When Life Gives You Lemons…: A Creative Approach to Teaching Sustainability to a Large and Diverse Postgraduate Engineering Cohort

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Abstract: A surprising impact of the COVID19 pandemic was the significant increase in taught postgraduate student enrolments across the UK higher education sector. Our university was no exception in this and total enrolment onto our Engineering MSc courses has more than doubled in each of the past two years. As a result, the September 2021 occurrence of the MSc-level Sustainability module had an enrolment of over 400 students across five disciplines. This Case Study showcases our efforts in planning and delivering this module in a meaningful way using active learning, authentic assessment and the leveraging of innovative delivery mechanisms and digital tools.

Research-informed lectures were delivered by a multidisciplinary teaching team, to reinforce the relevance of sustainability to students from a range of technical and cultural backgrounds. Seminars were designed to emulate an academic conference focusing on engineering contributions to the United Nations Sustainable Development Goals [SDGs], thereby capturing the students' imagination and promoting genuine engagement with discipline-specific sustainability issues. The SDGs also featured in group-based formative assessment and individual summative assessment. All sessions were run in hybrid mode due to prevalent travel restrictions in some countries. The resulting complex organisational needs were met using a variety of digital tools, including MS Teams and Power Automate, Blackboard Ultra, Turnitin Rubrics and QuickMarks.

The daunting physical and academic resource challenges of this module were overcome through a combination of collaboration, innovation and creativity. The result is a promising proof-of-concept model for the sustainable management of large modules with a diverse student cohort.

Keywords: assessment, sustainability, pedagogy, international, challenge management.

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1. INTRODUCTION

1.1 Research context

The Industry 4.0 revolution has called for changes in engineering education, with increased focus on productivity improvement, commercial and social value generation, and business acumen required for sustainable development (Trevelyan, 2019). Universities typically value independent thinking whereas engineering work requires inter-dependent thinking and action (Trevelyan, 2020). Engineering Practice research has identified a resulting lack of collaborative thinking in engineering education. In response, the learning outcomes in the latest Accreditation of Higher Education Programmes [AHEP4] for Masters programmes include the ability to evaluate the environmental and societal impact of engineering solutions and to minimise adverse impacts.

Universities are also faced with increasing resource constraints, as well as increasing emphasis on evaluating the quality of the student learning experience. Team teaching has emerged as a potential solution (McKenzie et al., 2022), supported by the blended learning approaches established during the COVID19 pandemic. The pandemic accelerated the digital transformation of higher education and sparked novelties that typically would take years to realise (Adedoyin & Soyaka, 2020).

1.2 Research problem

The focus of this paper is a Sustainability module, developed during the university's periodic review of Engineering courses in 2020-21. This module is core to MSc courses in Aerospace Engineering, Civil & Structural Engineering, Electrical Power & Energy Systems, Instrumentation & Control Engineering and Mechanical Engineering. The module examines the economic, social and environmental pillars of sustainability and their cultural context, using the UN Sustainable Development Goals [SDGs] (United Nations, 2015) as an overarching driver. The module also aims to highlight current research within the department in sustainability and low carbon technologies with examples from various engineering disciplines. Students are required to submit a single piece of coursework at the end of Week 12, the final week of teaching.

The module was originally intended for delivery to a maximum of 100 students, with online delivery a distinct possibility due to the pandemic. However, the unprecedented recruitment during the pandemic meant that there were 422 students enrolled on the first run of the module in Semester 1 of 2021-22. Furthermore, the university returned to on-campus teaching in the same semester. Given the significant space constraints on campus (the largest spaces have a capacity of 300) and the tight turnaround time for evaluation of student work (4 weeks), it was clear that the module had to be carefully designed, with focus on both delivery and assessment.

The Module Team faced several challenges to module operation and management, delivery and assessment, and these are encapsulated in Figure 1 below. In simple terms, the goal was to provide a meaningful learning experience for all students and to improve their ability to evaluate the multi-dimensional impact of complex sustainability problems and associated engineering solutions.

