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Assessing for Sustainability; reflective and peer learning assessments as a means of promoting student engagement

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Abstract

This paper considers a number of assessment approaches aimed at promoting learner engagement among engineering students on a bespoke sustainability module. Traditional assessment of university engineering courses typically involve closed book examinations, supplemented by participatory laboratories and associated reports. This approach is largely unfit-for-purpose for courses which seek to actively engage students to develop their reflective and critical thinking skills, as well as draw on their prior and experiential learning and knowledge.

The module in question is a course on 'Sustainability and Environmental Protection', taken by third year engineers and some graduate students on a Higher Diploma programme with various disciplinary backgrounds, at University College Cork. It seeks to facilitate student engagement and reflection by examining concepts, models and values around sustainability and sustainable development; relationships between socio-cultural and techno-economic complex systems; interconnection, problem framing, integrative thinking and transdisciplinarity, drivers of (un)sustainable behaviour and practices, and the role of ethics, values and worldviews. Various assessment modes are chosen to support this learning and associated learning outcomes around developing critical reflective analysis, empathetic, integrative and complex systems thinking. These include a critical book review, peer engagement in critiquing an academic article, and a group presentation. The paper will present some reflections from both students and staff on the value of these modes as learning tools.

Keywords: sustainability competences; transferable skills; open-ended activities; graduate attributes

1 Introduction

As well as 'core engineering competences', engineering programme also seek to develop both transferable skills and professional values in the engineering graduate. Moreover, and to an increasing extent, accreditation bodies require that graduates are equipped with a range of sustainability attributes (Byrne, 2023), which can traverse and transcend each of the aforementioned domains (Gutiérrez Ortiz et al., 2021). Modules and courses rich in core competences, for example in the domain of heat, momentum (fluids) or mass transfer, or in applied thermodynamics are most amenable to traditional assessment approaches such as closed book end of term examinations, where 'simple' computational problems may be advanced seeking determinate and/or unique solution sets. The examination of transferable skills however (e.g. communication, teamworking, dealing with complexity and uncertainty) and normative values (e.g. around safety, ethics, social and environmental wellbeing) do not typically lend themselves to assessment using such approaches. Teaching sustainability or (engineering) education for sustainable development also falls

into this framework. While core sustainability competences (e.g. having a knowledge and appreciation of the UN Sustainable Development Goals, or respective models, conceptions or definitions of sustainability/sustainable development) may be fairly readily examinable, the development and articulation of a more reflective and deeper understanding of the issues, problems and potential interventions, plus its complex and wicked nature, as well as ethical implications (Byrne and Mullally, 2014) require a more expansive and nuanced assessment toolbox, one involving various continuous assessment approaches. This paper considers some of the assessment techniques used on a module entitled 'Sustainability and Environmental Protection 1', taken as a core module by third year BE/ME students of Process and Chemical Engineering at University College Cork, as well as by a cohort of graduate students taking a Higher Diploma in Sustainability in Enterprise. The latter cohort generally comprise mature students from a diverse range of disciplinary backgrounds with a fairly extensive of life and work experiences, who are often drawn towards that programme by a desire to make a positive change professionally. The module thus provides a conducive space to allow for cross-pollination of ideas among a diverse range of (engineering and non-engineering) students, recognizing the value and importance of a transdisciplinary ethos and approach (Byrne and Mullally, 2016; Byrne et al., 2022), which it seeks to develop this through the module, in particular through peer engagement. The module is shared with the author and another lecturer on a half and half basis (the other half covers some core sustainability competences such as life cycle assessment), while the reflections here are confined to that of the author's part.

This paper will outline a range of continuous assessment modes employed as part of the module which have been developed (oftentimes by trial and error) in order to seek to precipitate an engaged student learning environment characterized by peer learning and reflective engagement. It reflects on the efficacy of the respective assessments, including by student feedback and evaluation. The feedback presented was garnered during the 2023 iteration of the module, which was taken by 61 students, comprising 42 undergraduate third year process and chemical engineering students, 18 higher diploma students studying a sustainability and enterprise programme, and one visiting student, a civil engineering undergraduate from the United States of America, totaling 61.

