PEDAGOGICAL APPROACHES TO PROJECT-BASED LEARNING: MEETING THE EDUCATION NEEDS OF THE GLOBALLY RESPONSIBLE ENGINEERING WORKFORCE

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Abstract: The world is facing increasing complexity, uncertainty, and change, such as the climate emergency, biodiversity loss and increasing inequalities. Engineering graduates entering the workplace will address sustainability and global challenges, well beyond the horizon of the Sustainable Development Goals (SDG). Addressing these requires disruption to traditional education pedagogies and approaches, to enable students to develop globally responsible outcomes and tackle the complex challenges of the future. Project-based learning is a unique and powerful tool for connecting across disciplines, experience levels, and stakeholders, with the goal of redefining engineering and the way that it is taught and practised. During a pivotal moment in an undergraduate student's learning, the Engineering for People Design Challenge encourages multi-disciplinary groups of university students to broaden their awareness of the social, environmental, economic, and ethical implications of engineering alongside technical skills when developing solutions. Since its conception in 2011, the in-curriculum design challenge has reached over 60,000 students. This paper explores how and where the design challenge has been embedded and some of the innovative approaches that embed globally responsible engineering principles and commitment for emerging graduate engineers. Approaches include cross-faculty delivery, multidisciplinary teams incorporating the arts and fully project-based learning. The findings of this paper are part of a longitudinal study to understand the dynamic approaches to delivering the design challenge and seeks to inspire educators and challenge traditional approaches to engineering education.

Keywords; global responsibility, design challenge, project-based learning, learning journey, competency, engineering for people

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1. INTRODUCTION

1.1 Engineering education design and delivery

Engineering plays a critical role in addressing global challenges and fulfilling the Sustainable Development Goals (SDGs), which "requires adopting a more thoughtful approach that encompasses the social, human, economic and environmental impacts of engineering" and "more complexity in the curriculum" (UNESCO, 2021). However, surveys and calls from industry highlight that education is currently not preparing engineers with the urgent skills to deliver sustainable development (Institution of Engineering Technology, 2021; EngineeringUK, 2022). The SDG Index for 2022 has highlighted no country will deliver on all 17 goals. Engineering curriculum used to evolve with the needs of society. However, it appears to have stagnated. Recent updates to engineering accreditation standards have included more areas relating to sustainable development and globally responsible engineering while encouraging more complexity within the

curriculum (Truslove, et al., 2021). However, these encourage rather than require working towards the SDGs and some are still input-based rather than outcome-based. It takes time to train engineers and current and future students will be working well beyond the existing SDGs into increasingly complex technologies and challenges. The skills gap coupled with stagnation in engineering curriculum leaves the profession lacking globally responsible engineers with the right skills for meeting SDGs by 2030 and beyond. Engineering education needs to move quickly to adapt.

Education for Sustainable Development empowers and motivates learners who are capable of critical thinking and shaping a sustainable future (UNESCO, 2017). Beagon, et al. (2022) explores what competencies are perceived by students, academics and industry to deliver on the SDGs and sustainable development. Alongside technical skills, the study highlighted all stakeholder groups identified: Social responsibility, sustainability awareness, ethical consequences, innovation, creativity, project management, communication, collaboration, and teamwork. Multi-disciplinary skills were also perceived as necessary. The World Economic Forum (2020) also highlights the skills needed for 2025 including creativity, critical thinking and navigating complexity. Learning outcomes that reflect the skills needed to tackle sustainability challenges will involve an interdisciplinary reorganisation of curriculum content, structure and delivery.

1.2 Engineering for People Design Challenge

Project and problem-based learning involve a complex learning process to identify problems and select approaches while working towards developing solutions. Adding complexity to the well-versed approach supports competency development, embedding social responsibility, knowledge retention and can bridge the gap between education and industry. It is not a question of if project and problem-based learning works but rather how it is implemented (UNESCO, 2021).