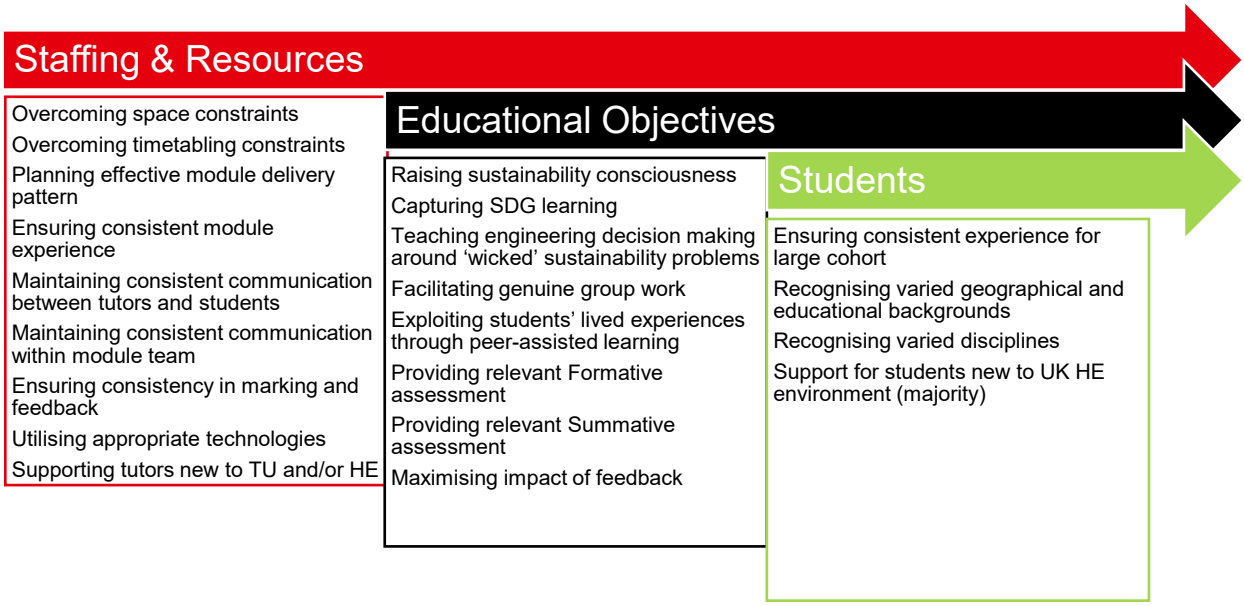

Figure 1 Challenges associated with the research problem

2. SOLVING THE RESEARCH PROBLEM

The problem described in Section 1.2 was solved using an approach that adopted multidisciplinary lectures that drew on the breadth of expertise within the department, a Sustainability Assessment Canvas [SAC] that served as a pedagogic and assessment tool, and a formative Group Learning Activity [GLA] that gave students an opportunity to explore a relevant sustainability issue and receive formative feedback. The individual Summative Assessment used the same template as the GLA to allow students to benefit from the approach taken during the formative assessment.

At the heart of this approach were the SAC and GLA, the latter of which took place in Week 9 of the module, allowing students to move out of a traditional lecture-based setting and into an active learning scenario. This was heavily supported by a range of technologies, see Figure 2 below.

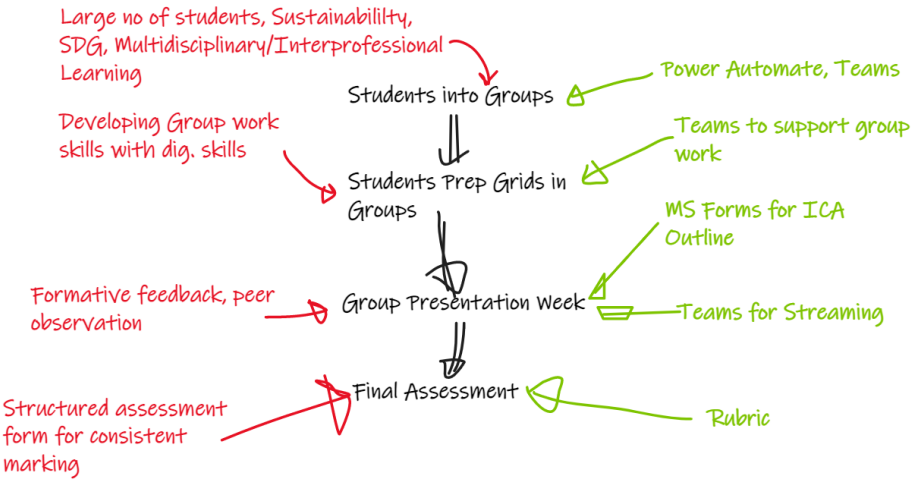

Figure 2 Integration of the GLA into the module, and the digital tools used at each stage

The design process for the module focused on a solution that would address a number of key questions, summarised below with a brief explanation of how they were addressed.

