2023

Tools To Reshape Engineering Education To Prepare Students And Professionals To Be Globally Responsible

Jonathan TRUSLOVE
Engineers Without Borders UK, United Kingdom, jonathan.truslove@ewb-uk.org

Sarah Jayne HITT
New Model Institute for Technology and Engineering (NMITE), sarah.hitt@nmite.ac.uk

Emma CRICHTON
Engineers Without Borders UK, United Kingdom, emma.crichton@ewb-uk.org

See next page for additional authors

Recommended Citation

Truslove, J., Hitt, S. J., Crichton, E., Kraus, J., & Upton, J. (2023). Tools To Reshape Engineering Education To Prepare Students And Professionals To Be Globally Responsible. European Society for Engineering Education (SEFI). DOI: 10.21427/1W7Y-XF49

TOOLS TO RESHAPE ENGINEERING EDUCATION TO PREPARE STUDENTS AND PROFESSIONALS TO BE GLOBALLY RESPONSIBLE (PRACTICE)

Jonathan Truslove [1]
Engineers Without Borders UK
London, UK
ORCID: 0000-0001-5671-0616

Sarah Jayne Hitt
New Model Institute for Technology and Engineering (NMITE)
Hereford, UK
ORCID: 0000-0002-0176-6214

Emma Crichton
Engineers Without Borders UK
London, UK

John Kraus
Engineers Without Borders UK
London, UK

Juliet Upton
Royal Academy of Engineering
London, UK

Conference Key Areas*: Embedding Sustainability and Ethics in the Curriculum, Engineering Skills and Competences; Lifelong Learning for a more sustainable world*

Keywords*: global responsibility, learning journey, competency, sustainability, upskill*

ABSTRACT

This paper describes the development of two tools that support educators to prepare the engineers of today and tomorrow for the simultaneous, deeply interconnected challenges that the 2023 Global Risks Report emphasises as a ‘polycrisis’. This picture is worsened when considering the Institution of Engineering and Technology

[1] *Corresponding Author:*
J. Truslove
jonathan.truslove@ewb-uk.org

in 2021 found that only 7% of 1,000 UK engineering companies with a sustainability strategy had the staff with the skills to fulfil it. Against this backdrop, meeting our commitments with integrity, upskilling the current workforce urgently, and ensuring degree courses are future-fit are crucial. In response, these two new actionable tools aid educators in exploring and accelerating curriculum change. First, the Global Responsibility Competency Compass is an articulation of the essential skills, knowledge and mindsets required by the globally responsible practices society needs today. The Compass is designed for everyday professionals in the engineering sector looking to effectively navigate the complexity, uncertainty, and challenges of our age. Second, the Reimagined Degree Map, helps educators develop robust action plans to consider the broader purpose of engineering education and design relevant learning. The Map supports the translation of intention into tangible changes by designing regular learning about engineers' understanding of their global responsibilities and how to navigate through them. This presentation will describe the context and process of the tools' development and present feedback from key stakeholders and early adopters. Early results suggest the tools can support educators in collaboratively embedding sustainability and global responsibility as a core tenet across higher engineering education.

1 INTRODUCTION

University is a formative stage in becoming an engineer. The ability of tomorrow's engineers to enter the workforce as skilled and responsible professionals is shaped by how we educate them today. Universities (and engineering practitioners at all levels) have a huge role to play in prioritising a broader role beyond the traditional focus on technical skills, to ensure engineers can act in a sustainable, ethical and equitable manner; in short - in a globally responsible manner. The recent flourishing of many new and innovative methods, programmes, and institutions attempting to address this reinvention shows that it starts with how engineers are educated (Graham 2018). Scholars now agree that engineering education must respond to and reflect a 'big picture' context, to help learners navigate the complexity and priorities of our age, not just short-term industry needs (Högfeldt et al. 2022). Yet, educators may struggle to find, understand, and/or enact tools within their teaching that enable this change.

