# THE DEVELOPMENT OF A SELF-PACED ONLINE COURSE ON SUSTAINABLE DEVELOPMENT FOR ENGINEERS

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## ABSTRACT

Building knowledge of sustainable development in engineering undergraduates equips them to develop future solutions to a variety of societal, environmental and economic challenges. A credit-bearing course has been developed over the last two years at the University of Liverpool to introduce Sustainable Development to first-year Engineering students. Respecting the diverse background and prior experience of this cohort, the course aimed to raise appreciation of global challenges and the role of professional engineers in contributing to their solutions, whilst giving students a knowledge baseline to provide context for further learning in sustainable engineering. It built on an existing self-paced online resource co-created with students, adding newly developed material and including sustainable development case studies specific to engineering. It was structured around the 17 UN Sustainable Development Goals in the context of the 5 P's: People, Planet, Prosperity, Peace and Partnerships. Case studies were aligned to one of the 5 P's with a commentary highlighting how and why engineers were involved in the activity. Assessment was an open book, online MCQ to check engagement and understanding, covering each of the 5 P's. After the first year of implementation, student feedback and satisfaction levels were gathered in an anonymous survey, with engagement measured by rates of completion in the MCQ assessment, and by online page view statistics. Following this, operational adjustments and course updates were made to address some of the major student feedback. This included greater explanation of the engineering skills and solutions that were employed in the case studies, and attempting to address what some students felt were subjective questions. Following updates to the self-paced course, it was deployed and evaluated during a second year. Future refinement will be informed by evaluating how this activity supported students during the rest of their studies, by building baseline knowledge of and appreciation for sustainable engineering across the cohort.

## KEYWORDS

Sustainable Development, Student Co-creation, Student Engagement, Self-paced Learning, Standard: 1

## INTRODUCTION

There are many drivers for engineering students to study sustainable development. A chief reason is to prepare engineering graduates for the challenges and threats to people around the world and to Earth's natural environment. Frameworks exist to categorise these challenges, for example the UN Sustainable Development Goals (SDGs) (United Nations, 2015).

Engineers in particular are and will be vital for developing sustainable solutions to the full range of these global challenges. In the QAA Subject Benchmark Statement for Engineering (QAA, 2023), sustainability and sustainable development are given priority in that document's overall definition of engineering and the importance of how engineers can help to achieve the UN SDGs is included.

Therefore, engineering graduates must contribute to the challenges typical to engineering, such as decarbonisation, and also those perhaps seen as less typical, such as eliminating poverty. The broad range of sustainable development and sustainable engineering solutions should be introduced early into an engineering degree programme to prepare students for this. Exposure to sustainable development solutions will additionally provide forward motivation for students to see how their studies can result in real-world improvements.

To develop sustainable solutions, engineers will develop skills in resilience, adaptability and problem-solving (QAA, 2023). Awareness and development of these skills within engineering programmes will benefit the student's learning in all aspects, not just in sustainable development contexts.

In addition, the current AHEP4 accreditation requirements the UK engineering programmes (Engineering Council, 2021) are enhanced compared to previous editions with respect to sustainability as well as other professional skills.

Finally, engineering graduates today will live and work in a globalised workplace and society. Many of the challenges associated with the SDGs are also global and inter-linked: personal and professional decisions in, for example, the UK will have impact around the world – consider plastic pollution of the world's oceans and its impact on marine life – so there must be wide awareness of global sustainable development challenges for the greatest chance of success.

In this context, implementation of sustainability and sustainable development teaching within engineering has been under review. As part of this, a course was developed at the University of Liverpool for year 1 students in mechanical engineering, aerospace engineering, product design engineering and industrial design, to aid in the comprehensive introduction of sustainable engineering. This is delivered within a common core module relating to Professional Skills. This course aims to bring the incoming cohort up to a common level of knowledge and understanding, recognising the cohort's diverse backgrounds and levels of knowledge and appreciation in this area. This aims to allow better participation in sustainable development learning later in the programme. The development, implementation and review of this introductory course is the focus of this implementation paper.