2 Module goals, content and learning outcomes

The module goals, content and learning outcomes for this part of the module are displayed in Table 1. The module is intentionally philosophical in nature, as it seeks to encourage students to engage with, and consider the nature of sustainability, including as it relates to the rest of the module, and across their respective programmes. It essentially seeks to offer students an opportunity to "see the wood from the trees', while developing the critical thinking skills and an appropriate understanding of complexity and context as they relate to the wicked, complex and interconnected aspects of (un)sustainability, including drivers outside the traditional technical domain that engineers operate within and feel more comfortable with.

Table 1 Some module attributes (PE3011 Sustainability and Environmental Protection 1)

Module Goal
To examine concepts, constructs, models and values relating to sustainability and sustainable development. To examine relationships between socio-cultural and techno-economic complex systems, drivers of (un)sustainable behaviour and practices, including ethics, values and worldviews. Interconnection, problem framing, integrative thinking and transdisciplinarity and how these relate to professional roles, responsibilities and practice.

Module Content
Sustainability and sustainable development; frameworks, concepts, constructs, models and values, including the UN Sustainable Development Goals. Concepts of progress, interconnection, integrative thinking, resilience, redundancy, growth and consumption (versus biophysical limits), system complexity, inherent uncertainty, non-equilibrium thermodynamics and process change and as they relate to professional practice and values, historical context and drivers for change and transformation.

Learning Outcomes
On successful completion of this module, students should be able to:

- Articulate contemporary frameworks, concepts, constructs, models, values and ethics around sustainability and sustainable development, including the UN Sustainable Development Goals;
- Identify the nature of complex systems, inherent uncertainty, non-equilibrium thermodynamics and process change as they relate to professional practice and the wider world;
- Identify different perspectives, framings, paradigms worldviews and diverse multi-cultural contexts, and work collaboratively with others in seeking (through inter- and transdisciplinary approaches) to propose useful interventions and potentially transformative outcomes;
- Develop and refine capacity for critical reflective analysis, empathetic, integrative and complex systems thinking.

3 Module Assessment

Table 2 outlines the assessment components that were employed to assess the above material during the 2023 iteration of the module. In addition, some other devices were used to promote peer engagement and participation across the module. In addition, a polling app (*slido*) was used to facilitate (anonymous) engagement, in particular around precipitating in-class discussion and engagements, while as part of the module, two students of various global heritage and backgrounds (from the USA and Poland) made respective presentations to their peers on sustainability from their own perspectives, relating to these part of the world, followed by class engagement and discussion.

Table 2 Some assessment components employed across the module

Assessment	Description	Marks
Book review	Write a newspaper/magazine style book review from a list of thought provoking books on some aspect of sustainability	20
In-class exercise(s)	A series of in-class peer and general class discussions, often using live polling app (*slido*); grades were awarded for participation	5
Peer paper reviews and reflections	Use of *Perusall*® app to read and comment on, and comment on peer comments for a selection of (three) selected papers	10
Group transdisciplinary sustainability assignment	Assignment where group identifies and reflects on authentically positive action, idea or initiative which can help precipitate transformative change	15

4 Student Feedback

At the completion of the module, students were asked to consider how each of the assessment approaches, as well as the polling app and the student global perspectives initiative, supported their engagement and learning of material. This was done using the voting app (anonymously, and without seeing the responses

of others in each case) where students were asked to rank the six assessment types/initiatives in order. The aggregated results, from 22 participants (a 36% response rate) is shown in Figure 1.

