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Creating an Exemplar of Sustainability in an Engineering Curriculum

Mark Latham[a]; Claire Dixon[a]; Tobias Selkirk[a]; David Barry[a]; Sam Brumale[a]; Arezoo Boroomandnia[a]
University of Melbourne Department of Infrastructure Engineering[a]
Corresponding Author Email: mark.latham@unimelb.edu.au

ABSTRACT

CONTEXT

Sustainability in engineering curricula continues to attract committed efforts to support graduates to contribute to sustainable development. Recent work has included attention to both the explicit and implicit curriculum. Drawing upon this work, The University of Melbourne adopted its Sustainability Plan 2030 in May 2022. The Plan includes priorities arranged in three domains *Amplifying action through campus and communities, Mobilising knowledge for action* and *Walking the talk in our operations.* This paper reports on the work of a Learning and Teaching Initiative Grant to work on one of the Plan's priorities *Graduates for a Sustainable Future* whilst leveraging a *Campus as a Living Laboratory* to focus students on issues in campus operations.

PURPOSE

The Plan calls for development of a performance indicator to track *Increase in students' and graduates' (self-reported) sustainability self-efficacy.* The European Commission published its GreenComp Sustainability Competence Framework in 2022 and the opportunity was identified to explore its use as the basis for measuring and reporting sustainability self-efficacy. To prepare for implementation across the university's broad teaching activities, it was considered that a pilot project would expose issues related to embedding sustainability (and measurement) in curricula. And pilot experience could be offered as an exemplar for the university's curriculum developers.

APPROACH

An established masters-level subject with a strong contribution to sustainable development and a case study-based design, *Environmental Management ISO14000,* was chosen as the management unit for a Living Laboratory centred on selected physical and administrative functions of campus management. The Dunning-Kruger effect, a cognitive bias whereby people with low competence overestimate their competence (compared with objective measures), was identified as a central issue to the measurement of self-reported sustainability self-efficacy. It was seen as critical to establish a context for students' self-assessment in which they would reflect on objective feedback received on their actual performance in individual assessment tasks. The subject coordinator needed to identify elements of assessment in which each of the twelve competences that make up the GreenComp framework would enable student success. Students were supported in a three phase survey with four competences linked to each assignment, including teaching refinements.

ACTUAL OUTCOMES

It was straightforward to link all twelve GreenComp competences to an environmental management subject based on ISO14001:2015. The university campus as a living laboratory provided excellent case study content and student access to facilities throughout subject delivery.

CONCLUSIONS

The use of the assessment tool is best planned at course level. The use of living laboratories is best examined based on the alignment of campus facilities and systems to subject requirements.

KEYWORDS

Sustainability in engineering education, Campus-based learning, Indigenous knowledge.

Context

Sustainability in engineering curricula continues to attract committed efforts to support graduates to contribute to sustainable development. Recent work (Gutierrez-Bucheli et al, 2022) has included attention to both the explicit and implicit curriculum. Drawing upon this growing body of work, the University adopted its Sustainability Plan 2030 (University of Melbourne, 2022) in May 2022. The Plan includes priorities arranged in three domains *Amplifying action through campus and communities, Mobilising knowledge for action* and *Walking the talk in our operations.* This paper reports on the work of a Learning and Teaching Initiative Grant to work on one of the Plan's priorities: *Graduates for a Sustainable Future* whilst leveraging a *Campus as a Living Laboratory* for a pilot project and to focus students on issues in campus operations.

Rajabifard et al (2021) and Scott (2022) have highlighted the value of students working on tasks that contribute to United Nations Sustainable Development Goals (UNSDGs) and the university Sustainability Plan 2030 has adopted university-specific targets to contribute to the UNSDGs.

The Sustainability Plan 2030 takes a pluralistic approach to definitions of sustainability whilst the university's Sustainability Charter (documented in the Plan) emphasises the interdisciplinary dimensions of sustainability's 'three pillars' noting that:

> *Global values and actions must be ecologically sound, socially just and economically viable, with success in one area not coming at the expense of the others.*

And further committing that:

> *The teaching and learning programs of the University inspire and support students to be leaders for a sustainable future. The University will:*
>
> *Ensure every graduate has a baseline threshold of sustainability knowledge;*
>
> *Prepare sustainability specialists through interdisciplinary education;*
>
> *Develop leaders across professions and fields to innovate, define, create and contribute to sustainable societies.*

Purpose

The Plan calls for development of a performance indicator to track *Increase in students' and graduates' (self-reported) sustainability self-efficacy.*

The European Commission recently published its GreenComp Sustainability Competence Framework (Bianchi et al, 2022) and the opportunity was identified to explore its use as the basis for measuring and reporting sustainability self-efficacy. GreenComp was attractive for being based on a comprehensive literature base (Bianchi, 2020).