1. **How do we ensure that all students understand the assessment requirements, given their varied geographical and educational backgrounds?** All students were provided with a large range of exemplars spanning disciplines and other contexts.
2. **How do we ensure consistency in marking and feedback provided by the large Module Team?** The SAC ensured that all student work followed a consistent pattern. The GLA provided an opportunity for tutors to develop a common understanding of the task set for students which, coupled with the use of a clear rubric, ensured that marking was consistent.
3. **How and when do we provide formative feedback so that students can use it in their summative preparation?** The GLA provided an opportunity for relevant formative feedback that was available for students to review as they prepared the summative submission.
4. **How do we provide personalised and generic formative feedback given the cohort size?** The GLA sessions enabled students to engage with tutors as a group, both to discuss their group task, but also obtain feedback on their proposed individual summative assessment topics.
5. **How do we make sure that the formative feedback provided is inclusive and is retrievable when needed?** GLA sessions were live streamed via MS Teams to allow all students to attend but were also recorded and made available via YouTube so students could access later.

6. **How do we structure the delivery pattern so that students are ready for the GLA?** The module started with exploration of SDGs and examples of 'wicked' sustainability problems, then onto drivers of sustainability, life cycles and their analysis with interdisciplinary examples before Week 9. Evaluation of engineering solutions was left for later. The intention was to get students to a level where they could reflect on sustainability issues and think about solutions.
7. **How do we maximise the impact of the formative assessment and use it to exploit the students' existing sustainability knowledge?** The GLA required student groups to explore the topics covered in lectures with focus on a particular context. This was then replicated in the individual summative assessment for a different context chosen by the student.
8. **How do we ensure a consistent lecture experience for all students, taking into account pandemic- and space-related constraints?** The lectures were run in HyFlex mode, where students chose to engage in person or online (live or recorded) via the Virtual Learning Environment [VLE]. Space constraints were addressed by assigning in-person attendees to one of two lecture groups on the timetable and delivering each lecture once to each group. Module Team members voluntarily observed other members' sessions to ensure consistency.
9. **How do we use digital tools to streamline the module delivery and assessment for students and tutors?** The use of digital tools focused on ways to reduce the operational overhead and facilitate an individual experience for each student, as described in Section 4 later.
10. **How do we ensure consistency in communication between students and tutors?** The Module Leader managed module design, operation and assessment. The Q&A feature in the VLE was used to moderate student queries outside lecture sessions so that all tutors could see previous communication. Complex queries were referred to the Module Leader. The Module Leader's weekly academic surgery hour served as a drop-in for any outstanding queries.
11. **How do we make the timetable work for the students?** The timetable was reworked collaboratively by the Module Leader, Department Management and Central Timetabling.

3. SUSTAINABILITY ASSESSMENT CANVAS FOR ASSESSMENT AS LEARNING

The assessment approach was a transformatory move from objectivist, teacher-centred teaching to a digitally enhanced constructivist, learner-centred, cooperative pedagogy (Hiltz & Turoff, 2005). The pandemic accelerated the shift from Assessment of Learning to Assessment as Learning [AaL] (Yan and Lang, 2021), leading to a tutor-supported framework for adaptive learning through which students, rather than tutors, manage their own learning gaps (Xin and Yang, 2022). This module used formative assessment extensively to promote students' learning and higher order skills. Evaluation focused on the strategies adopted to complete tasks and provided learners with a comprehensive portrait of their learning process.

The SAC was derived from the Business Model Canvas [BMC] described by Osterwalder and Pigneur (2010). The BMC, which is popular among business entrepreneurs (Ruiz-Ramirez et al., 2019), has been adapted here as a pedagogic tool for assessment. The assessment focused on the three pillars of sustainability, involved multicriteria levelled problems and incorporated multimodal level of feedback. A Guided Enquiry approach was used for formative feedback, following the scaffolding approach proposed in Vygotsky's Zone of Proximal Development [ZPD] (Bayer, 1996). Similar to Beed et al. (1991), some of the features of this approach included a collaborative context, operating in the zone of development and gradual withdrawal of support.