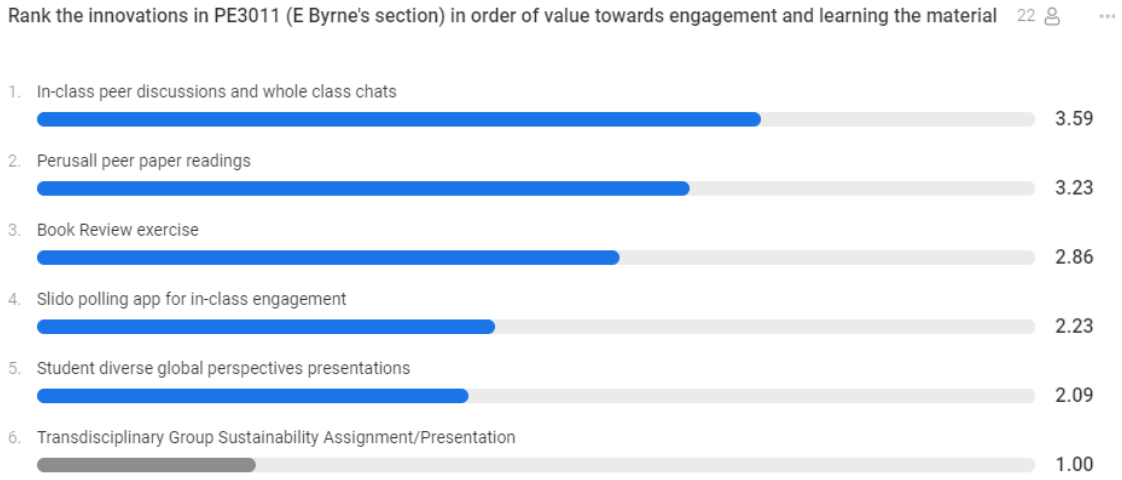

Figure 1 Student rankings of the value of respective initiatives towards engagement and learning

The in-class peer discussions proved to be the most popular initiative. These provided opportunities (on one or more occasion during nearly every class) for the students to discuss (in-class in small groups, via the voting app and/or by discussing their thoughts and reflections among peers in-class, and responding to same) their thoughts on some sustainability related discussion point. Despite this attracting the smallest amount of marks for all assessments, clearly students valued the opportunity to digest, reflect on, discuss with small number of peers, and then with the class as a whole on points related to material just covered. The out of class Perusall peer paper readings were also considered very valuable in facilitating learning engagement.

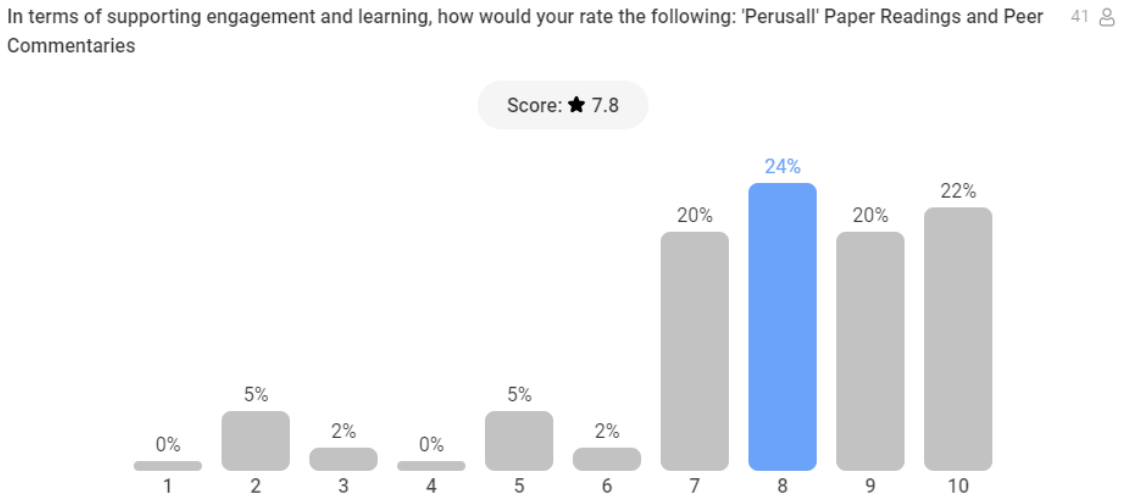

Figure 2 Student evaluation of engagement and learning value from peer paper readings

This is borne out by the very strong engagement as evidenced by usage statistics provided by the app. Students engaged thoroughly with the readings. The first paper reading (Bradshaw et al, 2021) attracted

some 272 comments plus 22 student questions among the cohort (of 61), with an average student engagement time (reading (paper, as well as comments) plus making annotations, responses, upvoting, etc.) of 106 minutes with the paper. The second article (Hickel at al., 2022) attracted even more comments and questions (411 and 23 respectively) over an average engagement time of 95 minutes. The final piece (Wessels, 2006) attracted 578 student comments and 21 student questions, with an average engagement time of 118 minutes. A separate question asked how valuable (on a 1-10 scale) the peer paper exercise was in terms of supporting engagement and learning. The aggregated results of this are shown in Figure 2.