Given the university's intent to work on measurement of sustainability self-efficacy outcomes broadly across teaching and learning activities, it was considered that a pilot project applying the self-efficacy metric might expose a range of issues related to embedding sustainability in curricula and that the pilot's case study could be presented as an exemplar for the university's curriculum developers to refer to. The case study was also expected to provide experience on issues associated with the use of a university campus as a Living Laboratory. Work on the tool itself and its use as part of a performance indicator is to be reported separately.

Approach

An established masters-level (final year Environmental Engineering) subject with a strong contribution to sustainable development and a case study-based design, *Environmental Management ISO14000,* was chosen as the exemplar subject and management unit for a Living Laboratory centred on selected physical and administrative functions of campus management. It's content is based on the frameworks of ISO14001, ISO14015 and ISO31000 as fertile ground for students to form integrated insights through:

1: Focus on organisations (broadly defined to include many kinds of social system existing to achieve objectives within a wider context of interests of environmental, social and economic relevance); and

2: Articulation of the roles of organisational leaders in the interdisciplinary effort of setting and achieving objectives and modelling of the culture required for organisational success and guiding the interdisciplinary approach required for risk-based environmental assessment (illustrated by the format of Table 1).

Table 1: Register of Environmental Aspects and Impacts Format

Activity	Aspect	Impact	Legislation Or Commitment	Organisation Policies/ Procedures	Controls Current	Current Risk Assessment			Additional Control Options Available	New Risk Assessment			Cost	Benefit/ Cost	Recommendation
						C	L	R		C	L	R			
									Eliminate Hazard						
									Substitute Hazard						
									Engineering Control						
									Administrative / Response Control						

The subject *Environmental Management ISO14000* can be understood in terms of a 3Ps model comprised of Practice-based, Place-based and Project-based.

Practice-based refers both to teaching by industry-based professionals and Intended Learning Outcomes that refer to industry practices in which the ISO14000 series of standards are applied. This has also shaped a focus on giving students the experience of role-playing being part of an operating organisation as well as being consultants to a facility manager or operator.

Place-based refers historically to multi-year partnerships with Toyota and Zoos Victoria as both those organisations embarked on certification of their management systems to ISO14001. Practical examples of environmental management concepts have also assumed that students are already familiar with at least some of the environmental aspects of gasoline retailing facilities. Since the university's first phase with its sustainability charter and sustainability plan in 2015, opportunities have increasingly emerged for students to engage with that work, particularly supported through using university campuses as living laboratories. These experiences have given students increasing ability to engage with the environmental and social context of their own campus and students have shown an enthusiasm to engage deeply with their campus.

Project-based aspect has encouraged the subject delivery team to engage afresh with their field trip hosts every year to identify their current challenges in continual improvement and take the opportunity to re-focus student assignments to encourage dialogue around those challenges. Fresh ideas from students, academics and site hosts working together has helped to prevent case study materials from becoming stale. A recent example was in the 2022 subject delivery when all participants were coming to grips with the Environment Protection Act 2017 (Vic) after it came into force on 1 July 2021. It was advantageous that the subject delivery team included a University Guest from EPA Victoria at that time.

Opportunities for Improvement

The key opportunity to improve the existing subject was seen as to better align it with the university's recently released Sustainability Plan, already described above as:

- Using a campus as a Living Laboratory. This was seen as financially beneficial after expensive adaptations required during COVID19 lockdowns, and offering a more diverse and resilient platform for adapting to future change demands;
- Piloting a sustainability competence framework to contribute to learning & teaching commitments/aspirations spelled out in the Sustainability Plan.