1.1 Context

Historically, engineering education has focused on graduates' ability to solve technical problems (Litzinger et al. 2013). While the value of technical skills in an increasingly tech-centric world should not be understated, the narrowing of focus on the technical alone has resulted in the exclusion of critical factors that ultimately interplay with the technical aspects of real-world engineering projects (Munir 2022). In the last decade, engineering educators have been faced with managing and implementing curricular changes, often at a fast pace. One factor has been the emergence of innovative ways to deliver engineering curricula that challenge the traditional lecture-based format of higher education, to deliver skills and project-based learning in response to real-world and industry concerns (Guerra et al. 2017). In addition, the Covid-19 pandemic required a particularly rapid response to switch to virtual learning and alternative assessments (Graham 2022). Faced with these challenges and the impetus to integrate learning for sustainable development, engineering educators may feel stymied about how to enact meaningful change within institutional structures.

People working in all fields are now required to navigate greater complexity and uncertainty in addressing societal and ecological risks. Engineering has to be part of that response, but to effectively do so it must embrace a broader role beyond its traditional focus on technical skills. Further, the sector is therefore being called upon to develop and apply the knowledge, skills and behaviours that reflect the broader impacts that its decisions have on society and the environment. However, when it comes to competency in the UK, there is a risk that an education and skills gap could hinder progress towards decarbonisation, sustainability strategies and net-zero 2050 targets (IET 2021; EngineeringUK 2022). Against this backdrop, educators need to consider what they are preparing tomorrow's engineers for, and why.

To address this challenge, Engineers Without Borders UK (EWB-UK) worked with the Royal Academy of Engineering (RAEng) to conduct a research study in 2019 on the extent to which global responsibility is embedded in engineering practice (Engineers Without Borders UK 2022). The findings from this study spurred an action in 2022, to spark wider change to reimagine what a globally responsible degree would look like and consist of. This work would build from the efforts EWB-UK has been undertaking to upskill over 250,000 people by 2030 with the skills and expertise to be globally responsible, highlighting the need to reimagine existing competency frameworks. This approach guided the development of tools that engineering educators can employ to equip future and current engineers with the skills required to respond effectively to the challenges of our age.

2 METHODOLOGY

2.1 Defining the skills gap

First, it was necessary to understand and define what knowledge, skills, and mindsets engineering students require in the area of global responsibility. To do so, we drew upon the four guiding principles for the teaching and practice of engineering that were established through the development of the EWB-UK strategy for 2021-2030 to put global responsibility at the heart of engineering: **Responsible** (To meet the needs of all people within the limits of our planet. This should be at the heart of engineering), **Purposeful** (To shape outcomes to be equitable and ethical throughout engineering and the life cycle of any project), **Inclusive** (To ensure that diverse viewpoints and knowledge are included and respected in the engineering process and outcomes) and **Regenerative** (To maximise the ability of all living systems, to achieve and maintain a healthier state and naturally co-evolve).

Initial proposals of related competencies under each principle were framed under knowledge, skills and mindsets to align with theories suggesting that learners must both acquire and integrate these three areas to achieve competence (Baartman and de Bruijn 2011). Research was then undertaken into existing competency frameworks and literature to understand how these principles are presented internationally and in the UK, to support embedding these principles into day-to-day engineering practice. This process revealed the large number of existing competency frameworks that help professionals focus on specific areas of training, build workforce capability and identify skills gaps, or make a determination about professional qualifications. With this in mind, the goal became not to replace these existing frameworks, but to enhance them and support the lifelong learning required from engineering professionals with the competencies of global responsibility. What emerged was the Global Responsibility Competency Compass as an articulation of the essential skills, knowledge and mindsets required to embed global responsibility

in engineering approaches and outcomes (which can be downloaded at www.ewb-uk.org/global-responsibility-competency-compass). The Compass sets out 12 competencies and is organised around the four guiding principles of global responsibility.

