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Moorhouse, C

zj20649@bristol.ac.uk

The Cabot Institute, University of Bristol, United Kingdom

Abstract

Uniquely placed to impact positive change, engineers have a responsibility to respond to the climate crisis. In turn, engineering educators have a responsibility to prepare graduates for this task. However, there is widespread appetite for change, evidenced by the skills-gap highlighted by industry, the dissatisfaction reported by many students, and feedback from teaching staff, who often report feeling burnt out.

This research (which is ongoing) aims to support improvements in undergraduate engineering education by exploring the preferences and priorities the students and staff and highlighting keys areas of agreement - which may indicate 'low hanging fruit' - and of friction - which may need more careful navigation. A mixed methods approach was taken, focussing on staff and undergraduate students within the University of Bristol's Faculty of Engineering.

A survey of 84 students revealed a wide range of responses regarding teaching quality, content relevance, and subjective experiences among undergraduates and suggested several predictors of satisfaction, including feeling that their courses are well aligned with their personal values, and that sustainability is well addressed.

A round of 13 interviews then explored the experiences and opinions of students and staff in more depth, looking at what they imagined an 'ideal' engineering education would look like, and how sustainability would fit into it. Early analysis has looked at the pervasive idea that 'you can't please everyone'; disagreement around the extent to which resourcing is a limiting factor to improvements; and the widely held view that to embed sustainability would mean to reference the topic more, within existing curricula.

1 Introduction

The role of an engineer is constantly evolving, in response to the continual emergence of new technologies, shifting global priorities and a broadening definition of the role (Magarian JN, Seering WP., 2021). It is important, then, that engineering education is able to adapt to the evolving skills needs of the industry (Gough & Scott, 2008).

One particularly urgent shift has been an increasing awareness of the climate crisis, and of the responsibility of engineers – and their educators - to help address it (Engineers 2030, 2024; Global Responsibility of Engineering, 2022). This has become a priority across the sector, with UK engineering companies increasingly calling for graduates equipped with sustainability-related skills (UK Skills Survey, 2020).

This research aims to support this adaptation, by exploring:

- How undergraduate students and staff conceive of the ideal engineering education, particularly with respect to sustainability.

- The potential impact of differences in these views on student satisfaction and on institutional change.

2 Literature Review

2.1 Demand for Change

Criticism of engineering education is rife. Many believe that it does not effectively prepare graduates for the working world, has not responded to the climate crisis with enough urgency, and neglects important skills such as creativity and systems thinking (Engineers 2030, 2024).

Engineering educators have a responsibility to prepare students to tackle global environmental challenges (Global Responsibility of Engineering, 2022). However, evidence suggests that universities are failing to equip engineering students to meet the needs of industry. For example, only 7% of engineering companies believe they have the skills they need to fulfil their sustainability strategies and around half are already struggling with a skills shortage strategies (UK Skills Survey, 2020).

2.2 Embedding Sustainability

In order to evaluate possible responses to this pressure, the purpose of engineering education, and (inextricably linked) how its success could be measured, must be considered. How sustainability should fit into the curriculum is a question which brings these issues to the surface. While there is widespread appetite for change within engineering education, particularly in response to the climate crisis, there is no consensus on what this change should look like.

For some, the best response would be to add sustainability related content into existing course structures. This might look like referring relevant issues or technologies where possible (but keeping the curriculum mostly unchanged) or it could mean replacing existing content with modules focussing on the topic more directly. William Wulf (former president of the National Academy of Engineering) believed that global contexts should be 'as fundamental as thermodynamics' to engineering courses, for example (Wulf, 2009).

Others believe that this would ‘have limited effect’ (Sterling et al., 2018) and truly ‘embedding’ sustainability would require systematic transformation. The idea here is that education unavoidably plays a storytelling role (Chachra, 2005; Facer, 2019; Molthan-Hill et al., 2020), so even apparently neutral content can perpetuate harmful ways of framing problems and seeing the world. For example, techno-optimistic worldviews are rarely challenged; problems are often simplified; and it is rare that subtracting from a situation, or leaving it alone, is encouraged. These habits might neglect to nurture ‘systems thinking’ (Engineers 2030, 2024). Proponents of this view might suggest that courses should give more time to reflection on ‘the values, ethics and morality’ of content (Kamp, 2023; Sterling, 2024) and be more interdisciplinary and community-focussed (Reimagined Degree Map, 2024).