## COURSE DEVELOPMENT

In embedding sustainability in engineering education, various approaches have been taken. Via literature review and consideration of higher education standards and accreditation requirements, a phased, holistic approach is preferred to integrate sustainability in a programme, rather than sustainable engineering being sectioned off into one module, as noted by Hussmann, 2010. Design and project-based modules have become a natural vehicle for application of sustainable engineering in practice, as seen in Miñano, 2016, Topping, 2022.

However, students have to start somewhere. It was seen as necessary to give a broad awareness and understanding of the concepts and challenges of sustainable development and sustainable engineering near the start of students' first academic year. Only then will they be able to adequately participate in integrated sustainability curriculum content and deliver project modules with true appreciation of the multiple dimensions of 'real-world' (i.e. sustainable) engineering in terms of societal, environmental and economic considerations. After this broad introduction, later sustainability- or sustainable development-related learning can focus on specialist knowledge and analysis, and the development of the competencies thought to be required for successfully tackling the challenges of sustainable development (UNESCO, 2017).

At Liverpool, the acquisition of specialist knowledge is begun later in year 1, continuing throughout all programme years. The year 1 sustainability learning continues with an assessment focused on consumer product carbon footprint measurement using the Eco Audit tool in software Granta EduPack by ANSYS and consideration of the triple bottom line (Zaharia, 2021). Application of sustainability practices and development of sustainable development competencies occurs via project modules in years 2, 3 and 4, including the capstone projects (Topping, 2022).

For the year 1 introductory course at Liverpool, it was decided to make developments to an existing resource that had been recognised nationally and had desirable characteristics already. The resource consisted of a self-paced online course, based in the Canvas virtual learning environment, named Sustainability in Action (SiA) that was co-created with students from the University of Liverpool (University of Liverpool, 2022). It was co-created in 2020 by students from a range of disciplines with the University Careers team and the University Centre for Innovation in Education. The aim of the Sustainability in Action course was to provide an optional introduction to all incoming students of the UN SDGs. The performance and success of this course is summarised in Figure 1.

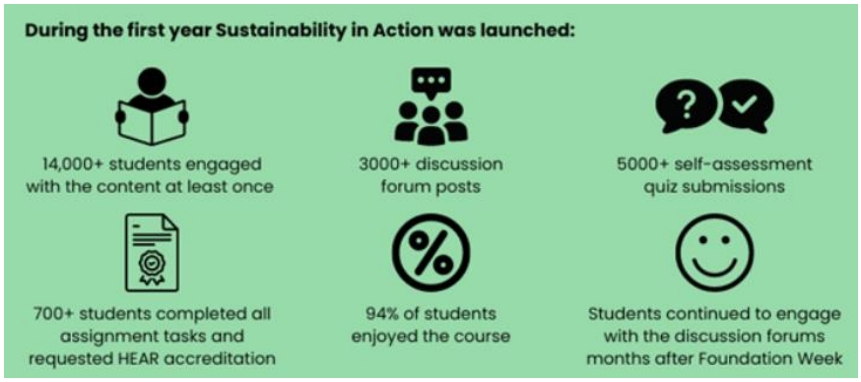


Figure 1. Summary of engagement and success of original SiA self-paced course, before customisation for engineering students (University of Liverpool, 2022)

The course was put in the context of the 5 P's of sustainable development: People, Planet, Prosperity, Peace and Partnerships (United Nations, 2015), as shown in Figure 2. Goals 1 – 6 map onto People; goals 7 – 11 onto Prosperity; goals 12 – 15 onto Planet; goal 16 onto Peace and goal 17 onto Partnerships. Goal 6 is sometimes placed under Planet also.

Within the SiA course, there are sub-modules focused on each P with method of content delivery being via infographic and Prezi presentation. Each sub-module has the following structure:

- an introduction to the SDGs and their underlying targets;
- A set of facts and figures to highlight the scale of the problems related to each SDG, and some of the work towards achieving them;
- Hot topics and case studies, relevant to those SDGs, for example renewable energy, fast fashion, climate justice: this section mainly served to define and exemplify commonly used terms within the topic of sustainable development, that new university students may not have encountered;
- A "What can you do" section;
- A research exercise: by completing all of these, students were eligible for HEAR recognition (Higher Education Achievement Report, 2015);
- A discussion forum for students to engage with each other.