2.2 Keeping curriculum relevant

The Compass is focused on the competencies required of multidisciplinary groups of professionals that work in engineering. These competencies must also be enabled through the education and training of these professionals, which in turn requires a change in higher engineering education (Högfeldt et al. 2022). Therefore, in response to the challenges inherent in supporting that change, the Reimagined Degree Map was developed to help guide curricular adaptation by shifting the focus on areas such as sustainability and global responsibility from being ad hoc and optional, to being of high quality and being a core thread across the education of engineers. Studies have shown that this is in demand by students, with 60% expressing they would like to learn more about areas such as sustainability (Students Organising for Sustainability 2021). Doing so will require “a more thoughtful approach that encompasses the social, human, economic and environmental impacts of engineering" and “more complexity in the curriculum” (UNESCO 2021, 123). However, making changes to curriculum also takes time, effort and motivation. The Map pulls from the experience of EWB-UK, the RAEng, expert educators, and a knowledge bank of research. It is rooted in a strong vision to integrate education that enables graduates to develop their ability to act sustainably, ethically and equitably throughout their careers. It is also action-oriented so that universities can make these changes practically and quickly. The Map is framed around a series of exercises to aid educators, deans and heads of departments to make changes to create, share and explore empathetic, impactful and relevant changes to engineering curriculum, including:

1. Bringing together teams across faculty, school or engineering departments in creative collaborations to build a shared understanding of the current state of engineering education at their institution, and build teams' confidence in critical conversations with students about the future of engineering.
2. Exploring the broader context for today's educational system (the complexity, uncertainty and challenges of our age), to keep curriculum relevant and translating what this means for civil, mechanical, electrical, general and chemical higher education engineering courses.
3. Identifying interventions educators can make to curriculum (such as adapting learning outcomes, active pedagogies/techniques to deliver complexity, real-world project briefs and mindset development, maximising multi-disciplinary experiences, and authentic assessments), to design relevant learning for students to understand and embrace their broader responsibilities as a core thread of their learning experience.

In unpacking the complexity of holistic student learning journeys, the Compass and models such as Doughnut Economics (Raworth 2017) and the UN’s Sustainable Development Goals, helped guide initial ideation by providing a framing of the global context and professional development needs emerging engineers will be entering into. The Map is also rooted in well-versed models for building learning, mindsets and approaches over time, including: Bloom’s taxonomy of learning, Bill Lucas’s habits of mind (Lucas and Hanson 2014), Maslow’s hierarchy of needs (Maslow

1943), and Kohlberg and Rest's theories of moral development (Rest et al. 2000). Sustainability components can link to competencies required by accrediting or professional organisations (e.g. AHEP 4, GAPC, UK-SPEC), while linking to other curriculum maps for different engineering disciplines, meaning educators can see an example of how the sustainability components can link to learning outcomes in particular modules.

3 DISCUSSION

3.1 Consultations

To test the approaches and content articulated in the Map and the Compass, a series of consultations and testing with educators, students and professionals in the sector was undertaken. These were conducted through events, conferences and workshops with participants via surveys using Menti (www.menti.com) to gather feedback. These consultations were undertaken in the context of the Accreditation of Higher Education Programmes (AHEP), which in the UK aligns with the Engineering Council's Standard for Professional Engineering Competence (UK-SPEC) for professionals' competence and commitment. During the consultation phase of the Compass development, the Engineering Council endorsed it "as a useful resource that complements the requirements of UK-SPEC. This tool helps to bring to life and articulate the skills and actions everyday engineering professionals need to act in a way that is sustainable, equitable and ethical" (Engineering Council 2023). AHEP is intended to be read in the context of the competence and commitment required for professional qualifications (Engineering Council 2020). Participants during consultations were asked to reflect on their vision for the future of higher engineering education. An example of the responses is presented in Figure 1.

Fig. 1. In one word, what is your vision for engineering education (educators at the Institution of Structural Engineers, n=23).

Ideas related to sustainability, regenerative practices and the inclusivity of approaches came out as top themes for the future vision of higher engineering education, with similar responses from other engagements. When students were asked what they thought was an engineer's most valuable attributes, the responses were ranked in the order as: problem solver, socially aware, environmentally aware, collaborative, technical and interpersonal. However, participants' reflections on their own education suggested that sustainability was not a core part of their higher education, and is not so for current students (Figure 2).

