne Law School, MSD - Melbourne School of Design, SCI - Faculty of Science.

Figure 6. Percentage of the subjects that are connected to at least one of the 17 SDGs.

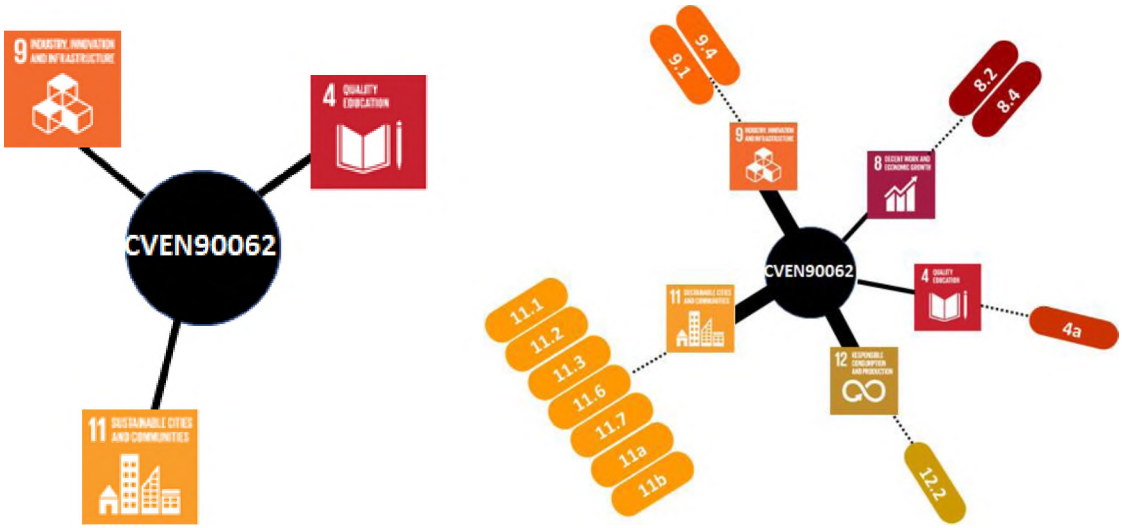
VALIDATION THROUGH SURVEY OF THE SUBJECT COORDINATORS

To validate the results of the mapping, a survey involving the subject coordinators was conducted. The survey is currently in progress, and this section describes the process and presents examples of results. The subject coordinators were invited to complete a questionnaire to confirm the links between their subjects and the SDGs' targets that have been identified in the mapping process. The subject coordinators were also asked to indicate the linkage strength by rating between 1 to 3, where 1 indicates the subject being weakly linked to the SDG and 3 indicates the subject being strongly linked to the SDG. An example of the survey with its response can be found in the Appendix. Examples of the survey results are shown in Figures 7b and 8b. The results from the mapping process described in the previous section are presented as a comparison in Figures 7a and 8a. It is shown that the survey allows for richer data to be obtained, including the link to SDG targets and the linkage strength. The subject coordinators were also asked to identify specific targets and indicators covered by the subject (Figures 7b and 8b). Importantly, the survey has also identified a new link between the subjects and SDGs, as demonstrated in Figure 8. The additional link could be as a result of the subject coordinator linking the application of theories covered in the subject with the SDGs.



(a) Results of the mapping process (b) results of the survey questionnaire

Figure 7. Link between a sample subject EVCS90025 and the SDGs.



(a) Results of the mapping process (b) results of the survey questionnaire

Figure 8. Link between a sample subject CVEN90062 Building Information Modelling and the SDGs.

VISUALISATION USING DIGITAL TWIN

A plugin has been developed and added to the digital twin of the University of Melbourne Parkville campus (https://uom.digitwin.com.au/). Digital twin is a digital representation of a physical object or system that is updated using real-time data. The digital twin representation provides a visualisation tool on how the Schools in the University of Melbourne cover sustainability within their subjects. The digital twin visualisation can aid in decision making in subjects development and teaching and learning activities on sustainability.