The Engineering for People Design Challenge is an in-curricular educational programme that seeks to inspire the next generation of globally responsible engineers to be Responsible, Purposeful, Inclusive and Regenerative (Engineers Without Borders UK, 2021a). Delivered through a project-based learning pedagogy, multi-disciplinary groups of university students participate in the design challenge to broaden their awareness of the social, environmental, economic, and ethical implications of engineering alongside technical skills (Engineers Without Borders UK, 2021b). Based on the EWB Challenge run by Engineers Without Borders Australia, the Engineering for People Design Challenge is delivered in partnership between Engineers Without Borders South Africa and Engineers Without Borders UK. Since its launch in 2011, the design challenge has been delivered to over 60,000 students in the UK and Ireland since 2011, in South Africa and the USA since 2019, and in Cameroon since 2022. It is embedded in the first or second year (or third year for a five-year master's course) of undergraduate engineering, or related curriculum, making it a mandatory part of the degree course. Educators can incorporate the design challenge in a way that works best for them such as integration into an existing module or launched as a new course. Each year, a real-world design brief is developed in collaboration with a community partner. This resource is shaped by the insights and reflections from the local community to develop a portrait of the place and the engineering challenges in the local area. Students work in teams to propose a solution to a challenge presented in the design brief (see www.engineering-for-people.org). The Engineering for People Design Challenge is also a national competition. Top student submissions to the Grand Final which showcases the impact of the design challenge on students learning and provides an excellent opportunity for students to present their work to future employers and

industry experts. Submissions are reviewed against a common set of marking criteria by international expert reviewers. See Neuman and Truslove, 2021, on how this review process benefits volunteer reviewers in many of the same ways as the participating students, providing further opportunities to scale impacts in engineering education and industry.

2. APPROACH

2.1 Monitoring and evaluation

This paper forms part of a longitudinal study that looks at the impact and delivery over ten years of the design challenge in engineering education. This paper explores the delivery approaches that have been taken in delivering the Engineering for People Design Challenge, with particular attention across the COVID pandemic, that seeks to inspire and challenge traditional approaches to engineering education. This paper also forms part of a larger body of work by Engineers Without Borders UK on producing an actionable framework that measures the competency of embedding globally responsibility in engineering through knowledge, skills, and behaviours.

2.2 Annual participation and interviews with educators

The Engineering for People Design Challenge takes a monitoring, evaluation and learning approach to improve upon the delivery of the design challenge each year. Educators confirm their participation in the design challenge with their country's Engineers Without Borders partner (e.g., South Africa or the UK) through initial surveys, and provide details on the disciplines and modules involved, student engagement and what educators hope to achieve. The variations in approaches for participating universities in Ireland, South Africa, the UK, and the USA were explored. Semi-structured interviews conducted in 2017 were also explored. Transcribed interviews of four educators at Sheffield University, University of East Anglia, Imperial College London and the University of Greenwich are interrogated. All four universities have continued to participate to date in the Engineering for People Design Challenge since the interviews were conducted.

3. DELIVERY OF ENGINEERING FOR PEOPLE

3.1 Participation and curriculum integration

Table 1 presents the breakdown of participation in the Engineering for People Design Challenge and the delivery at universities. During 2019-2022, engagement in the design challenge has increased despite the disruption of adapting to delivering education during the COVID pandemic.

Table 1 Overview of delivery and student engagement

Overall			Participating universities								
Year	No. of universities [a]	Total students	Credits [c]			Duration (weeks)			No. of students		
			Min	Max	Avg.	Min	Max	Avg.	Min	Max	Avg.
2021-22	47	11,297	0	60	13	0.5	45	14	6	1,272	205
2020-21	44	10,349	0	30	12	0.6	39	15	8	1,400	229
2019-20	37	7,494	0	30	13	0.6	35.8	14	15	1,200	196
2018-19[b]	30	5,991	0	40	14	0.6	51.43	18	30	1,400	206

[a] Responses can include multiple sign-ups from the same university. [b] Responses include participating universities from the UK only. [c] USA: Min=0.6, Max=3, Avg.=1.2, South Africa: Min=8, Max=44, Avg.=17.7.

Educators have embedded the design challenge into their curriculum in different formats. Delivery ranges from intensive delivery across a week to one or two semesters. The University of Sheffield explained how intensive delivery success comes down to structure, staff support and buy-in.