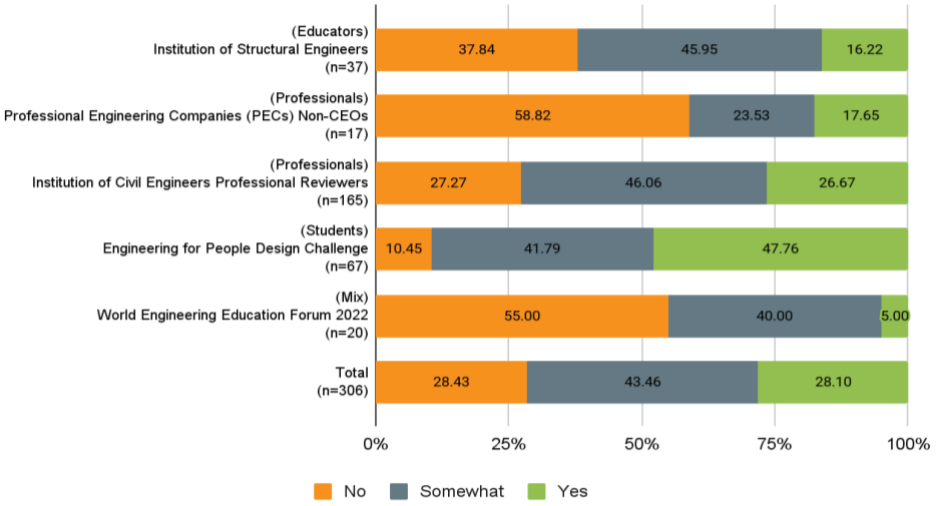

Fig. 2. In your opinion, did your degree, or equivalent, prepare you to act sustainably and equitably? (Note: Students at first and second-year undergraduate reflect on their degree currently. The Engineering for People Design Challenge is a real-world in-curriculum design challenge delivered through project-based learning, to broaden awareness of the social, environmental, economic, and ethical implications of engineering alongside technical skills).

Across professionals and educators, less than a third reflected that sustainability was core to their education. Less than half of students reflected that sustainability is core to their current education, complementing previous studies that this is in demand from students (Students Organising for Sustainability 2021). Nearly 72% of total participants said sustainability either “is not” or “is somewhat” included in their higher education. There is a consistent vision of embedding sustainability and global responsibility into how higher education is taught (Figure 1) and recognition that higher engineering education has yet to embed it as a core tenet (Figure 2). Participants - both practitioners and educators - also expressed notable importance and willingness attached to changing how engineering is taught and practised (Figure 3). However, there is a confidence gap in understanding how to do so.