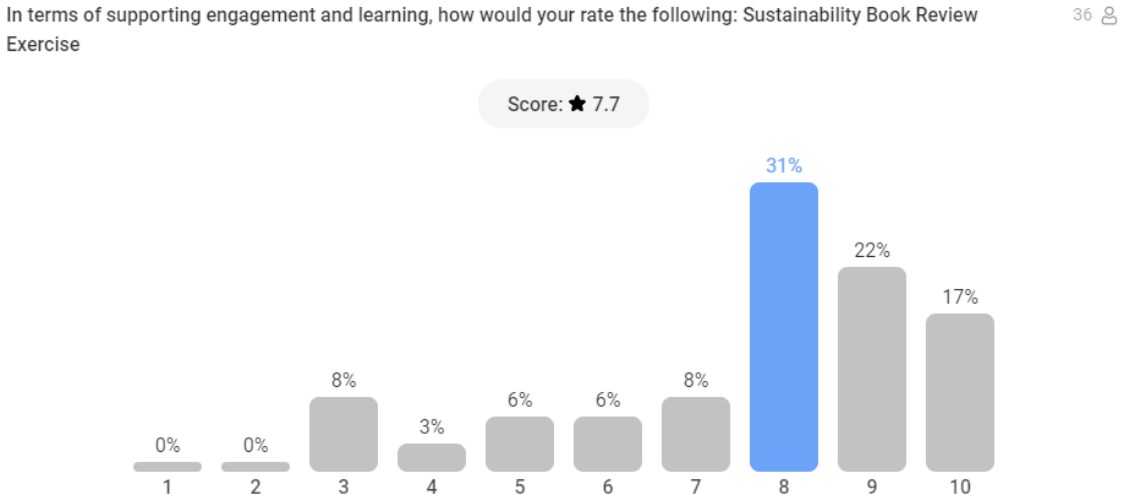

Figure 3 Student evaluation of engagement and learning value from the book review.

An average score of 7.8 was realised among 41 respondent (67% response rate), while just 6 students gave a score of below 7. This compares with a slightly lower average of 7.7 overall for the book review exercise, where 8 students (from 36 respondents) gave a score of less than 7 (Figure 3).

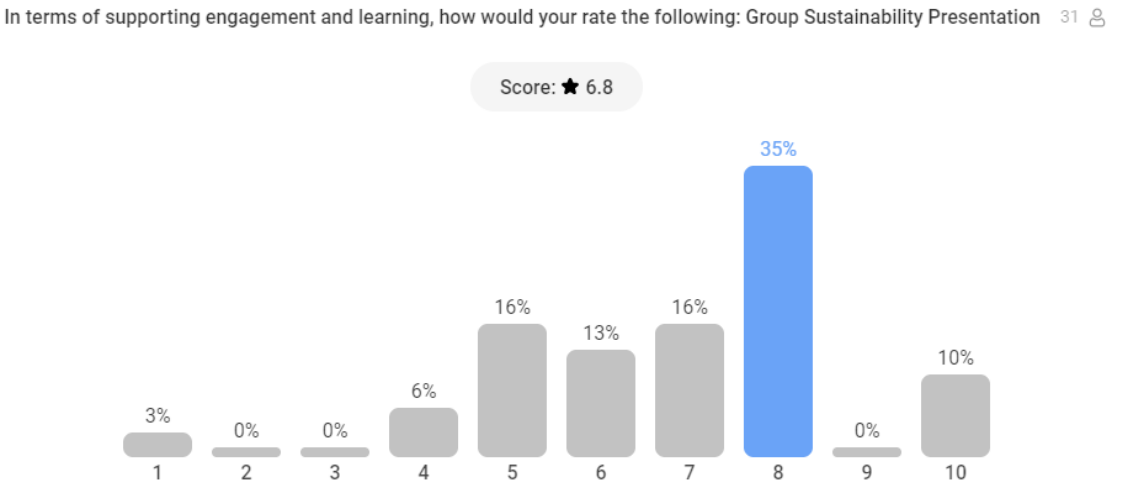

Figure 4 Student evaluation of engagement and learning value from group transdisciplinary sustainability assignment.