The SAC was driven by the three pillars of sustainability, as shown in Figure 3. It served as a scaffolded means of taking the student through a chosen 'wicked' sustainability problem. Examples included Dharavi, India for SDG11: *Sustainable Cities and Communities*, and USA for SDG8: *Decent Work and Economic Growth*. The intention was to develop a holistic view of sustainability problems and their engineering solutions based on systems thinking. Students achieved this by first researching the case background, and identifying the key social, economic and environmental factors and their linked impact. They then identified potential engineering solutions and their associated cultural contexts. Key metrics were also identified to gauge if the strategies and recommendations had borne fruit over the relevant period.

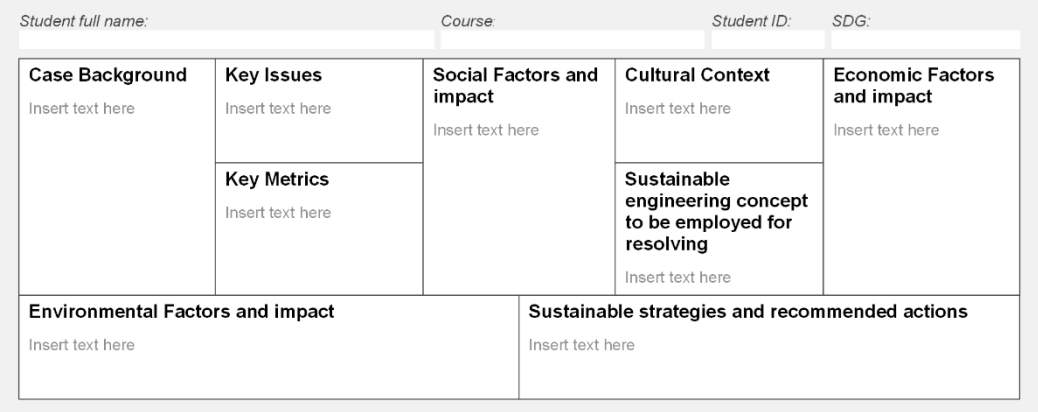

Figure 3 Sustainability Assessment Canvas template, developed by the Module Leader

4. FACILITATING THE STUDENT EXPERIENCE

4.1 Module Team

The Module Team comprised 10 members from different engineering disciplines. All 10 members were involved in supporting and assessing both the GLA and the summative assessment. The lecture sessions were split between 5 academics from different engineering disciplines partly to capture the sustainability-related research undertaken in these specialisms and to inform teaching.

4.2 Delivery Pattern

The sequencing of topics and the delivery pattern based were decided based on summative and formative assessment objectives as mentioned in Section 2. In Week 8, two complete SAC examples were demonstrated to help students understand the approach required for the assessment.

4.3 Timetabling

The module specification dictates 12 hours of lectures and 12 hours of seminars per student. The largest space on campus had already been secured for a weekly 2-hour combined lecture and seminar session. The booking was subsequently repurposed to run each lecture twice, as mentioned in Section 2. One seminar was timetabled as an online session, leaving 11 hours for the GLA.

To achieve this, Department Management booked as many suitable rooms as possible for each available timeslot, ensuring that the total seating time across the week (number of seats x total time booked) exceeded the student time required (422 students x 11 hours). The Module Leader then assigned student groups and tutors to these sessions. Students not assigned to a room were assigned to an online session. Central Timetabling then attached each student to these timetabled sessions,

to comply with attendance monitoring requirements. As a result, each student had 7 hours of on-campus seminars and 13 hours of online seminars listed on their GLA timetable.

4.4 Group Learning Activity

The GLA design was informed by Vygotsky's ZPD (Beed et al., 1991; Bekiryazici, 2015). The cohort already possessed some sustainability knowledge due to the students' varied backgrounds. The Module Team enhanced this knowledge to facilitate critical and holistic evaluation of sustainability problems and their solutions. A scaffolded approach was designed to maximise learning opportunities through directed work and enable peer-assisted learning. The students were split into 40 groups using an MS Forms SDG preference ranking survey. Each group was given one of 10 outline case studies (based on 10 separate SDGs) developed by the Module Team. The outline provided sufficient structure for tutors to scaffold learning through feedback, whilst allowing groups to develop the SAC as desired.

During the GLA week, the Module Team used the available physical spaces to operate a Centre Stage with Satellite Rooms. The Centre Stage was managed by three tutors whereas the Satellite Rooms typically had one tutor. Groups presented their completed SACs and were given feedback at the Centre Stage. This was streamed live to the Satellite Rooms via MS Teams. In the Satellite Rooms, those who were yet to present could seek tutor feedback and watch the Centre Stage livestream to gain further insights. The sessions were recorded, uploaded to YouTube as private unlisted videos and shared on the VLE so that the feedback was available to all. Over the course of the week, students could also discuss their own summative assessment outlines with tutors.