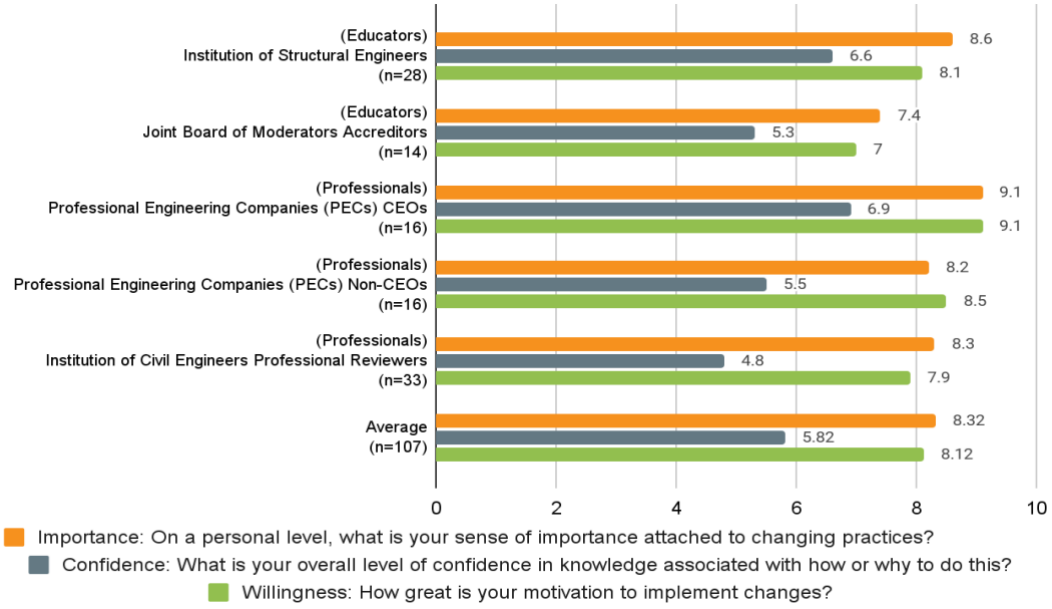

Fig. 3. Movement towards changing practice to embed global responsibility. (Note: Joint Board of Moderators asked through the context of the Climate Emergency).

During engagements, educators cited the top barriers to ensuring teaching focuses on global responsibility:

- The pace of change needed and the stress this places on individuals.
- Hesitance in managing the change well with the time available while keeping accreditation and improving student satisfaction.
- Access to globally relevant (and up-to-date/diverse) expertise to support teaching about sustainability that is motivational to students.

For educators looking to keep curriculum and learning outcomes relevant, the Compass provides a useful framing to inform learning outcomes throughout the curriculum. It encourages lifelong learning for emerging engineers and supports the reskilling of engineering professionals (to pursue topics that may have been absent from the individual's formal education) and constant evolution in competency through educational activities. Across all engagements, there was a key focus on competencies related to critical thinking, awareness, navigating complexity, resilience, empathy, collaboration and inclusion, and identifying solutions. Participants also recognised that knowledge and skills are a strong focus in higher engineering education, while mindset development, reflected in the Compass, is more challenging to reflect in the current curriculum. However, early feedback on the Map suggests that starting with exploring the broader context and what mindsets students are developing was helpful framing while showing how it can be incorporated into existing areas of accreditation and signposting to best practice. Additional feedback also indicated that the Map could be effective in collaboration and communication with professional engineering institutions and other university departments - with the aim of bringing all engineering courses together for a minimum standard of delivery that is directly relevant to industry and society.

3.2 Limitations and future work

The development of the Compass and the Map has been informed by research incorporating insights internationally and in the UK. However, for practical reasons, the consultations and testing with the educators, students and professionals presented in this paper were limited to the geographical association of the authors (except for the World Engineering Education Forum and Institution of Civil Engineering Professional Reviewers). Expanding on how these tools are received globally can be expected as these tools develop and roll out. Future work will include sharing relevant learning within a global community of educators and practitioners and critically reflecting on how to continuously evolve what globally responsible engineering looks like. Longer term, it will be important to tilt towards greater geographic diversity in capturing lessons learnt and gaining wider perspectives to inform research and advocacy efforts in the global educational systems. In particular, this should include engagement with more educators in emerging economies where there are large numbers of engineering graduates (or where capacity is growing in the future).

The exercises in the Map aim to identify creative collaborations that can deliver high-quality learning, to bring in wider expertise, from different departments, faculties and industry, and focus the time spent by educators more effectively. It is not incumbent on individual educators to create all learning content and deliver it to students. For example, the Engineering for People Design Challenge provides evidence of higher engineering education working with organisations to embed relevant and complex contexts in engineering curricula. The RAEng and EWB-UK are bringing together a

group of early adopters made up of higher engineering educators to test the Map, and a community of contributors for both tools to support their delivery and adoption while building knowledge on how they are used to accelerate change.

4 SUMMARY

While the Map and Compass are separate tools, they are complementary and are intended to inform each other in designing holistic learning journeys from higher education to professional life with global responsibility as a core thread. Both are aimed at giving users greater agency.

Engineers do not work only with engineers and must work in deep collaboration with other disciplines, foster active participation from citizens in decision-making, and adopt holistic approaches. The positioning of the Compass is purposefully not exclusive to engineers; it values the multi- and interdisciplinary contribution of non-technical skills and also challenges the value that engineering typically places on the dominance of narrow competencies. In turn, the Map encourages collaboration to prepare emerging engineers in the multidisciplinary delivery of real-world projects, within the curriculum. The outcomes of the early adopter engagement will be shared during the conference.