The plugin was designed to visualise the embedding of sustainability in the subjects in two ways. The users can visualise the SDGs and the primary goal covered by a specific school, as shown in Figure 9. The primary goal in the figure represents the SDG covered by the largest number of subjects in the School. Figure 9 shows the SDGs covered by the subjects offered by the School of Electrical, Mechanical and Infrastructure Engineering. Alternatively, the users can also visualise the Schools that covers a specific SDG in their subjects. An example is shown in Figure 10, presenting the Schools that cover SDG 11.

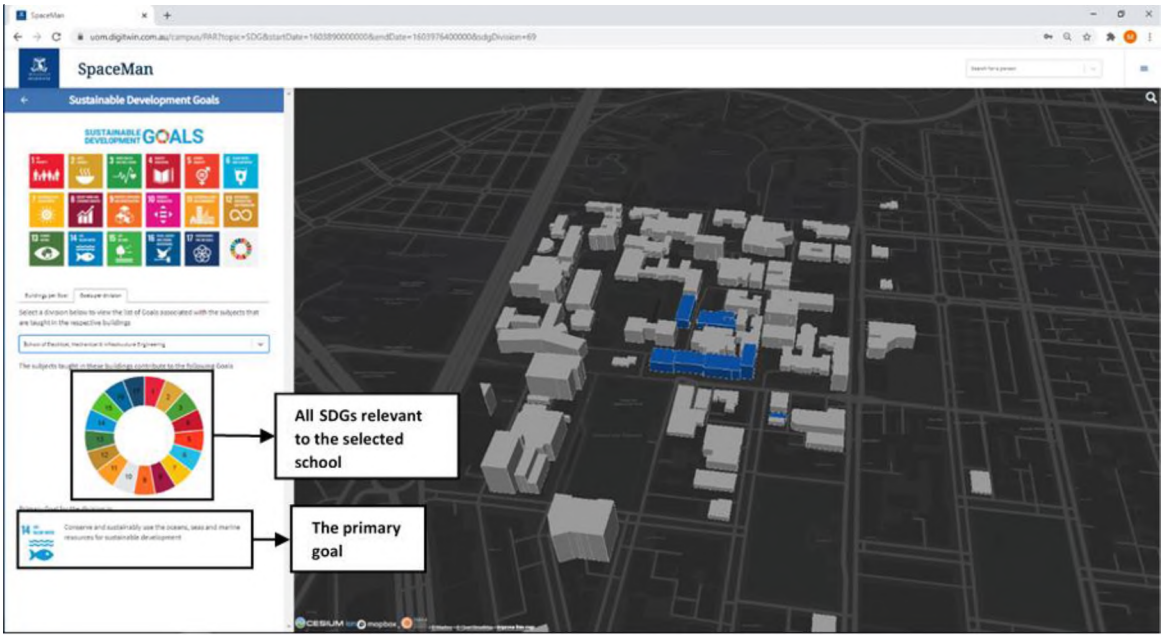


Figure 9. Digital twin of the University of Melbourne Parkville campus showing the SDGs covered by the School of Electrical, Mechanical and Infrastructure Engineering.

