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CONVERSATIONS: TEACHING SUSTAINABILITY IN ENGINEERING

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ABSTRACT

Our research focuses on embedding sustainability in the engineering curriculum in ways that are efficient, coherent and inclusive. An important strand of work within this wider remit is finding suitable approaches for promoting collaboration between institutions and academics and advance the understanding of what 'sustainability' means in engineering education in the first place, by producing reliable data that can inform our future practice, leading to institutional change. In this paper, we report and discuss the organisation and the findings of a series of inter-institutional conversations that took place during two in person workshops, with the central theme of embedding sustainability in the engineering curriculum, held at a University in the UK during spring 2022 and the online meetings and interactions that followed. These meetings provided an opportunity for engineering educators from universities in the southwest of England to share experiences from their current practice when teaching about and for sustainability. The workshops explored the feasibility of setting up of an online platform for sharing teaching and learning resources and techniques, all relating to sustainability issues in an engineering education context. They also spoke to the importance of collaboration and cooperation

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1 INTRODUCTION

The 21st century has seen the advancement of sustainability seen as a core value in all aspects of our society, including higher education. The United Nations Educational, Scientific and Cultural Organization (UNESCO) declared 2005 to 2014 to be the Decade of Education for Sustainable Development, in an attempt to coordinate efforts within higher education institutions to achieve a sustainable future (Thürer et al 2017). With this advancement in mind, there have been many publications in recent years on the subject of the integration of sustainability into the engineering curriculum. Most of the research involves the presentation of cases studies (Weiss and Barth 2019; Leifler and Dahlin 2020) from a quantitative and positivistic perspective by studying “what works” (Gutierrez-Bucheli, Kidman and Reid 2022). A second prominent line of research focuses on defining the competencies students should develop during their degrees to contribute to the resolution of conflicts related to sustainability (Quelhas et al 2019). Limited work considers actual student outcomes, that is, exploring the differences between actual and expected learning outcomes. The literature lacks evidence of monitoring students’ interior transformations (Gutierrez-Bucheli, Kidman and Reid 2022). Also, there are not many research studies on the barriers, at institutional and individual academic level, to embedding sustainability in the curriculum.

Four main impediments (Gale et al 2015) have been identified: (1) disciplinary contestation (confusion over what sustainability means); (2) institutional fragmentation, preventing real interdisciplinary approaches due to difficulties in true collaboration; (3) economic globalisation, that has transformed higher education into just another unsustainable market; (4) time-pressed academics with no time to engage fully with the challenge.

It seems, from the research landscape, that there are many pockets of good practice; that there is a proliferation of courses and degrees in sustainability studies but, embedding sustainability as a core across the higher education curriculum has not happened. Most engineering programmes focus on standard engineering science, which can be traced back to the technological race during the cold war (Leydens and Lucena 2017). Whilst some social and ethical aspects are present in most programmes, there is a persistent divide between the social and the technical. In fact, past studies such as (Cech 2014), point out that student interest in public welfare declines over the course of their engineering degree.

Many engineering programmes are attempting to embed sustainability into their curriculum in isolation and substantial benefits could be achieved if joining forces in creating materials, with an emphasis on ontology, detailed methodology and practice. The idea of a platform for collaborating and sharing resources was inspired by the work presented in (Davidson et al 2016), where the need of such as repository was discussed. In this work, the outputs of a workshop discussing the need of the repository were presented with a focus on the practical side - on assessing the community’s preference for a repository and identifying barriers to its adoption.

In our work, we widen the concept of the repository presented in Davidson et al and we discussed the idea with a selected group of colleagues sharing our journeys of embedding sustainability in engineering education. We also argue that, rather than creating a passive repository, we should create an online collaboration space, where we don’t only share resources, but also experiences and we enable academic to connect and expand their networks. During May and June 2022, two in-person workshops on Teaching Sustainability in Engineering brought together 28 educators

to discuss current practice and the feasibility of setting up a shared resources platform with teaching and assessment materials related to sustainability in engineering education. The participants were all academics teaching sustainability in an engineering context at the universities of Bristol (host), Bath, Cardiff and Exeter. We start this paper by explaining our approach to organising the workshops, including their format and predefined themes. This is followed by the presentation and analysis of the discussions around the predefined themes. We then reflect on the emerging areas outside the predefined themes and future steps.

2 METHODOLOGY

In this work, a workshop is used as a research methodology, with the aim of gathering reliable information and feedback about teaching sustainability in engineering that will lead to organisational change. Workshops are ideal for studies that are emergent or unpredictable (Ørngreen and Levinsen 2017), with the findings feeding back into future practice. The central idea of the approach is for participants and researchers to work together in a collaborative manner, with the researchers retaining the control. We considered the different roles that researchers can have in a workshop as research methodology, and two members of the research team adopted clinician roles, focusing on participant needs while the third adopted an ethnographer role, focusing on the research (Ørngreen and Levinsen 2017). An emphasis was placed on not treating participants as consultative research objects, but as research partners. This methodology gained ethics approval from the host institution.