A better understanding of how engineering students relate to these perspectives could offer valuable insight into the possibilities for change within the sector.

2.3 Examples of Change

Setting this contention aside, the science of learning can help inform an understanding of ‘best practise’, regarding methods of teaching. There is strong evidence, for example, for the efficacy of ‘active learning’ (Dolmans et al., 2016; Freeman et al., 2014; Prince, 2004), and the emotional experiences of students (such as boredom, enjoyment, or pride) are well recognised to be central to engagement and

learning (Pekrun et al., 2011), although the body of research on emotions within *engineering* education specifically is still 'dispersed and not well consolidated' (Lönngren et al., 2023).

Several newer institutions have pioneered new models of engineering education, informed by the science of learning. For example, Minerva (USA), NMITE and TEDI (UK), and Aalborg (Denmark) all use flipped classroom formats, use active learning pedagogies such as problem-based learning, and minimise their reliance on standard 'chalk and talk' lectures (Habbal et al., 2024; Kerrey, 2018; *NMITE*, n.d.; *TEDI London*, 2025).

2.4 Barriers to Change

These examples serve to demonstrate the fact that alternative approaches to the higher education of engineering are possible. Despite this, many demonstrably positive changes have not been widely implemented (Graham, 2018). This is not for lack of will - educators generally express 'genuine and strong interest in improving student outcomes' (Henderson & Dancy, 2011). Nor is it a lack of know-how; there are numerous resource banks and toolkits designed to support these transitions (Engineering Professors Council, n.d.; Finelli et al., 2014; Reimagined Degree Map, 2024). So what are the barriers blocking the pipeline from research into practise?

A multitude of answers emerge from the literature aiming to address this question, ranging in scale from practical constraints such as classroom layouts, to larger topics of leadership and responsibility (Henderson & Dancy, 2011; IET & EPC, 2019). This research aims to focus in particular on the motivations of faculty members, rather than on logistical/resource constraints.

2.5 Research Questions

In conclusion, there is clear demand for updated engineering curriculum, but also many barriers to change, including a lack of research into the preferences of engineering staff and students with respect to proposed changes. While it is understood that the preferences of students vary widely, and that universities embody 'a set of tensions, permanently present' (Anderson, 2010), a more precise understanding of the priorities of faculty members is necessary for the most appropriate balance to be stuck. In light of this, the following research questions have been defined:

1. What are the priorities and beliefs of engineering students and staff, with respect to their courses, and to the topic of sustainability?
2. Do these preferences impact student satisfaction?
3. Does misalignment in these preferences (within faculties) create a barrier for change?

3 Methods

The research objectives identified relate to engineering students' experiences, and to staff and students' priorities with respect to engineering education. A mixed methods approach was taken, comprised of a survey and interview phase. This allowed the data to capture a breadth of student experiences, and for individual preferences to be understood in more depth. The scope was limited to participants from within the University of Bristol, for ease of recruitment, and so that variation within a single faculty could be explored.

3.1 Student Survey

The purpose of the student survey was to gain a broad understanding of the experiences of engineering students at Bristol. It asked for participants' course and year group, and then consisted of 29 multiple choice questions, and the option to add a free-text comment. 84 student participants were recruited, via

posters, emails and social media, and in person. Their responses were anonymous unless they opted in to being invited to interview. This sample included students from all year groups, and across a range of courses, including Mechanical, Aerospace, Design, Electrical and Civil Engineering, and Engineering Maths.

Most aspects of success in HE can be categorised as relating to: the quality of teaching, the choice of content, or the student experience. The survey broke each of these categories down into a number of proxies, and also asked about the variation of each between units. By including questions about various aspects and components of each, I was able to gain a richer understanding of students' varied experiences, within the constraints of a short, multi-choice survey.

With respect to the 'student experience' category, students were asked how frequently they experienced a range of emotions (e.g. stress, boredom, excitement), in relation to their course. I used the framework of Russell's 'circumplex' model (Russell, 1980) to conceptualise these, including emotions from each quarter of the circumplex.

3.2 Interview Phase

The purpose of the interview phase of this research was to explore people's preferences and experiences in more depth, and to bring in the perspectives of staff, as well as students.

There were 13 participants: seven staff and six students, across a range of programmes, career/study stages, and levels of satisfaction. Students were recruited via email, having opted into being contacted following their survey completion, and staff were contacted directly (having been identified via the faculty SharePoint, or recommended by other staff). Interviews were semi-structured and were between 30 minutes and hour in length. They were recorded and transcribed.