"I think the majority [students] come to either value it or see it as a good part of their, at least as an integral part of their design education…We now have a semi-formalized review meeting at the end of Wednesday where students have a semi-formal setting to present to members of staff and PhD students. On Friday afternoon when they are being assessed, that is done with members of staff. Staff input is really important just for showing the value of it" University of Sheffield

3.2 Delivering to disciplines

Figure 1 presents the disciplines involved in the design challenge. A significant proportion of responses (29.1-41.4%) were through Engineering (General), which covers modules on general engineering skills and concepts across the engineering faculties reflective of the early undergraduate curriculum. Engineering (Multi-disciplinary) can include multiple engineering disciplines (for example Mechanical Engineering and Civil Engineering). Delivery across multiple engineering disciplines has grown from 2% of universities in 2018-19 to 32.7% of universities in 2021-22. N/A represents where the discipline was not disclosed during sign-up.

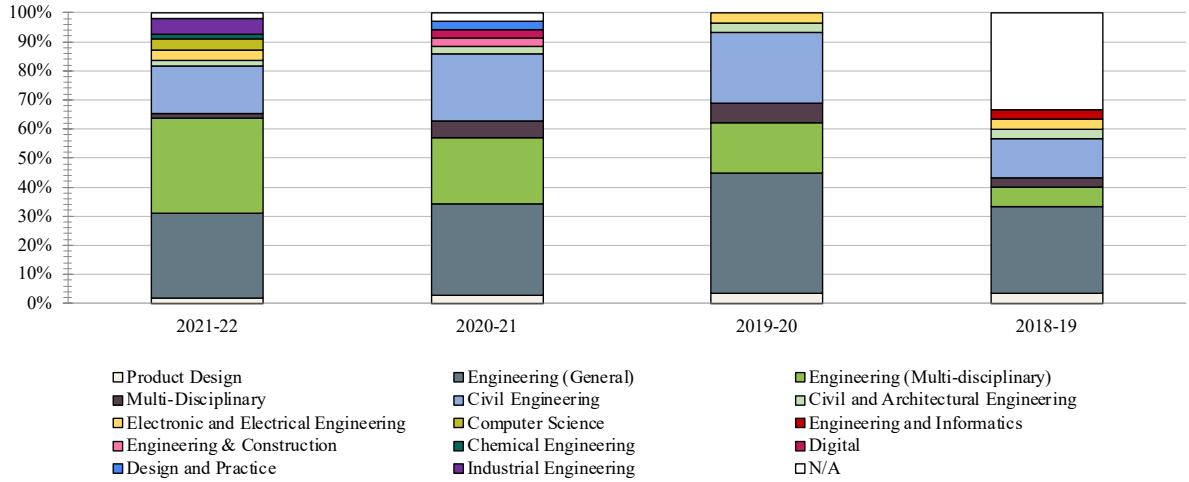

Figure 1 Distribution of disciplines delivering Engineering for People

Integration with existing modules also opens opportunities for cross-faculty and multidisciplinary engagement, to break out of the silo of engineering and attract engagement across undergraduates and staff (Byrne and Mullally 2016).

"Our program is open to undergraduates from across Imperial College…What we do is within the module that we offer, they can study any of these 4 streams….Design for Sustainable development. Which is probably best aligned to students who want to enter the Engineers Without Borders competition… Design for Economic Development where the students have to design an enterprise.... possibly a business or an NGO…Visualising Global Challenges stream…the students are actually producing a piece of artwork… Design for Local

Sustainability…they look at different case studies, they look at our campus and they come up with designs that could improve some aspects of sustainability…in the streams, [the students] are in the same classroom, but doing different aspects of the project" Imperial College London

Further, opportunities within existing modules to integrate the design challenge can strengthen the facilitation of broader skills development, that is relevant across engineering education.

"The Engineering Practice Module that we put this in, every first-year engineering student does it. It focuses on challenging soft skills if you like…. we have a sort of multidisciplinary first year to some extent." University of East Anglia

"One of which was Engineering and Professional skills…It's a very wide-ranging course and we were struggling a little bit with the context of how we sort of ensure that students really do get some of the principles of it…It covers obviously some of the engineering design challenges, but it does it in a way that actually introduces and embeds a lot of the professional skills we are looking for, so team working, time management project planning, all sorts of things really that students get to learn on the job." University of Greenwich

3.3 Institutional buy-in

Any curriculum changes can face internal barriers. Staff capacity while also delivering expected learning outcomes and faculty requirements are noted as the main barriers to institutional buy-in. While the minimum credits are no credits (Table 1), the non-credit bearing does not mean the design challenge is not mandatory.