On the other hand, the transdisciplinary group sustainability assignment and associated presentation were deemed to be easily the least useful means of engagement. A major caveat might be attached to this however.

The survey was conducted during the last formal class for the module. While all the other assignments had been completed by then, this assignment had been prescribed only, and the deadline for submission was some time later. Thus students had thus not really engaged with this assignment by the time of the survey. This assessment piece is the subject of another paper at EESD2023, which can be consulted for a more comprehensive appraisal (Byrne, 2023a). Nevertheless, a significant majority of students (61%) still gave this exercise a 7 out of 10 or better in terms of its capacity to support material engagement and learning for the module.

4.1 Overall student assessment

Students were also asked on their teaching and learning experience of the module as a whole, and on the capacity of the associated module materials to support engagement and learning (from the author's part of the module); including slides, supplementary notes, etc. Bearing in mind that most of the class taking the module were undergraduate engineering students (70%) more used to quantitative type modules, typically covering core engineering competencies, assessed with significant closed book exam components, there may be a likelihood that students would feel less confident or less comfortable or happy with the ability of this rather different and/or novel set of continuous assessments to provoke good material engagement and learning. They may also feel that the material itself is without the remit of their usual engineering practice or experience, and may even be mildly hostile to it. This however was not at all borne out by the findings, as is evidenced by Figures 5 and 6.

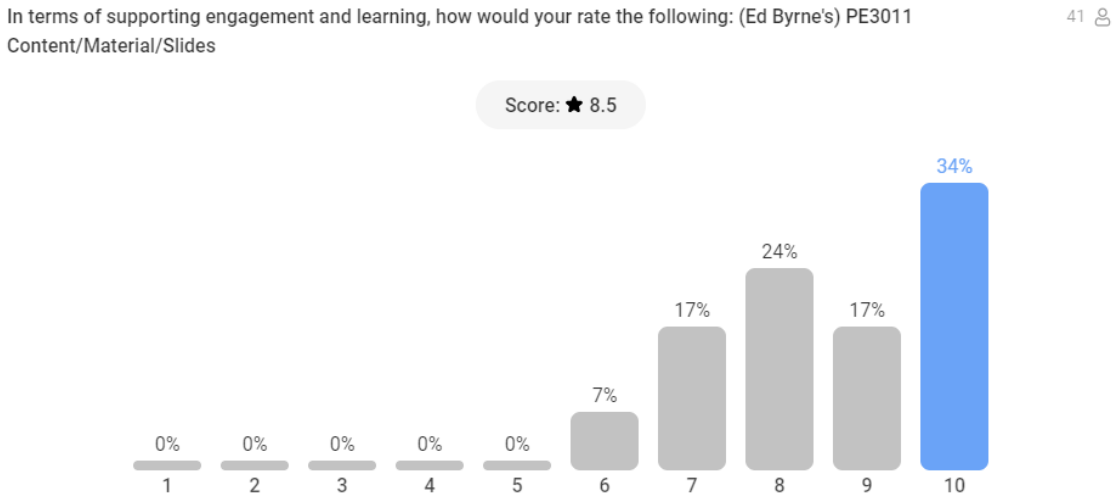

Figure 5 Student rating of how module materials support engagement and learning.

Indeed students offered the two highest aggregate scores to the questions posed, indicating strong satisfaction with both the quality and relevance of the material, certainly in its ability to support engagement and learning (Figure 5), as well as most emphatically around their teaching and learning experience of the module as a whole (Figure 6), the latter of which attracted a score of 9 or 10 among 74% of respondents (26 out of 35). These findings are however consistent with informal student feedback on the topic; many are engaged with and lead the local university Engineers Without Borders chapter for example, while for this generation of undergrad students at least, (un)sustainability is the background soundtrack to their lives in a way that it has not been for older generations.