Asking people to imagine 'ideal' scenarios can provide valuable insight and inspiration for change (Fernando et al., 2019; Levitas, 2013), as well as helping avoid discussions getting stuck on 'hygiene factors' (Gibbs & Wood, 2018). For these reasons, participants were asked to imagine the best possible version of their courses (or of engineering education more generally), if there were no practical constraints. This was a crucial section of the interview, and aimed to reveal what people felt the ultimate goal or purpose of engineering education should be.

Participants were also asked to imagine a 'bare minimum' version of their course, to identify what they felt the responsibility of the university was, with respect to its teaching. And finally, they were asked how they understood the term 'embedding sustainability', how important they felt it was, and what it would mean – in their view – to perfectly embed sustainability into an engineering curriculum.

3.3 Analysis

A table of Spearman's rank order coefficients – appropriate for smaller sample sizes and ordinal data (Cohen et al., 2011) - was used to identify relationships between survey variables.

Interview transcripts were analysed inductively with reflexive thematic analysis, in relation to the research questions, following Braun and Clarke's six stage process (Braun & Clarke, 2006).

4 Preliminary Results and Discussion

Collection and analysis of data is ongoing, so *all of the following results are preliminary*. This section is intended to provide an initial idea of how the data I have gathered may be used.

4.1 Survey Results

84 engineering students at Bristol University have completed the student survey. Table 1 displays some notable r values taken from the Spearman's correlation matrix of survey variables. Only a selection of variables are shown in the table, for simplicity, and they have been paraphrased for space.

Table 1: Spearman's Rho Values for Selected Survey Variables.

	Survey Variable	Correlation
Agreement with statement in relation to course	Aligns well with personal values and ethics	0.26
	Allowing to reach potential as an engineer	0.48
	Preparing well for a career in engineering	0.44
	Content will *not* be useful after university	-0.25
	Some topics or skills are neglected	-0.32
	Thorough understanding of content	0.36
	Teaching is effective	0.48
	Sustainability is well addressed	0.24
	Standard of teaching varies between units	-0.28
Frequency of emotion in relation to course	*Excitement / Enthusiasm*	0.33
	Stress / Pressure	-0.22
	Neutrality / Emotionlessness	-0.29
	Interest / Curiosity	0.34
	Dread	-0.26
	Confusion	not significant
	Sadness / Dissatisfaction	-0.32
	Boredom / Disinterest	-0.31
	Enjoyment / Delight	0.51

Figures 1 and 2 help visualise two of these correlations. Here, it can be noted that while there is a negative correlation between dread and satisfaction, they were several students who reported feeling dread 'extremely often / constantly' but also reported high levels of satisfaction with their courses. The student interviews were able to provide insight into this findings. For example, one participant who had reported high levels of dread explained that this was mostly in relation to exams, and that they felt it was inevitable.

Many variables are straightforwardly good or bad, in this context. For example, a high standard of teaching would clearly be good. However, a more nuanced interpretation is required of the emotions, as some 'negative' emotions may be useful (Pekrun, 2006). For example, experiences of stress and pressure can be motivating. For all variables, it is important to bear in mind the wide-ranging predispositions of students (Oishi & Tay, 2019), and to not assume causation.