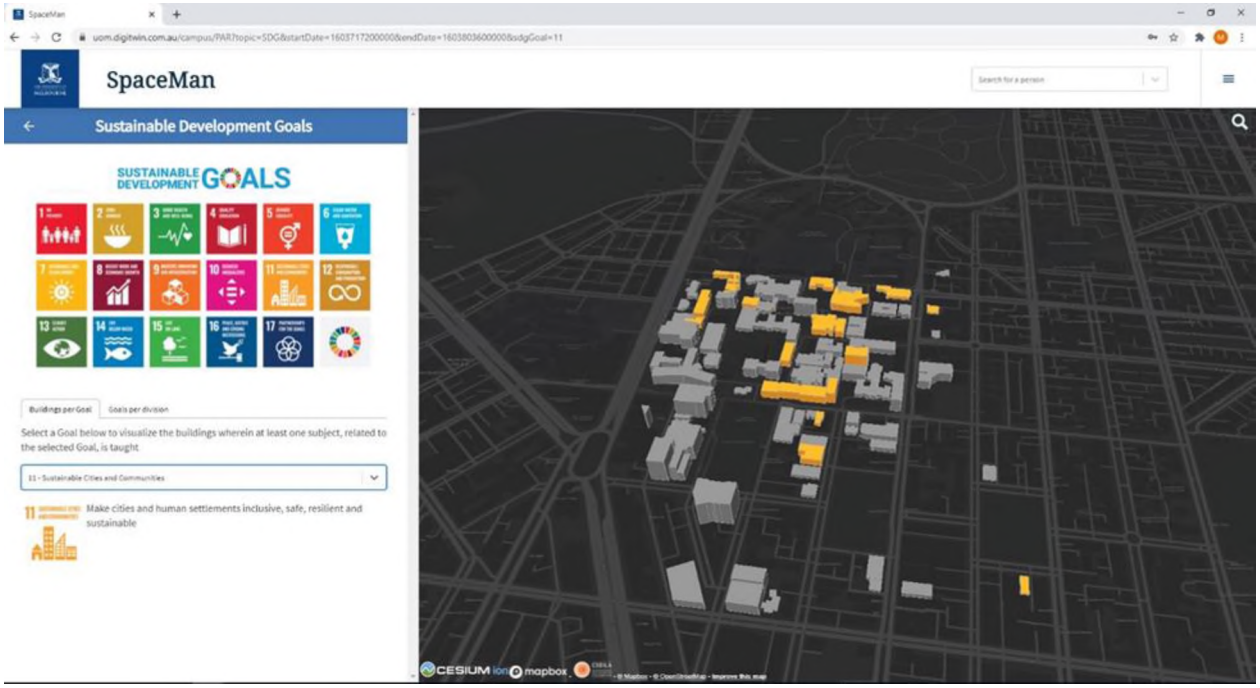


Figure 10. The Digital Twin of the University of Melbourne Parkville campus showing the Schools covering SDG 11 (in yellow).

It should be noted that the visualisation is currently based on outcomes of the mapping process, hence based on unvalidated data. However, the digital twin platform allows for new data to be simultaneously included as they are validated. The platform also provides a foundation for visualisation of future work, such as the number of subjects linked into a certain SDG, students' enrollment in the subjects, research (and researchers) related to the SDGs in each School, and sustainability in policy, operation, and engagement in each School.

EMBEDDING SUSTAINBILITY IN SUBJECTS: EXAMPLES AND NEXT STEPS

The mapping of the SDGs and validation through a survey questionnaire provide an understanding of the links between the subjects and SDGs. The next step of the process is to broaden the coverage of the SDGs in more subjects and strengthen the links. The process is currently ongoing, and this section presents the current progress of the Department of Infrastructure Engineering, a department in the School of Electrical, Mechanical and Infrastructure Engineering, in embedding sustainability in their subjects.

The Department follows the approaches reported in the literature (Peet et al. 2004; Kamp 2006; Lozano and Young 2013): designing an elementary course on sustainability and intertwining sustainability concepts in regular disciplinary courses. The description of the elementary course and a few examples are presented herein.

Elementary course on sustainability

The "CVEN90043 Sustainable Infrastructure Engineering" is a one-semester long subject that attracts 200-300 Masters students from across the Faculty of Engineering and Information Technology at the University of Melbourne. The subject is a core subject in the Master of Civil Engineering degree pathway, however, will be a cores subject for all master degrees pathway offered by the Department of Infrastructure Engineering (Master of Civil Engineering and its specialisations, Master of Environmental Engineering and its specialisations, Master of Digital Engineering and its specialisations) from 2023. The subject covers a wide range of topics related to sustainability in Infrastructure Engineering with a specific focus on the environmental, economic and social implications of engineering projects as most students are prepared for the technical aspects of the subject. Students learn about the importance of infrastructure projects for the betterment of society and short term and long-term effects due to their actions. They also learn about complications in decision making in such projects in consideration of social equity, quality of life and wellbeing. Students learn about various methods such as n-Bottom line (nBL) framework (Foliente et al. 2007)

and UN Sustainability Goals (SDGs) to evaluate infrastructure projects.