4.5 Digital Support for Group Work

The set up for student collaboration in the VLE offered limited control, prompting the Module Team to use MS Teams, enhanced by the automation capabilities of MS Power Automate. The process utilised two MS Excel tables – the first with a list of Teams to be created (one per group), and the second with a list of individuals to be added to each Team.

The SAC outlines were given to students 1 week before the GLA. The lecture session for the week explained the expectations of group work and the GLA. MS Teams facilitated an inclusive HyFlex approach to group work (Gooneratne & Russell, 2021), allowing part-time students, full-time students in the UK and those still overseas to collaborate as required to complete the required tasks.

4.6 Summative Assessment

The format of the summative assessment and its link to the GLA have been discussed in previous sections. In addition to the SAC, students were also required to include sources and additional information (references and other supporting documentation); reflection on GLA (to highlight lessons learnt); and their sustainability assessment approach (to evaluate the multi-dimensional impact of their chosen engineering solutions).

4.7 Marking summative assessment

The Module Leader developed a Grading Rubric in consultation with other Module Tutors. The rubric evaluated the students' ability to appraise sustainability factors, assess sustainability issues and propose viable solutions, and justify them in a professional manner by evaluating their impact.

The coursework was set up as a Turnitin™ submission on the VLE to combat plagiarism. The QuickMarks feature was used to facilitate the consistent use of appropriate feedback phrases. The moderation consisted of a pre-marking briefing by the Module Leader and a mid-marking benchmarking exercise. Both sessions were conducted via MS Teams and recorded for easy

referral. The marking was completed by all members of the Module Team except the Module Leader, who acted as internal moderator and evaluated a random sample to ensure consistency.

5. EVALUATION AND KEY FINDINGS

5.1 Tutor Feedback

Feedback was gathered from the Module Team with a particular focus on the GLA and the marking process for the summative assessment. Key observations included the following:

- Students with low confidence appeared to welcome the opportunity to discuss their ideas for the topic of their summative assessment during the GLA.
- Many students had based their summative work on topics grounded in their home countries, suggesting that allowing them to co-create the assessment offered intrinsic internationalisation.
- The use of the SAC streamlined the marking process by collecting the evidence of the students' level of understanding in a form that was easy to interrogate.

5.2 Student Feedback

Student feedback was collected using the university's established evaluation survey platform. Quantitative feedback was positive with strong agreement for the following statements:

- I have received helpful and informative feedback on my work within this module so far (Agree/Strongly Agree 75.4%)
- Feedback has helped me develop and improve my learning (Agree/Strongly Agree 76.1%)

The survey ran from Week 8 to 10. Those who responded before the GLA in Week 9 expressed an anxiousness regarding the assessments not seen with later respondents.

5.3 Objective Measures

Attendance data revealed strong engagement throughout the module. Average physical lecture attendance was 85%, with an additional 10% joining the live online simulcasts. The average recorded attendance during the GLA was 64% with each student attending an average of three sessions during the week, although this figure excludes students who worked collectively in other rooms or attended presentations outside of their designated sessions.

Analytics were obtained for the YouTube videos of the GLA sessions. 79% of the views (1505 viewings) took place in Week 12 i.e. in the run-up to the final submission, suggesting that students were using the formative feedback to inform the development of their individual work.

The final marks were analysed with 95% of students passing the module at the first attempt, with 43% of students passing with distinction i.e. a mark of over 70%.

6. CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE

This case study offers valuable insights into a sustainable solution to the challenges posed by a large and diverse student cohort in Engineering education. Reflecting on the challenges posed earlier, these are some areas for future consideration: the timetabling process should be improved to facilitate a better GLA timetable; the SAC and GLA should be introduced to students earlier in the module; the HyFlex mode of the GLA should be maintained even in a post-pandemic climate. Whilst Warburton (2003) posited that active transformatory learning activities are not well served by large classes, the feedback on this module demonstrates a positive response to its design and delivery. Tutors and students found the sessions engaging and appreciated the opportunity for

students to co-create their summative assessment topic. The digitally enhanced, scaffolded, tutor-supported approach adopted in this module has helped students develop a level of critical analysis that is integral to sustainable engineering, and this bodes well for similar modules.

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