"At the moment it is constrained by the academics available" Imperial College London

"They all have their very heavy teaching workload, they all have research workloads as well, they're supervising undergraduates, postgrads, PhD students…So, I understand that me saying "oh, would you mind giving up a bit of extra free time to support these students" is not always the best news." University of Greenwich

I think the hardest thing we come up against is we make it compulsory, and it is not credit-bearing." University of Sheffield

However, while there are tensions between requiring the design challenge to be in the curriculum and reaching as many students as possible, varying significantly from a couple of hundred students to a thousand students in one university (Table 1), embedding the design challenge in the curriculum can influence wider improvements and opportunities for enhancing teaching. Accreditation and industry bodies are calling on changes to curriculum that prepare future graduates with the skills to creatively work across disciplines and that acknowledges the growing uncertainty and complexity of the challenges they will face in their careers. Exploring opportunities outside departments can open doors to integrating aspects that are needed for the engineering curriculum.

"There was a series of workshops that were hosted on the Global Dimension of Engineering Education...At the time I was in Civil Engineering, but I was also in a faculty of engineering

working group to look at developing multidisciplinary working in the faculty of engineering…In Civil Engineering we already have quite a strong focus on Environmental issues at an early stage and that wasn't the case in every department. The focus on humans and designing for people came into different departments in some ways more than others. It was that human, ethical, environmental, and social side of engineering that we wanted to try and give a good kick-off at the first-year level. After that, it was combined with other focuses in the faculty to develop team working, employability skills, etc. So, from my point of view, there was a good engineering education basis and then it was combined with other skills and interdisciplinary working which came all together as things we had identified that we wanted to do." University of Sheffield

A siloed approach to teaching concepts of sustainable development can be attributed to falling short of critical skills which are more likely to be offered optionally or at the postgraduate level (Alexa, et al., 2020). Emphasising the holistic benefits, from university goals to student skills development to meet the requirements for accreditation, has helped increase buy-in and is a successful driver for integrating Engineering for People into the curriculum.

"Staff, those that are involved, the majority of those that are involved come to see the benefit of it. Directors of learning and teaching and departments value it because…we do link it to their development with respect to accreditation requirements. We have attached learning outcomes to it and departments value it for that as well. I think our industry partners again comment favourably on it, they like the exposure, they like the exposure students get to themes in the week but also to group working and interdisciplinarity of it as well." University of Sheffield

"It was kind of a natural choice really, it covered all of the civil disciplines, yet it actually covers a lot of other things as well…And I've got some really, really positive feedback from most of my students about what they learned from it, how they learnt and how they grew, the kind of research they did and all those things.' University of Greenwich

3.4 Motivation and connections between students

Not every student will have the same experience or perspectives. Bringing disciplines to work together breaks out of the silo of engineering. Peer assessment between disciplines as part of the assessment process in some universities can provide students with a rich experience and the space to welcome diverse perspectives and find creative solutions through inclusivity.

"*They have to provide a consultancy report on another team of peers…and then when they write their own report, they have to explain how they responded to that consultancy report….I think the students enjoy being in a room with lots of other students doing kind of exciting projects. And they definitely enjoy the peer review of other students who are not necessarily in the same streams." Imperial College London*

While not all students and educators will be drawn to the global aspect of the Engineering for People Design Challenge, the competition aspect can be a strong motivator for participation in modules at university. However, the journey educators and students go on through participation can facilitate awareness of the role engineers can play in global contexts and challenges.

"So, because this is a competition, this will drive them more than I can teach them. So it wasn't driven by the need to give them the Global perspective at all, to be honest. But I now realise of course, how important that is." University of East Anglia

Drawing on the experience of those who have participated in Engineering for People is another way of motivating current participating students, whilst gaining support in delivery. Aligning to the volunteer reviewer experience discussed in Bryce and Truslove, 2021, engaging past participating students can be seen as a bi-directional inspirational and educational opportunity.