Lectures are complemented by case studies, individual student tasks and a group project. Industry guest lecturers are also invited to conduct lectures to provide students with an understanding of practical applications and their impacts on society. Tutorials are designed to develop student skills, knowledge and understanding of the topics covered in the lectures and support the students in completing the assignments. Student assignments include developing in-depth knowledge of sustainability concepts in infrastructure projects and demonstrating their applications. A semester-long project looking at sustainability aspects of a real infrastructure project is one of the main learning activities students perform in this subject. Business as usual (BAU) and any alternative solutions they propose to enhance the sustainability of the project, considering engineering, social, economic and environmental bottom lines, provide them with a greater understanding of the concepts and meaningful applications to real engineering projects. Students are expected to provide a comprehensive report and oral presentation demonstrating their findings. An example of an analysis of results using spider diagrams showcasing different level bottom lines and their indicators is shown in Figure 11. In addition to this activity, students also perform individual tasks on improving their skills required to examine, analyse and provide recommendations related to infrastructure projects and their elements. Students develop critical thinking, analytical skills, research, oral and written communication skills through these activities.

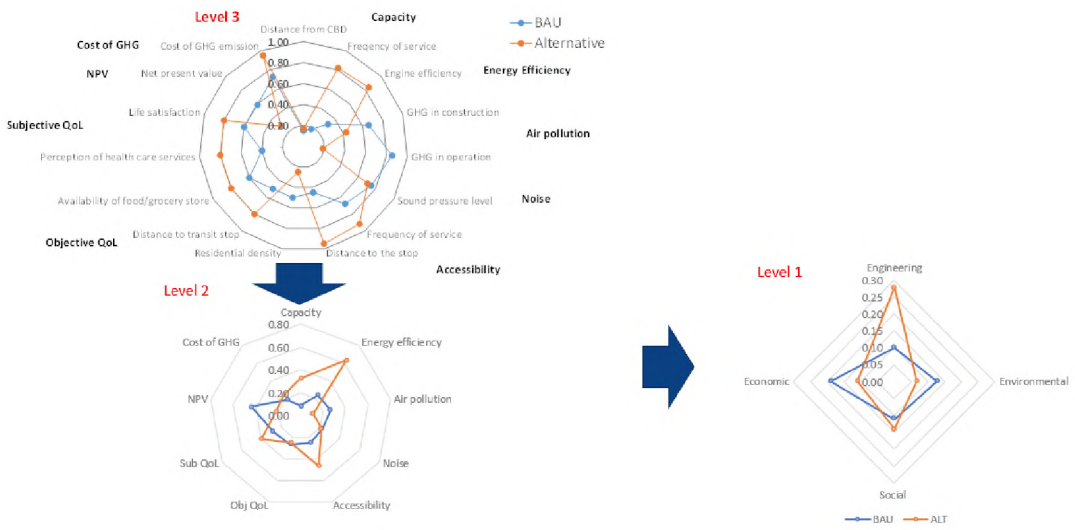
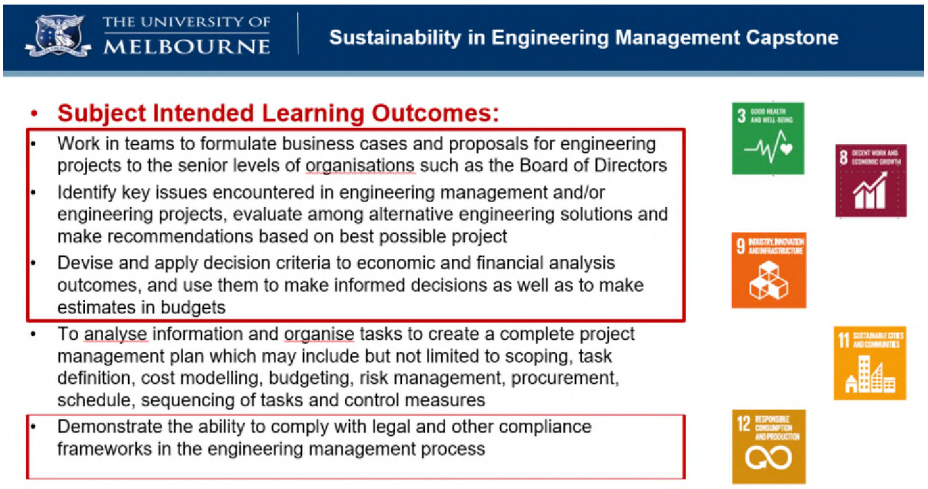