(a)


(b)


Figure 2. (a) The 17 Sustainable Development Goals (SDGs), (b) The 5 P's of sustainable development. From United Nations, 2015

### *Developing an Engineering-specific version*

The SiA course was then developed to contextualise the SDG content for the target engineering students. The structure based around the 5 P's remained similar, with two major changes:

- Inclusion of sets of engineering sustainable development case studies in place of the 'Hot topics and case studies' sections from SiA. An infographic was created that summarised and contextualised the case studies, as well as the original case study text or media being provided;
- Replacement of the HEAR assessment exercises with credit-bearing online quizzes designed to check engagement and understanding.

The original SiA case studies and the 'What can you do' sections were still accessible to the students for their general interest but did not form part of the mandatory course track. The Prezi content was converted to new infographics to give a consistent approach; exemplar infographics are shown in Figure 3. The course material was made available in an accessible text format in addition to the infographics.

(a) (b)

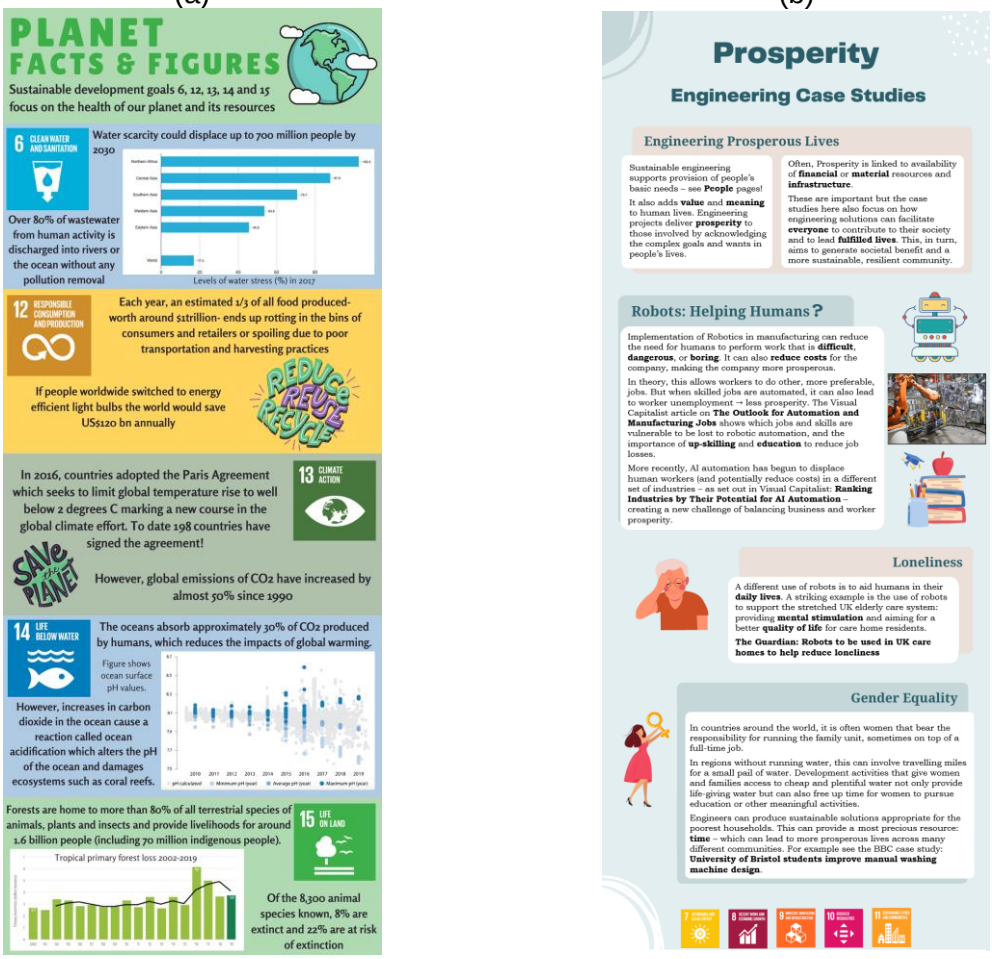


Figure 3. (a) Exemplar Infographic from the original SiA course, (b) Infographic made especially for the engineering version

Case studies were sought that could show practicing engineers and other professionals working to solve SDG issues, grouped by P. This involved research drawing on expertise of the authors to locate suitable items: ranging from YouTube videos, news articles, technical articles, industry articles, with a selection of the case studies used summarised in Table 1.