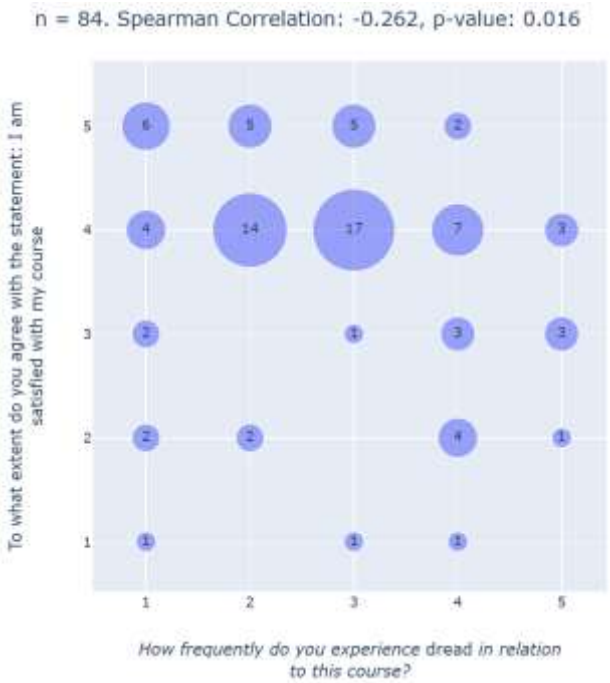

Figure 1: Frequency of Dread Against Satisfaction

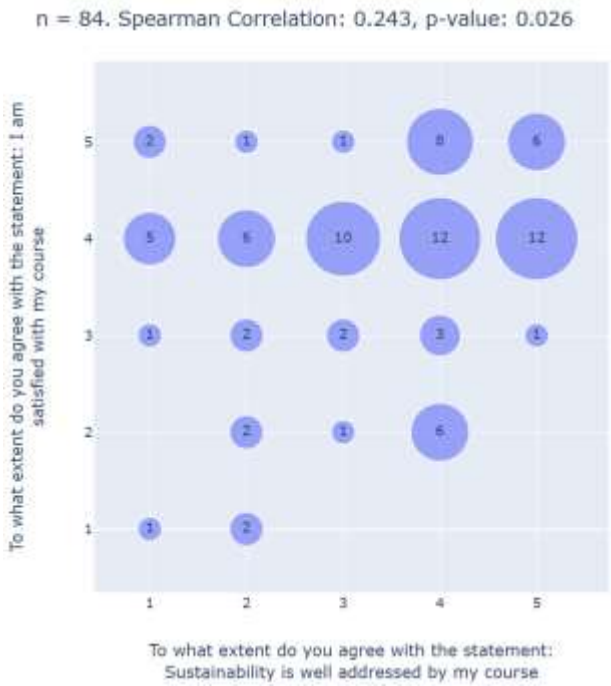

Figure 2:Sustainability Well Addressed Against Satisfaction

4.2 Interview Findings

Early analysis of 6 student and 7 staff interviews, using a reflexive thematic approach, has generated three preliminary themes: 1) the idea that you can't please everyone 2) disagreement in perceived barriers to change and 3) the idea that references to sustainability should be pervasive.

1) 'You Can't Please Everyone'

Many participants – particularly staff – were certain that pleasing everyone would be 'totally impossible,' as 'different things work for different people'. The high variation in teaching quality reported by students in the survey was mostly put down (by staff) to this.

However, there was not much variation in students' descriptions of their ideals – a finding which could challenge this assumption. For example, almost all expressed a desire for more practical work within their courses, and felt that it in general, cohorts would agree on which units were most effectively taught:

'I'd say there was definitely consensus – like strong consensus. There's generally lecturers in each section of: mid, everyone loves them, and everyone agrees that they're terrible at teaching. And there's not a lot of personal variation on those opinions, I think.'

2) Disagreement on Perceived Barriers to Change

In line with existing research (IET & EPC, 2019), resourcing was the most commonly cited barrier to improving engineering courses at Bristol. However, there was disagreement among staff abound whether the limiting factor was in fact resource constraints or, instead, a lack of will. Whilst many were certain that most proposed changes would 'cost too much', and the faculty 'just don't have the time or the money', others were less sure, calling this 'a rubbish reason', and expressing the belief that 'we could probably make all of those things happen if we wanted to'.

3) Pervasive Reference to Sustainability

Most participants felt that embedding sustainability into engineering courses was important, and – when asked what it would look like to do this well – described making it 'pervasive', by referencing the topic 'every time that it could be applicable'. Most felt that the existing structure and rough content of the courses could remain unchanged. Some staff members raised more radical ideas, such as including 'low tech' solutions in the curriculum or having students work on projects 'for the community good', but felt these 'would [not] be very well welcomed,' as most other faculty members wanted to 'just carry on' and not make any 'dramatic' changes.

5 Conclusion

This paper has summarised the preliminary findings of a student survey and round of interviews exploring the experiences and priorities of engineering undergraduate students and staff at the University of Bristol.

Early analysis of the survey responses has revealed a wide range of experiences among the undergraduate population and has suggested relationships between aspects of these experiences.

Staff and student interviews explored people's conceptions of an 'ideal' engineering education, including what it would mean to perfectly embed sustainability within it. In these conversations, broad agreement around the importance of embedding sustainability more deeply into courses was found, but there was disagreement around the feasibility of improvements, and resignation to the idea that it is not possible to please everyone.

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