"We have alumni come in during the week and that's another source that people find useful. People who have done it, in years in the past come back and volunteer to come and support it. So, we have good relationships with alumni coming back." University of Sheffield

"If we have a poster day, I'll be inviting students from all the engineering programs of all years. I'll have 2nd, 3rd and 4th years there and that would hopefully be quite encouraging for the 1st years, so they see that some of their peers who have been through the…presenting previous years on the EWB cohort, so they can discuss it with each other." University of Greenwich

4. FINAL REMARKS

Educators have ownership over how the Engineering for People Design Challenge is embedded into their curriculum, which has seen the design challenge adapted in a variety of different ways, reflecting their responsibility and agency as educators. The design challenge has been launched as a new module or integrated into the existing curriculum and delivered over a term, academic year or intensive delivery. Participation has continued to grow, despite the disruption of the COVID pandemic. Participating universities have shown that practically embedding the design challenge as a mandatory part of the curriculum is possible and can inspire and open new avenues for transformative curriculum change, whilst connecting disciplines and faculties. It is important to recognise that alongside the structure of delivering the design challenge in the curriculum, the instructional discourse and regulative discourse have an impact on education. Overall, the design challenge is providing students with the opportunity to engage across disciplines, practice creativity and equip them with the skills needed by future engineers and sought out by industry. A workshop at the UK Grand Finals in June 2022 has brought together the educators delivering the design challenge, to critically reflect on its delivery, the lessons learned and to look forward to future visioning of transformative engineering education. This activity will also help inform wider work between Engineers Without Borders UK and the Royal Academy of Engineering on higher education embedding sustainability and global responsibility into engineering curriculum. The outcomes will be shared during the conference.

5. REFERENCES

Alexa, L., Maier, V., Șerban, A. and Craciunescu, R. 2020. Engineers Changing the World: Education for Sustainability in Romanian Technical Universities—An Empirical Web-Based Content Analysis. Sustainability, 12(5), 1983.

Beagon, U., Kövesib, K., Tabasb. B, Nørgaardc, B, Lehtinend, R., Bowe, B., Gillet, C. and Monrad Spliid, C. 2022, Preparing engineering students for the challenges of the SDGs: what competencies are required?. European Journal of Engineering Education, 1-23.

Byrne, E. and Mullally, G, 2016. Seeing Beyond Silos: Transdisciplinary approaches to education as a means of addressing sustainability issues. In: Leal Filho, W., Nesbit, S. (eds) New Developments in Engineering Education for Sustainable Development. World Sustainability Series. Springer, Cham, 23-34.

EngineeringUK, 2022. Net zero workforce: An analysis of existing research, Url: https://www.engineeringuk.com/research/briefings/net-zero-workforce/.

Engineers Without Borders UK, 2021a. Reaching the tipping point for globally responsible engineering. Our Strategy 2021-2030., Url: https://www.ewb-uk.org/wp-content/uploads/2021/05/Engineers_Without_Borders_UK_Strategy_2021_2030.pdf.

Engineers Without Borders UK, 2021b. Engineering for People Design Challenge, Url: https://www.ewb-uk.org/upskill/design-challenges/engineering-for-people-designchallenge/

Institution of Engineering Technology, 2021. 93% of industry without skills to meet 2050 climate targets, Url: https://www.theiet.org/media/press-releases/press-releases-2021/2-february-2021-93-of-industrywithout-skills-to-meet-2050-climate-targets/.

Neuman, B. and Truslove, J. 2021. Volunteer Professionals in an Undergraduate Design Challenge: Contributing to and Practicing Globally Responsible Engineering, *Research in Engineering Education Symposium & Australasian Association for Engineering Education Conference*, Perth, WA, 5-8 December 2021.

Truslove, J., Crichton, E., Chance, S. and Cresswell-Maynard, K. 2021. Momentum Towards Incorporating Global Responsibility in Engineering Education and Accreditation in the UK, *Research in Engineering Education Symposium & Australasian Association for Engineering Education Conference*, Perth, WA, 5-8 December 2021.

UNESCO, 2017. *Education for Sustainable Development Goals: Learning Objectives.* Paris, France.

UNESCO, 2021. *Engineering for sustainable development: delivering on the Sustainable Development Goals*. Paris, France.

World Economic Forum, 2020. The Future of Jobs Report 2020, *World Economic Forum*, Switzerland. Url: https://www3.weforum.org/docs/WEF_Future_of_Jobs_2020.pdf.

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