Another link (focusing the scope of our Living Laboratory) was to engage with the University's Reconciliation Action Plan 2018-2022 (University of Melbourne, 2018), particularly its signature project to create a New Student Precinct Project. Engagement with Traditional Owners (TOs) in the development of that project drew focus on how the natural topography has been modified with development (since 1855) of the university campus; the campus still drains to the Birrarung (Yarra River), but through engineered drainage. Yet memory of the Bouverie Creek watercourse as a habitat for short-finned eels (Anguilla Australis) is still very significant to the Wurrundjeri Woiworrung TOs as highlighted by Greenaway to Comte (2018):

> *The eels continue to swim through the stormwater pipes of the University. They rear their heads up in some of the ponds and stormwater grates that exist on the campus. For me, the metaphor of the eel is quite powerful. It is a story that connects over time and place because what it talks to is the notion of resilience—resilience of Indigenous people, after 240 years, and their commitment to showcasing culture and connecting and maintaining relationships to country.*

Greenaway's "resilience" is a valuable theme that resonates with organisation-based elements of ISO14001:2015 and that presents an opportunity for future incorporation of indigenous cultural knowledge. This (and other) reports of campus stormwater drains and other infrastructure providing habitat for eels capture imaginations of students of the environment to apply their developing disciplines to living laboratory projects centred on their very own place of study where they have the opportunity to immerse themselves in subject matter every day of semester, not just on field trip day. We expected it would prove straightforward to focus learning on campus features relevant to the specialisations of students from environmental, chemical and civil engineering courses taking the subject as well as environmental students from the Faculty of Science – giving students from each discipline the opportunity to contribute authentically to an interdisciplinary effort.

It has also been hoped that through in-depth exposure to the campus subject matter as a Living Laboratory, students may identify data gaps in reliable environmental assessment and recommend projects to investigate the campus and its environment in more detail. Recommendations from student assignments could be the genesis of capstone projects that might yield new knowledge for a feedback loop to continually improve assignment briefing materials. For example, in 2023 we offered a capstone project to investigate the confirmed (but not fully explained) unexpected sighting of an eel living in a reed pond on campus.

Sustainability Self-Efficacy Assessment

It was decided to treat Sustainability Self-Efficacy as a concept comparable to Sustainability Competence except that 'self-efficacy' would be distinguished by self-assessment compared to 'competence'. (Competence would be assessed objectively by an independent expert skilled in training and assessment). This work has been the fortunate inheritor of work recently published by Bianchi et al (2022) on the GreenComp Sustainability Competence framework that emerged from a substantial body of work for the European Commission (see also Bianchi, 2020), distilling the work of many respected workers on sustainability competence into a consolidated framework. We chose to rely on that work because of recency, thoroughness and compatible purpose.

GreenComp's twelve competences are listed in Table 2. The GreenComp publication (Bianchi, 2022) includes definitions and assessment criteria supporting each competence based on Knowledge, Skills and Attitudes as well as a useful visualisation of synergies in the framework.

Table 2: GreenComp Competences in Area Groups (Bianchi et al, 2022)

Embodying Sustainability Values	Embracing Complexity in Sustainability	Envisioning Sustainable Futures	Acting for Sustainability
Valuing Sustainability	System Thinking	Futures Literacy	Political Agency
Supporting Fairness	Critical Thinking	Adaptability	Collective Action
Promoting Nature	Problem Framing	Exploratory Thinking	Individual Initiative

The Dunning-Kruger effect (Kruger & Dunning, 1999) was identified as a central issue to the measurement of self-reported sustainability self-efficacy. It was seen as critical to establish a context for students' self-assessment in which they would reflect on objective feedback received from academics on their actual performance in individual assessment tasks. Hence it was important for the subject coordinator to identify elements of assessment in which each of the twelve competences that make up the GreenComp framework could enable student success.

Subject Changes using GreenComp

Since introduction of the Sustainability Self-Efficacy Assessment was a pilot, it was not seen as appropriate to make subject changes of the significance that would require a Subject Handbook change. But it was still possible and beneficial to:

1: Use the GreenComp framework to illustrate in a lecture how the Competence requirements of ISO14001:2015-7.2 might be implemented by an organisation;

2: Suggest GreenComp as an optional tool for observing the leadership behaviours of academic and professional staff and reflecting on their own behaviours during learning activities; and

3: Flag to students the GreenComp competences likely to contribute to successful completion of their experiential learning assignments.

Notes in rubric headings were a simple mechanism for making the links between the twelve competences and the three assignments (four competences per assignment) that were identified as the best distribution across the link opportunities available.

Students were supported to use the online survey questionnaire in three phases. Because their participation was optional, we promoted the value of participation to them as being an introduction to the kinds of behavioural competence framework used by some potential employers. Participation attracted 7 students from a cohort of 46. Outside the scope of this paper a cohort of 39 students have subsequently undertaken the online survey and that work will be reported in a separate paper focused on data collection, measurement, analysis and reporting.