Table 1. Examples of engineering case studies used

| | | |
|---|---|---|
| People | Farming First - How the World's Engineers Can Make Hunger History | Web Article: https://farmingfirst.org/2015/04/fethi-thabet-how-the-worlds-engineers-can-make-hunger-history/ |
| Planet | How Singapore Fixed its Big Trash Problem | Video: https://www.youtube.com/watch?v=r-q5V6LDxEY |
| Prosperity | BBC: University of Bristol students improve manual washing machine design | Web Article: https://www.bbc.co.uk/news/uk-england-bristol-61641123 |
| Peace | How to Incorporate Social Justice into the Engineering Design Process in Seven Steps | Web Article: https://www.engineeringforchange.org/news/incorporate-social-justice-engineering-design-process-seven-steps/ |
| Partnerships | Nearly all countries agree to stem flow of plastic waste into poor nations | Web Article: https://www.theguardian.com/environment/2019/may/10/nearly-all-the-worlds-countries-sign-plastic-waste-deal-except-us |

In selecting suitable case studies to support the goals and 5 P's, the following criteria were used:

- **Length of resource**: around 15 case studies were used and the target time for the whole assessment was 6 hours. Therefore, resources that students could consume in several minutes were sought.
- **Media**: written articles were used but alternative formats were considered highly important to retain student interest and engagement whilst undertaking the course.
- **Location**: It is important to note that some of the SDGs are local in character, so poverty or environmental destruction in the UK will look different and have different solutions than the same in a Global South nation. For this reason, it is important to present cases to the students that cover different parts of the world.
- **Coverage of non-typical engineering topics**: to engage with students to communicate the idea that engineers can, should and do contribute to the solutions for all 17 SDGs rather than those lying close to traditional engineering applications. Providing as many diverse sustainable engineering applications as possible in the case studies can promote the widest student interest in this core topic.

A wide array of case studies was found during the search phase; all of these including those not selected for the final course have been put into a case study bank, listed by SDG, for deployment within other teaching materials. Therefore, the case study search and selection process has been highly valuable for the wider teaching teams at Liverpool.

The course as presented to the student in the Canvas environment was accessible only one page in turn. This aimed to give some structure for the students to access, understand and digest the sustainable development content in the planned order.

The assessed quizzes for every P were available once the pages for that P were each accessed but the quiz was not a prerequisite element to proceed to the next P section. In addition, the quizzes were not timed and multiple attempts were allowed although no indication of quiz scoring was given upon submission. This gave students flexibility to read and re-read the materials whilst attempting the quiz and aimed to deter a surface learning approach. In the accompanying lecture and assessment instructions, students were encouraged to spend one session on each of the 5 P's, reading the course material and answering the quizzes. Making the course "user friendly" was seen as important so as not to deter students from the start of their higher education journey in sustainability and sustainable development.

## DEPLOYMENT OF THE COURSE: YEAR 1

In the first year of student use of the engineering version of the course, two weeks were given to the students and quizzes were devised with 5 questions for each of People, Planet, Prosperity, Peace and Partnerships. The quizzes were aimed to assess the engagement with and comprehension of the course material. Quiz questions were set as to be answered solely from the provided course materials and case study articles/videos, except for the Peace quiz (the fourth out of five), whereby a short text was given (previously unseen in the course) about which the 5 questions were asked. This was utilised to vary the assessment to maintain student engagement. Questions were a mix of multiple choice, multiple answer, fill in the blank and numerical (requiring very simple calculation based on the numerical data given during the course materials). The assessment was introduced and set in the second week of the first semester, meaning it was the first university assessment that some of the students will have seen.