Figure 11. Example of presentation of results.

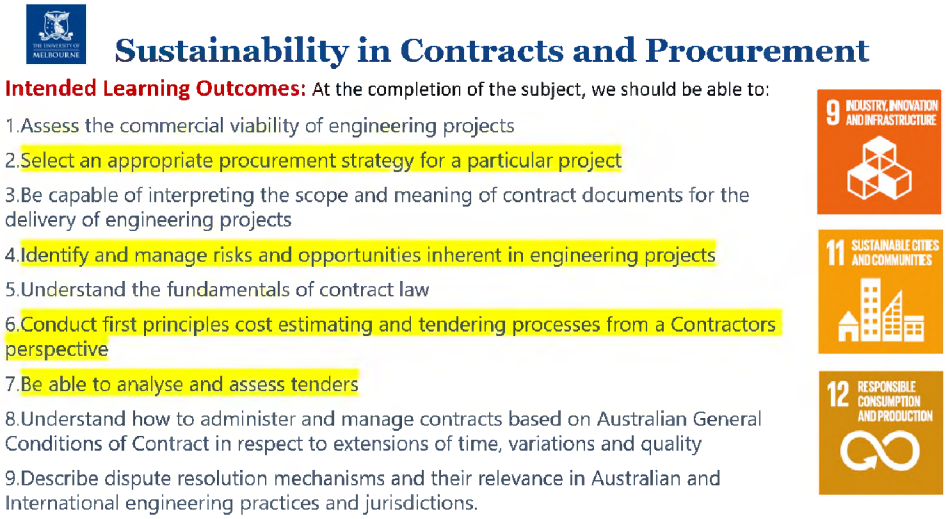
Intertwining sustainability concepts in subjects

The process of integrating elements of SDGs in the subjects was initiated by a core team that is led by a Sustainability Fellow. The core team initiated discussions with the subject coordinators on the links between their subjects and the SDGs and how the SDGs can be embedded in the subjects. The subjects can have their contents directly covering the SDGs, and as such, the SDGs elements can be incorporated within the lectures. Many subjects covering specific theoretical content and technical skills may not have contents that are not directly related to the SDGs. For these subjects, the SDGs can also be incorporated in projects and exercises, demonstrating real-world applications of the knowledge and skills learnt in the subjects. It is currently left to the subject coordinators' discretion how they embed the SDGs in their subjects.