From a methodological point of view, both primary and secondary data were collected from the workshops. Primary data is produced in real time, in our case, researchers produced personal notes and both participants and researchers collected their thoughts using jamboards, a web-based whiteboard system. Secondary data resulted from the retrospective analysis and representations of '*what happened*' during the workshop.

The workshops were designed using a conceptual format (Ørngreen and Levinsen 2017), with a set of predefined phases: we started the discussion by presenting a predefined set of themes for discussion, focusing on current practices and the teaching resources that are used to embed and teach sustainability in the engineering curriculum. We tried to define the need and barriers for a repository and had conversations about the challenges of teaching sustainability in engineering in general and the setup and maintenance of a repository. Some other avenues for discussion emerged during the workshop and will be detailed in the following sections. The predefined themes can be summarised as a reflection on:

- *What students should know: intended learning outcomes.*
- *Our current practice and teaching resources.*
- *Feasibility of creating an online platform for collaboration.*

The outcomes of the two workshops are merged and presented in the following sections.

3 WORKSHOP THEMES: ANALYSIS OF THE DISCUSSIONS

In this section we report on the discussion around the three predefined themes questions already mentioned in Section 2.

Theme 1: What students should know: learning outcomes.

Central to the idea of intended learning outcomes (ILOs) is that teaching should be planned based on the competencies students should develop instead of the results of the learning process. In general, HE institutions in the UK now follow the principle of constructive alignment (Biggs 1996), which means teaching activities and assessment should be aligned to the ILOs. This model has been endorsed in HE policy worldwide. In Europe, educational programmes are said to be more transparent and comparable due to this framework (Havnes and Prøitz 2016). There are some important concerns about this model, as it can be managerial, diminish academic freedom and be focused too much on what can be measured. This last concern is very important when talking about sustainability teaching because many of the competencies we are set to assist the students in developing can be abstract and difficult to quantify and/or express as learning outcomes (Erikson and Erikson 2018). If our students should develop a disposition for critical thinking that includes self-reflection or critical reflection on the world at large, this cannot be separated from the students' private worldviews. Writing learning outcomes about such outcomes implies expectations of performativity that can be seen as an infringement on students' academic freedom (Macfalane 2017). Creating learning outcomes that specify a 'correct' outcome of critical thinking is contrary to the very idea of critical thinking (Erikson and Erikson 2018). Participants attempted to define intended learning outcomes in relation to teaching sustainability in engineering. The gathered information is shown in Figure 1 as a word cloud, where the largest fonts show the highest frequency of a notion. Notions such as awareness and understanding appear quite a few times. We need to emphasise that we are not talking about awareness and understanding in a strict disciplinary context but in a generic context: students need to be able to develop awareness and understanding outside their areas of expertise.



Figure 1. Intended Learning Outcomes defined during the first workshop

Participants agreed that in order to embed and integrate sustainability into the curriculum, we need to broaden the base of the engineering education and make it more interdisciplinary. A limitation to new approaches is the workload which is already high for both students and staff. Teaching new topics would require us to abandon some of the existing content. The professional institutions that accredit engineering programmes may not accept the dilution of the technical content. However, the new edition of the Engineering Council framework for accreditation in the UK does move towards explicitly including aspects of communications,

sustainability, management, or EDI, compared to its previous versions (Engineering Council 2020).

The conversation evolved from critical thinking, to system's thinking and even more philosophically, the purpose of education. For most stakeholders, from policy makers to councils, the current focus is on employability: it seems that employability is the key concept in higher education. Graduate employment rate is often used to assess the quality of university provision, despite employability and employment being two different concepts (Cheng et al 2021). It was also discussed how interdisciplinary systems and critical thinking might not be a key factor for employability.

Theme 2: Our current practice and teaching resources.

In the second part of the workshops, we focused on practical aspects: what are we currently doing when teaching sustainability. We posed these three questions to the participants:

- *What materials do you currently use in your teaching?*
- *Are there any teaching techniques that have worked particularly well or particularly poorly for this topic?*
- *What would make it easier for you to teach sustainability in engineering?*

Participants were divided into teams for discussion. When asked about the teaching materials they use, participants mentioned traditional tools such as textbooks for technical content or journal articles which we would expect to be consulted. They also mentioned a wealth of other resources which are much more in tune with the latest developments, such as newspaper articles from the Guardian or the Financial Times, IPCC reports, Ted Talks, Fly zero reports by the Aerospace Technology Institute, governmental reports, interviews with professionals, games, news or podcasts. These resources are inherently dynamic and take up significant time to research and keep up to date, compared with the traditional science-focused books that have been known to us and have been part of the curriculum for a number of years.