Some questions tested the students' appreciation of what some of the case studies communicated about engineering in the context of sustainable development. For example, there was a fill the blank question regarding disaster relief, where the two correct answers were "working with people not for people" and "This is a ground up approach".

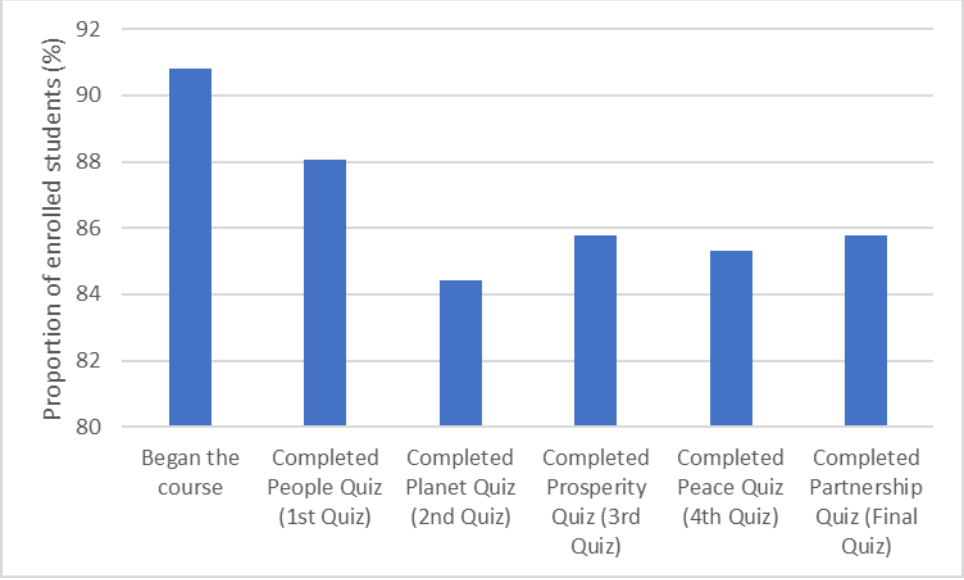


Figure 4. Summary of student engagement during the first year of delivery

Engagement with the course and the assessments can be analysed via proportion of total students enrolled on this core course that engaged with the course or completed it. This is shown in Figure 4, where it is seen engagement was overall high with some drop off of participation towards the end of the self-paced course. Nearly 10% of the students did not engage at all; this could partly be explained by the early timing of this assessment in the university calendar but this was also noted as a target for improving engagement the following year. 93% of those opening the first page of the course completed all 5 quizzes, which is seen as a successful engagement of the students' interest in this topic. There were multiple page views aggregated per student across all parts of the course, indicating that at least some students were using the learning material as intended – to read then return to when needed for quiz questions.

## FEEDBACK AND DEVELOPMENT AFTER YEAR 1

To allow for continual improvement of this course, an anonymous online course feedback survey was made available to the students once they had completed the quiz assessments. The questions focussed on perceived time spent on the course (compared to expected 6 hours), perceived extent of learning from the course and ease of navigation of the online course. Students were also given free text boxes to comment on positive experiences with the course and aspects they thought could be improved.

The course survey was responded to by just over a third of students. Of these over 70% rated 4 out of 5 or higher to the question "How much did you learn about Sustainable Development?". Perception of amount of time spent on the course was in line with the author's expectation.

Students had feedback comments on the ease of navigation of the course and some operational improvements were made before deployment in the second year, including curtailing of some legacy content from the original SiA course that was developed for all students.

There were some encouraging feedback comments from students stating what they had enjoyed learning about and how interesting they had found the course and the case studies. This in itself implies a level of positive engagement with a significant proportion of the students. The main areas for improvement that were commented on were:

- Reducing the ambiguity or subjectivity of some of the quiz questions.
    - All quiz questions were reviewed. Questions where it was thought that we were trying to "put words into the students' mouths" were reworded. Where possible the correct answers for multiple choice questions were taken as quotes from the case study source. The Prosperity section question set was reduced in particular as 'prosperity' is particularly subjective. Quiz questions were reduced to 4 for Prosperity, Peace and Partnerships, but expanded to 9 for People and Planet, where more objective questions regarding the relevant data and case studies could be set.
- Improved opportunity for peer discussion of the issues that the course raised.
    - This was a feature of the original SiA course via the online discussion board, which was removed from the engineering version.
    - In the second year, a two-hour in-person instructor-guided group workshop was held to facilitate the discussion of some of the key concepts from the course.