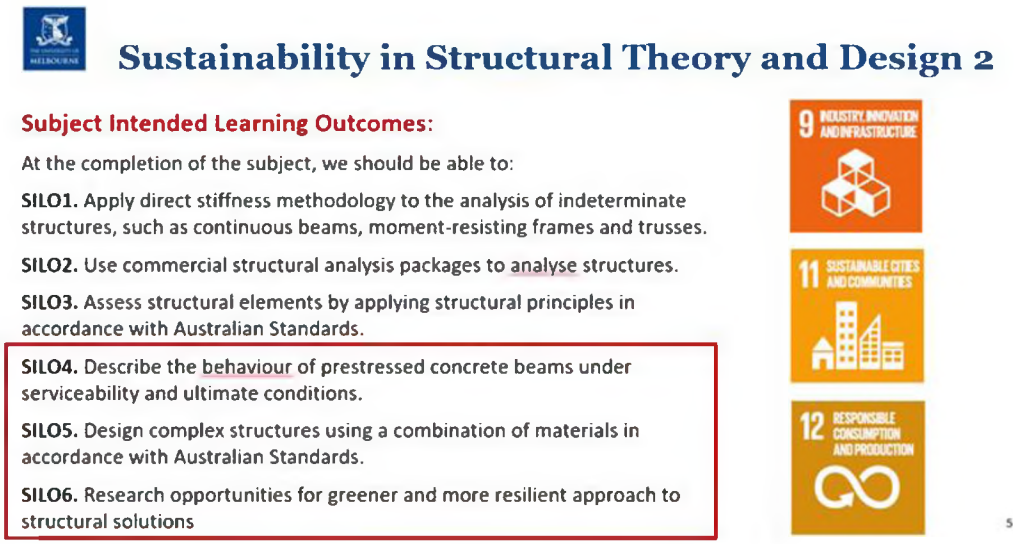
To achieve sustainable development goals, graduates need to feel empowered to make sustainable decisions in their professional practice. Increasing students' awareness of the importance of the SDGs and students' understanding of how their learning contributes to SDGs is essential to achieving this. As an important first step, the intended learning outcomes and how they address SDGs are discussed with students in each subject within the lectures. Examples are presented in Figure 12 for subjects in Master of Engineering Project Management and Master of Civil Engineering. More practical approaches, including a shift in teaching pedagogy, to develop a deeper understanding of SDGs amongst the students will be considered as a part of future work.



(a) Intended learning outcomes of Engineering Management Capstone



(b) Intended learning outcomes of Contracts and Procurement



(c) Intended learning outcomes of Structural Theory and Design 2

Figure 12. Examples of slides presented to students to illustrate how the subjects' intended learning outcomes address the SDGs.

CONCLUSION

The paper presents a pilot study to identify links between the University of Melbourne's curricula with sustainability knowledge using the 17 Sustainable Development Goals as a framework. The pilot study is a part of a university-wide initiative that is aimed to embed sustainability knowledge and values in its curricula. The SDGs were initially mapped against the subjects offered by the University using the framework analysis method based on the keywords and phrases extracted from the Inter-Agency and Expert Group on Sustainable Development Goal Indicators, the 2030 Agenda for Sustainable Development and the University's subject handbook. The analysis was conducted on six Schools offering 2157 subjects. The results presented are showing links between each subject and the SDGs and the number of subjects offered by each School that address the SDGs. The method only extracted keywords and phrases from the subject handbook. Hence, it only identifies the links if the SDGs are explicitly addressed in the subjects' intended learning outcomes and contents. As a result, a stronger link was identified for Schools that offer a wide range of majors (specialisations). The subjects' content may not reflect the SDGs in some technical subjects, although the concept may be addressed in the examples, assignments, and practice classes. A survey questionnaire was conducted involving the subject coordinators, and this process is important to validate the data obtained from the framework analysis method. The subject coordinators were invited to confirm or reject the links identified by the method and indicate the linkage strength with the SDGs. It was found that the process could identify links with new SDGs and identify the targets and indicators addressed in the subjects.

The next step in the Sustainability in Curricula initiative is aimed to strengthen and broaden the links and increasing awareness of the students. This step is currently in progress. The approach adopted by the Department of Infrastructure includes designing an elementary course in sustainability and intertwining sustainability concepts in the courses. Some examples were provided with the paper along with examples of information communicated to the students, demonstrating how what they are learning addresses the SDGs, which form an important step. Other pedagogical approaches to allow a deeper understanding of SDGs amongst students is currently under investigation.

REFERENCES

Boks, C. and Diehl, J.C. (2006), "Integration of sustainability in regular courses: experiences in industrial design engineering", *Journal of Cleaner Production*, Vol 14 No. 9-11, pp 932-939.