In answer to the second question, participants brought up techniques such as: role play, guided discussions on current events, letting students think outside the box, setting grand challenges, linking activities with people's lived experiences, creating strong links with technical content, using anonymous polling software or working with external partners and entities such as Engineers without Borders. These activities require careful preparation and are more challenging to manage, adding again to staff workload and stress, which was identified as a challenge in the second part of the question. One of the most important issues identified was keeping the students engaged with sustainability and other complex wicked problems. Engineering students typically learn to solve well-structured problems using established methods to arrive to a solution (Lönngren 2019). Other challenges centred around the difficulty of catering for very large cohorts, staying abstract or teaching sustainability in isolation, in parallel with the technical content.

The last question in this section was about what would be helpful for the participants in their sustainability teaching. All answers hover around two areas: (1) fully understanding what is going on at university and programme level with clear

definitions of what we are trying to achieve (2) collaboration and sharing, a good indication of the need of the proposed online platform.

Theme 3: Feasibility of creating an online platform for collaboration

In the final part of the workshops, we focused on the idea of developing an online platform with teaching materials on sustainability. Again, groups were formed to discuss the answers to the following questions:

- *Would you be interested in using an online platform for teaching materials, sharing your own teaching materials, or both?*
- *What would encourage you to use and share materials on the platform?*
- *What would you expect from the online materials?*
- *In your opinion, what are the main challenges for such a platform?*

In answer to the first question, there was a consensus that a platform would be a helpful tool. For the second question, four main areas emerged: (1) ease of searching materials and a clear user guide, (2) hosting interactive/inclusive/rich materials, (3) having information about the source of materials and the authors and (4) attributing sources to authors.

We also talked about additional information that could be added to the teaching resources such as the setting in which they should be or have been used (cohort size, staff to student ratio, student's feedback on the activity) and also adding AHEP tags, relating material to accreditation criteria. The need for clear licencing rules was also noted, and the need of a mechanism for attribution to authors that could be used for career development and an indicator for career progression was reiterated. Moving into the last of the pre-defined question, the challenges for establishing a platform, three main issues were discussed: copyright, the cost of the curation of the materials and worries about sharing your own materials with others: *'Is the content right? Will others agree/like it?'*

The issue of curation is very important, in the past there have been several attempts to create networks and repositories that died after a short while due to lack of funds for maintenance. Several ideas to produce income were discussed such as authoring a fee-paying online book, creating an open access journal or hosting the repository under the university IT umbrella.

4 EMERGING THEMES

As anticipated, a series of relevant associated issues emerged, such as the lack of a clearly defined ontology for sustainability in engineering education and the tensions arising at different levels due to conflicting views on what sustainability means and its purpose in engineering in general, and in engineering education in particular.

These are all part of the wider research project we are undertaking.

First and most important, the need to take a step back from learning outcomes and explore the definition of an ontology for sustainability teaching in engineering. The main challenge we identified was that sustainability means different things to different people, so we need to accommodate that clearly into the ontology, we need to embrace and work with different views on sustainability. There is a fundamental debate whether to adopt a strong or a weak conception of sustainability (Ayres, Van den Bergh and Gowdy 2001) engineering students need to be aware of all

approaches and be able to take their own position in the sustainability discourse (Advance HE 2021).

Secondly, there was a clear appetite and need for collaboration, not only with academics already actively working on embedding sustainability in the curriculum, that tend to have a similar view on what sustainability means, but also to reach out to others not engaging or not interested in the sustainability agenda. We also discussed the need to more actively embed the student voice in the definition of our frameworks by offering opportunities for students to work as researchers on our projects.

Building on the reflections and findings presented in this paper, our wider work includes establishing a definition of an ontology that acknowledges the different facets of sustainability, the mapping of current provision against this ontology, the creation of test cases with examples. This is work in progress and it has been developed in close collaboration with undergraduate and postgraduate students, working as co-researchers.

5 SUMMARY AND FUTURE WORK

In this paper we present the outcomes of two cross-institutional workshops organised in the context of setting up a platform for sharing resources for teaching sustainability in engineering education. The workshops covered three thematic areas around learning outcomes, current practice and associated approaches and barriers, and the development of teaching resources.

Based on the positive feedback and discussions held in the workshop, we have created an online platform featuring the desired characteristics and functionality. This is already active and it now needs to be populated with materials and resources. Once the first set of resources are added, we will invite academics to register and start sharing practice and collaborating.

Future work includes the creation of training resources to inform and inspire academics who do not currently engage with the sustainability agenda.

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