The linkages mapped between GreenComp competences and assessment tasks are shown in Figure 3 whilst Figure 4 shows the specific student activities within those tasks where the competence is expected to enable student achievement.

In general, teaching activities identified as strongly linked to the assessment tasks benefiting from the specific competences were refined to better complement participants' development.

Assessment activities during fieldwork were also adjusted to enable students to work on fewer tasks but with more time for depth. The fieldwork tutors were selected and organised more on their distinct disciplinary expertise than in the past with the intent that they would be conversant with the model answers that students visiting their area were working towards – enabling them to coach students in their observation of facilities and their questions to site hosts.

Figure 1: Mapping to Major Learning Activities

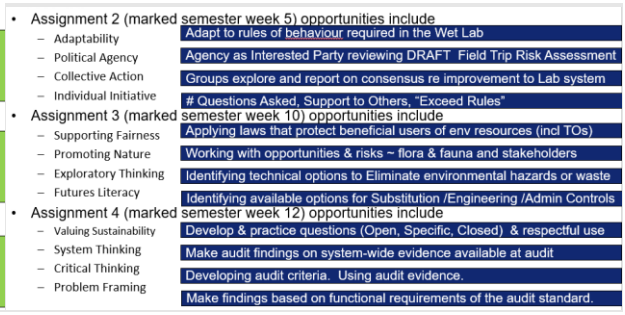

Figure 2: Mapping to Assessment Tasks

Subject Changes using the Living Laboratory

The use of the campus as a living laboratory is particularly useful for learning about sustainability because the students themselves are already stakeholders in the campus, with at least some awareness of other stakeholders and their interests. This is a good basis for learning about sustainability as a whole-of-society concept and the role of institutions in supporting social changes that require a systematic approach. The international standard itself states, "the purpose of (ISO14001:2015) is to provide organizations with a framework to protect the environment and respond to changing environmental conditions in balance with socio-economic needs."

Assignment 2 was already based on campus in a wet laboratory that most students would know well. The most significant change required them to review and comment on the draft risk management plan for the Assignment 3 field trip to outdoor facilities in their faculty's precinct.

Assignment 3 required the most significant changes to define environmental assessment tasks relevant to the faculty precinct and appropriate to the skills available from a cohort of students studying environmental, civil and chemical engineering as well as environmental science. The precinct has a diverse range of environmental aspects at a light industrial scale, but it was decided to offer students a suite of tasks anchored around modifications already made to the natural ecosystem that provided habitat for eels before the campus was developed; and to examine the possibility that habitat for eels might be maintained or enhanced for the future through planned construction of an eel pond along the original course of Bouverie Creek.

Figures 3 to 6 provide an appreciation of the experiences facilitated for students based on the pre-site provision of technical documents and the opportunity to interact with campus management hosts responsible for relevant physical facilities during the field trip to identify (potential pollution) Sources, Pathways and Receptors in the environment (Geological Survey of Ireland, 2023).

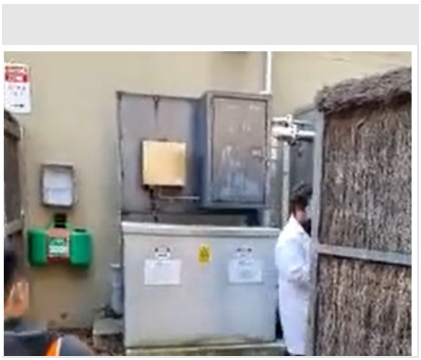

Figure 4: Chemical Spill Source

Figure 5: Landscape Receptor

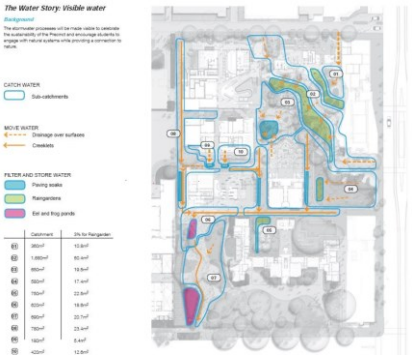

Figure 6: Pathways to Eel Pond

A tutor was assigned to accompany each campus management host to facilitate interaction with students and later to use their multidiscipline expertise to facilitate a group's assessment. A typical model answer provided to tutors to help them guide their students is shown as Table 3.