The authors would like to thank the valuable contributions of educators, students, representatives of professional engineering institutions and consultants who continued to contribute to the development and iteration of these tools. The authors would also like to thank the anonymous reviewers for their constructive feedback to improve this paper.

REFERENCES

Baartman, Liesbeth K.J., and Elly de Bruijn. “Integrating Knowledge, Skills and Attitudes: Conceptualising Learning Processes Towards Vocational Competence.” *Educational research review* 6, no. 2 (2011): 125–134.

Engineering Council. 2020. *The Accreditation of Higher Education Programmes (AHEP).* 4th Edition. https://www.engc.org.uk/media/3464/ahep-fourth-edition.pdf.

Engineering Council. 2023. *Global Responsibility Competency Compass*. https://www.engc.org.uk/standards-guidance/guidance/global-responsibility-competency-compass/.

EngineeringUK. 2022. *Net Zero Workforce: An Analysis of Existing Research*. https://www.engineeringuk.com/research-policy/industry-workforce/net-zero-workforce/.

Engineers Without Borders UK. 2022. *Global responsibility of engineering The extent to which global responsibility is embedded into engineering practice: an exploratory study*. https://www.ewb-uk.org/global-responsibility-of-engineering-an-exploratory-study/.

Graham, Ruth. 2018. *The Global State of the Art in Engineering Education*. Massachusetts Institute of Technology. https://www.cti-commission.fr/wp-content/uploads/2017/10/Phase-1-engineering-education-benchmarking-study-2017.pdf.

Guerra, Aida, Ronald Ulseth, and Anette Kolmos, Eds. *PBL in Engineering Education : International Perspectives on Curriculum Change*. Rotterdam: Sense Publishers, 2017.

Högfeldt, Anna-Karin, Lena Gumaelius, Per Berglund, Leif Kari, Arnold Pears, and Viggo Kann. “Leadership, Support and Organisation for Academics’ Participation in Engineering Education Change for Sustainable Development.” European Journal of Engineering Education, 48, no. 2 (2023): 240–266.

IET. 2021. “93% of Industry Without Skills to Meet 2050 Climate Targets.” https://www.theiet.org/media/press-releases/press-releases-2021/press-releases-2021-january-march/2-february-2021-93-of-industry-without-skills-to-meet-2050-climate-targets/.

Litzinger, Thomas, Lisa R. Lattuca, Roger Hadgraft, and Wendy Newstetter. “Engineering Education and the Development of Expertise.” *Journal of engineering education (Washington, D.C.)* 100, no. 1 (2011): 123–150.

Lucas, Bill, and Janet Hanson. 2014. "Thinking like an engineer: Using engineering habits of mind to redesign engineering education for global competitiveness." SEFI 2014 Annual Conference, University of Birmingham, Birmingham, United Kingdom.

Maslow, A.H. “A Theory of Human Motivation”. *Psychological Review (Washington, DC: American Psychological Association)* 50, no.4 (1943): 430-437.

Munir, Fouzia. “More Than Technical Experts: Engineering Professionals’ Perspectives on the Role of Soft Skills in Their Practice.” *Industry & higher education* 36, no. 3 (2022): 294–305.

Raworth, Kate. Doughnut Economics: Seven Ways to Think Like a 21st-Century Economist. London: Random House, 2017.

Rest, James R., Darcia Narvaez, Stephen J. Thoma, and Muriel J. Bebeau. “A Neo-Kohlbergian Approach to Morality Research.” Journal of moral education 29, no. 4 (2000): 381–395.

Students Organising for Sustainability. 2021. “Sustainability Skills Survey.” Accessed May 2, 2023. https://www.sos-uk.org/research/sustainability-skills-survey.

UNESCO. 2021. Engineering for sustainable development: delivering on the Sustainable Development Goals. Paris, France. https://www.unesco.org/en/basic-sciences-engineering/report.

World Economic Forum. 2023. *The Global Risks Report 2023*. 18th Edition. https://www.weforum.org/reports/globalrisks-report-2023/.