- To include more focus on what was being done and how to solve some of the issues presented via the SDGs.
    - The infographics that summarised the case studies were reviewed and rewritten, with strong emphasis on what the engineers involved had done and why.
- Data and examples were not up-to-date.
    - Case studies were used dating back to 2011 whereby the authors had used their judgement on whether this was still relevant. However, it could be perceived by the students that these were no longer relevant. Similarly, facts and figures from the underlying original SiA course were occasionally more than 5 years old – this could be related to the period of data collection for certain data types (which may not be appreciated by students) but also to the fact that the major work to create this course was undertaken in 2020, now four years ago. The course will need ongoing refresh most years.

## DEPLOYMENT OF THE COURSE: YEAR 2

With the previously described changes responding to student experience, the course was re-run in the following academic year. Actual performance in the assessment quiz is of course relative so here it is only compared between the first and second year of operation. It should be noted that the assessment was put back by four weeks to the middle of the semester in the second year of operation, and the quiz questions were altered as previously discussed. In Table 2, are the average scores per P and overall between the two years, averaged only for those submitting the assessed quiz.

Table 2. Student assessment score (%) summary across both years of delivery

| Year | People | Planet | Prosperity | Peace | Partnerships | Overall |
|---|---|---|---|---|---|---|
| 1 | 79 | 89 | 72 | 76 | 70 | 77 |
| 2 | 80 | 80 | 90 | 85 | 79 | 80 |

Overall there was a slight increase in student performance between years. The overall high average score (>70%) is deemed satisfactory at this level, particularly as it may help to encourage students to remain enthused in these topics. The slight increase in performance may be due to the improved wording of some of the questions; the quality improvements to teaching material; and the shifting of the assessment to later in the students' first semester.
A similar level and trend were seen in engagement with the course, as for the first year of delivery, seen in Figure 4. In particular the loss of participation of around 5-10% of students between the first and last quiz. One potential remedy that could be considered for future years is the operation of just one longer quiz, covering all 5 P's.

## CONCLUSIONS

The development of an introductory self-paced course on sustainable development for year 1 engineering students has been outlined in this paper. To meet the objectives and required level of such a course, an existing successful in-house course for all students was modified for an engineering audience via incorporation of sustainable engineering case studies and a newly created quiz assessment to test engagement and understanding. Case studies were selected from as wide a range of sources and applications as possible to promote the enthusiasm of students in a diverse cohort.

Significant student engagement and satisfaction with the course was evaluated during the first year of delivery. Some key feedback was gathered via an anonymous feedback survey and action taken to address issues raised to improve the student experience for the next year of delivery. Performance and engagement were consistent across both years reported here.

The method of customising a generic course relating to a professional skill or area of common interest (such as sustainable development here) with case studies specific for engineering or any other subject area may be useful in implementing new learning materials in future, in a pragmatic and effective way.

Future analysis of the effectiveness of this course and similar courses could be to compare student satisfaction and engagement with student background, to ensure that the content is accessible and stimulating for all students. Follow up evaluation of students' recall of the key issues and concepts can be undertaken to assess the impact that the course has had on embedding awareness and appreciation of sustainable development, for example during later projects or specialist sustainability modules, throughout the programme.

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***Tony Topping*** is a Senior Learning Technologist in the School of Engineering at the University of Liverpool. Tony holds an MA in Academic Practice and has 15 years of technical experience having previously worked as a Teaching & Research Technician where he developed and delivered authentic learning experiences. Working closely with faculty and educational developers, his current work focuses on blending pedagogic and technical knowledge to find innovative ways to engage learners and broaden engineering education. He is currently the co-lead for the UK and Ireland CDIO region.

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