Bruntland, G. H. (1987). *Report of the World Commission on environment and development; our common future, Bruntland report*. New York: UN Documents, 1987.

Foliente, G, Kearns, A., Maheepala, S., Bai, X. and Barnett, G. (2007) "Beyond Triple-Bottom-Line – Sustainable Cities RD&D at CSIRO", Procs. State of Australian Cities National Conference(SOAC2007), 28-30 November 2007, Adelaide, Australia *(8) (PDF) Beyond Triple Bottom Line - Sustainable Cities RD&D at CSIRO.*

Gale, N.K., Heath, G., Cameron, E., Rashid, S., and Redwood, S. (2013), "Using the framework method for the analysis of qualitative data in multi-disciplinary health research", *BMC medical research methodology*, Vol. 13 No. 1, pp 1-8.

Guerra, A. (2017), "Integration of sustainability in engineering education", *International Journal of Sustainability in Higher Education*, Vol. 18 No. 3, pp 436-454.

Kamp, L. (2006), "Engineering education in sustainable development at Delft University of Technology", *Journal of Cleaner Production*, Vol. 14 No. (9-11), pp 928-931.

Leal Filho, W., Shiel, C., and Paco, A. (2016), "Implementing and operationalising integrative approaches to sustainability in higher education: the role of project-oriented learning", *Journal of Cleaner Production*, Vol. 133., pp 126-135.

Lozano, R. and Young, W. (2013), "Assessing sustainability in university curricula: exploring the influence of student numbers and course credits", *Journal of Cleaner Production*, Vol. 49, pp 134-141.

Palacin-Silva, M.V., Seffah, A., and Porras, J. (2018), "Infusing sustainability into software

engineering education: Lessons learned from capstone projects", *Journal of Cleaner Production*, Vol. 172, pp 4338-4347.

Peet, D.J., Mulder, K.F., and Bijma, A. (2004), "Integrating SD into engineering courses at the Delft University of Technology", *International Journal of Sustainability in Higher Education,* Vol. 5 No. 3, pp 278-288.

Rieckmann, M. (2017). *Education for sustainable development goals: Learning objectives*, UNESCO Publishing.

United Nations DESA (2016), *Transforming our world: The 2030 agenda for sustainable development,* United Nations Publications

United Nations Economic and Social Council. (2016), *Report of the Inter-Agency and Expert Group on Sustainable Development Goal Indicators*, United Nations Publications

Appendix Survey Questionnaire

Building Information Modeling (CVEN90062)

Goal No	Sustainable Development goals	Corresponding Indicator		Initial evaluation	Linkage Strength (1-weak strength, 2- moderate strength, 3- Strong strength)	Any comments
1	End poverty in all its forms everywhere					
2	End hunger, achieve food security and improved nutrition and promote sustainable agriculture					
3	Ensure healthy lives and promote wellbeing for all at all ages					
4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all	4a Build and upgrade education facilities that are child, disability and gender sensitive and provide safe, non-violent, inclusive and effective learning environments for all		Included ✓	1	

5	Achieve gender equality and empower all women and girls					
6	Ensure availability and sustainable management of water and sanitation for all					
7	Ensure access to affordable, reliable, sustainable and modern energy for all					
8	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all				2	
9	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	9.1 Develop quality, reliable, sustainable and resilient infrastructure, including regional and trans-border infrastructure, to support economic development and human wellbeing, with a focus on affordable and equitable access for all		Included ✓	3	
		9.4 By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities			3	

10	Reduce inequality within and among countries					
11	Make cities and human settlements inclusive, safe, resilient and sustainable	11.1 By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums		Included ✓		
		11.2 By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons			3	
		11.3 By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries			3	
		11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management			3	
		11.7 By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities			3	
		11.a Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning			3	
		11.b By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015–2030, holistic disaster risk management at all levels			3	

12	Ensure sustainable consumption and production patterns				3	
13	Take urgent action to combat climate change and its impacts					
14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development					
15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss					
16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels					
17	Strengthen the means of implementation and revitalize the global partnership for sustainable development