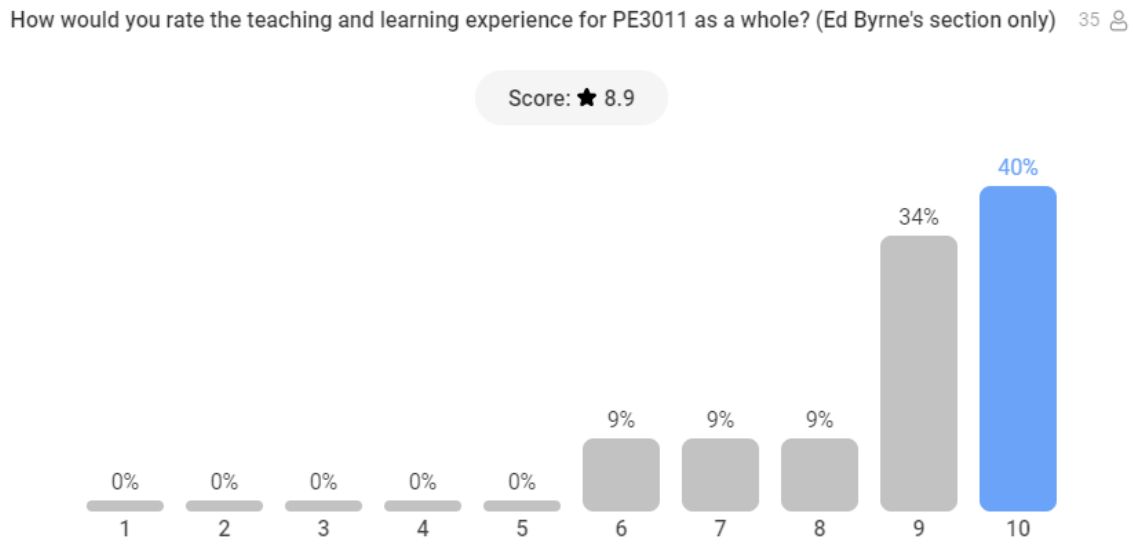

Figure 6 Student rating of module teaching and learning experience.

5 Student reflections

To help gauge to what extent students self-conceptions of sustainability evolved in line with the module learning outcomes – for example to what extent the complexity, interconnectedness or uncertainty of sustainability issues have become more evident to students' themselves – an open question was posed to students anonymously, asking them the following question: *"How might you describe how your conception of 'Sustainability' has evolved (if at all) by taking this (part of the) module?"*

The student responses cohered well with their survey claims (and that of the work they presented as part of the module assessments), with students demonstrating a strong progression and clearly articulated evolution in their awareness and understanding. To demonstrate this, a selection of 20 student responses (out of 30 offered) to the above question are presented here.

- It has evolved significantly from the point of view that, working towards being sustainable is an all encompassing approach to life & not just a simple theory that be solved simply by one initiative.
- It has allowed me to think about sustainability in a different light and highlights the complexity of the issue.
- Seeing sustainability in the sense of a complete system, from the social to the universal, the constraints and impacts.
- How wider evolution (human, planetary ext.) has pushed us to the current state.
- My grasp of the complexity of the world we live in and how a simplified perspective of that world fails to account for really important dynamics - has evolved from this class.
- Sustainability is a compound of a number of disciplines- complex, with no one answer.
- More consideration given to how people's perceptions of the world can impact their views of sustainability.
- This has been my favourite module. ☺
- I feel more confident.
- How the issue or sustainability is a society wide problem.
- I look at it with a holistic mindset now, before my view on sustainability was just recycling, reducing fossil fuels etc. Now I see it as a way of life.
- There's more than just an environmental aspect to sustainability.
- Importance of joining together to overcome individual paralysis.

- I have more of a wide scope view on it now especially as we've discussed the transformation of sustainability throughout the years.
- Being more open minded to different solutions
- It hasn't really changed except for the means of achieving it.
- Consuming what I need as opposed to what I want!
- Not restricted to environmental issues but also social and economic.
- Sustainability is a multidisciplinary issue which can only be put in place when all disciplines work together.
- It's much more complex than just reducing emissions and protecting species.

6 Conclusion

This paper explores some assessment approaches to a sustainability module delivered to chemical engineers and others, one which seeks to explore sustainability framings and contexts, while seeking to enhance understanding of complexity, uncertainty and engaging with same. Student feedback and work appears to demonstrate some good alignment between intended learning outcomes, assessment approaches, and student engagement and learning.

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