Table 3: Register of Environmental Aspects & Impacts (example of an Aspect/Impact pair)

Activity	Aspect	Impact	Legal	Policy	Current Control	Current Risks			Additional Controls	Mod Risks		
						C	L	R		C	L	R
Deliveries to/from Departments occur within a stormwater catchment Noting that this stormwater is both harvested for use at the Campus and discharges off site into the Bouverie Street and other drains.	A spill during a delivery to/from the Chemistry store or at the trade waste treatment system - up gradient of Monash Rd - would result in the in liquid chemical interacting with the stormwater system.	Spills and incidents cause contamination of the stormwater system. Resulting in contaminated stormwater leaving the site near Gate 8 and so entering Bouverie Street Drain and the Yarra River.	EP Act 2017 s. 25(1), s.31, & s.32(2) Potential penalty s.25(1) Person $370,000 Business $1,850,000 s. 32(2) Person $44,000 Business $222,000 SEPP(WoV) EP Act 2017 Environmental Reference Standards	Chemical Management Guidelines Emergency Response SOP. UoM Sustainability Plan Targets re Healthy Ecosystems: No net loss of biodiversity by 2025. Increase of biodiversity relative to defined baseline years by 2030	Minimal volume of chemicals stored in the Chemistry building. Wastes stored in small containers (10 litres) Training	4	B	5	Eliminate No chemicals used in Chemistry, no treatment of trade waste from Chemistry. Substitute Use dry chemical additives in trade waste systems. Engineering Isolation valve at discharge . Undercover bunded loading/unloading delivery area. Administrative Mark all stormwater pits	5 5 4 4 4	E B B D B	1 4 5 3 4

Victoria's new Environment Protection Act 2017 (that came into force 1/7/2021) established a General Environmental Duty (GED) that requires duty holders to "*so far as reasonably practicable minimise risks of harm to human health and the environment."* Guidance from EPA Victoria (2020) on *reasonably practicable* provides students with advice relevant to the university's interdisciplinary principle favouring decisions that are *ecologically sound, socially just and economically viable, with success in one area not coming at the expense of the others.*

Assignment 4 required place-based change in as much as the university's campus management unit became the auditee organisation and a gap analysis provided to the system coordinator.

Two students who had earned honours in the subject in 2022 later participated enthusiastically in pilot implementation of the new assignments 3 and 4 and provided constructive input to design.

Outcomes

As expected, it was straightforward to link all twelve of the GreenComp sustainability competences to the subject on environmental management based on the relevant international

standard ISO14001:2015. As a result, feedback has become available on students' reflections on their competence in a wider range of criteria (e.g. political agency) than are usually explicit in an engineering curriculum. It is recognised that not all subjects can cover all competences and that an established emphasis on student participation was helpful to the pilot work.

The success in piloting the self-assessment in a management systems subject has underlined the value of including management systems in engineering course curricula since ISO-standard management systems provide a recognised model for the integration of multi-discipline contributions into an organisation, including a clear articulation of the role of leadership .

Using the university campus as a living laboratory provided excellent case study content relevant to students' courses. There are also opportunities to adapt the choices of case studies.

The ongoing work to develop the university's environmental management system provided constructive engagement between academic and professional staff in the context of the subject delivery collaboration. It is hoped that this engagement will continue as implementation progresses and that this will offer students opportunities to engage with practical problems.

The academic performance of the 2023 student cohort was comparable to recent years. Whilst average marks were slightly higher than in 2022, the improvement cannot be claimed to be statistically significant. Rather the benefits have been manifest more in the continued access to the field trip locations and organisation information that was previously treated as confidential to hosts; this enabled academic staff to deal more flexibly with students who missed activities due to ill health and other important personal issues.

Recommendations

Based on student feedback and a debrief with teaching staff, we recommend the following:

1. **Course-level integration**: Future systematic use of an assessment tool is best planned at course level rather than subject level to ensure competence development is focused on the best subject-based opportunities that exist in the course, with student participation a consideration.

2. **Core subject considerations**: Subjects framed around standards for management systems and risk management should be considered as potential core subjects in courses seeking to develop integrated sustainability competence in graduates. Considering this, it may be useful to examine a mapping between Engineers Australia Stage 1 Competences and GreenComp.

3. **Campus as a living lab**: Universities should consider the potential to adopt sustainability objectives based on their own operations; using their own operations as a "Living Laboratory" where student learning can occur based on Projects with ongoing access to the Place and expertise in relevant Practice. For this to succeed on a continuing basis, academic staff should engender mutually beneficial partnerships with campus management personnel. But success may be constrained by the availability of facilities and systems relevant to subject requirements.

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