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Momentum Towards Incorporating Global Responsibility in Engineering Education and Accreditation in the UK

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ABSTRACT

CONTEXT
Engineering is uniquely placed to help address global challenges such as those surrounding the climate crisis, and the sustainable use and management of resources. However, studies have found UK engineering companies that have adopted sustainability strategies do not have enough staff with the skills to achieve them. There is an urgent need to upskill the current workforce and prepare future generations to operate in a responsible and ethical manner in tackling today's challenges. Recent updates to the standard of engineering accreditation in the UK provide notable opportunities to transform university curricula to create globally responsible engineers.

PURPOSE
This preliminary study explores the integration of global responsibility areas of learning and skill sets in engineering education accreditation. Recent revisions to accreditation are to be implemented at the end of 2021. The purpose of this study is to highlight how global responsibility principles are integrated and framed in engineering accreditation in the UK today.

APPROACH
This paper explores patterns within the recent updates made to engineering accreditation in the UK. The previous third edition and newly published fourth edition of the Engineering Council Accreditation of Higher Education Programmes (AHEP) are central to this research. Forward looking strategies from prominent voices in the sector including the Royal Academy of Engineering (2020-2025) and Engineers Without Borders UK (2021-2030), are viewed through the lens of Bloom's Taxonomy, a hierarchical model for categorizing learning objectives into levels of complexity, to generate preliminary findings.

ACTUAL OUTCOMES
Addressing sustainability, global responsibility and the Sustainable Development Goals (SDGs) requires more complexity in a students' learning process than engineering curricula currently provide. Sustainability, ethics, diversity and inclusion are fundamental to engineering education and enable inclusive design solutions and outcomes. The most notable change to AHEP is refining how global responsibility is presented and evolving the way it is taught. Changes incorporated in the new AHEP4 recognise the responsibility and skills needed of engineers to create positive change to society and global challenges. Yet by the time AHEP4 is realised the SDGs will be halfway through the Decade of Action. Achieving crucial SDG benchmarks will require both curricular change embedded in accreditation standards and a notable shift in the culture of engineering that embeds a professional commitment to behave more responsibly, individually and collectively.

SUMMARY
Incorporating global responsibility into engineering accreditation is necessary to prepare students to address global challenges. Newly updated accreditation standards frame engineering education around principles of globally responsible engineering while encouraging more complexity within the curricula, such as through problem-based learning approaches. This provides a strong starting point for engineering curricula and educators to prepare emerging engineers to act responsibly in the face of the urgent and dynamic global challenges.

KEYWORDS
Global responsibility; ethics; accreditation; Bloom's taxonomy; sustainability; climate emergency

Introduction

The Sustainable Development Goals (SDG) Decade of Action 2020-2030 is well underway. At the same time the world is facing significant global challenges including a climate and biodiversity emergency. This emergency has been exacerbated by the COVID-19 pandemic, which has significantly and unprecedentedly impacted health, society, economy and education, while exposing and worsening existing injustices and inequalities globally (UNDESA, 2020). Engineers have a responsibility to tackle global challenges. Their work overlaps all the SDGs, including goals for a sustainable society, healthy environment, inclusive economy, and a recovery that is regenerative as well as inclusive and equitable. Individually and collectively, engineers need to accelerate their efforts towards meeting the SDGs (UNESCO, 2021). Raworth's (2017) doughnut economics model visually highlights the space at which humanity can thrive, providing both a social foundation (to ensure that no one is left falling short on life's essentials) and an ecological ceiling (to ensure that humanity does not collectively overshoot the planetary boundaries that protect Earth's life-supporting systems). However, at least four of the planetary limits identified by Raworth have already been overshot, specifically, atmospheric carbon dioxide, biodiversity, nitrogen/phosphorus loading, and land conversion (Raworth, 2017). At the same time, millions still lack access to basic human rights such as clean water and energy, unsustainable practices and materials are used across the engineering sector, and limited consideration is given to broader impacts on society and the planet. For example, concentrations of carbon dioxide discharged into the atmosphere are at the highest levels in the past 3 million years, pushing the climate to the point of catastrophic change within the next decade (IPPC, 2018). The majority of carbon emissions contributing to the climate emergency originate from industries enabled by engineers, with the building and construction sector alone responsible for 38% of global emissions (UNEP, 2020).

Sustainable development ensures people have their basic human needs met, that solutions are equitably shared, and that they do not drain and deplete the planet's fundamental ecosystems and natural resources for the future generations. Engineering graduates need a range of skills in order to create, develop or apply new or existing technologies, tackle today's global challenges and deliver on the SDGs. However, a study by the Institution of Engineering and Technology found that only 7% of engineering companies that have a sustainability strategy also have the staff with the skills to fulfil it, and only 53% of survey respondents believed it was possible for their companies to meet net zero by 2050 (IET, 2021). UNESCO (2021) recognises there is a responsibility for engineers to incorporate more than technical aspects into their solutions, and adopt approaches that consider social, environmental and economic impacts. There is therefore an urgent requirement to upskill the current engineering workforce and transform engineering education to prepare future graduates to practice engineering responsibly. Engineering curricula must be revised to incorporate the skills required to mitigate global and local challenges, societal aspirations and needs. This goes beyond an understanding of the impact engineering has to people and planet, and includes consideration of the values, principles and skills engineers put into practice every day. However, the UNESCO (2021) report recognises these values are generally yet to be incorporated into most educational institutions' engineering curricula.

Context

Strategies calling for globally responsible engineering

To frame what global responsibility in engineering looks like, this study draws on recent strategies released by prominent voices in the sector. It looks at strategies by Engineers Without Borders UK on 'Reaching the tipping point for globally responsible engineering 2021-2030' and another by the Royal Academy of Engineering (RAEng) titled 'Strategy 2020–2025 Engineering for a sustainable society and inclusive economy'. Both documents recognise engineering's role, and its responsibility to society, in tackling social and environmental injustice.

The Engineers Without Borders UK movement works to put 'global responsibility at the heart of engineering' for a safe and just future for all, by inspiring, upskilling and driving change within engineering education and profession (see: www.ewb-uk.org). The Engineers Without Borders UK 2021-2030 strategy sets out four key principles for global responsibility that should be embedded into the culture of how engineering is taught and practiced (Engineers Without Borders UK, 2021). Engineers and engineering needs to be: Responsible (to meet the needs of all people within the limits of our planet); Purposeful (to consider all the impacts of engineering, from a project or product's inception to the end of its life which should be at a global and local scale, for people and the planet); Inclusive (to ensure that diverse viewpoints and knowledge are included and respected in the engineering process); and Regenerative (to actively restore and regenerate ecological systems, rather than just reducing impact).

The RAEng is the UK's National Academy for engineering and technology. It brings together engineers to advance and promote excellence in engineering for the benefit of society (see: www.raeng.org.uk). The RAEng's overarching goal for 2020-2025 is 'to harness the power of engineering to build a sustainable society and an inclusive economy that works for everyone' (RAEng, 2020). The strategy recognises that 'engineers are influential agents of change in the drive for a more sustainable society' and works to 'embed sustainability and global responsibility as a core element of engineering education, training and professionalism'.

Accreditation Bodies and Updates

In the UK, the Engineering Council sets the requirements and degree standards for the Accreditation of Higher Education Programmes (AHEP) in engineering. These standards are developed through consultation with the engineering professions, employers and academics. AHEP standards align with the Engineering Councils UK Standard for Professional Engineering Competence (UK-SPEC). These standards set out the competence and commitment for Engineering Technicians (Eng Tech), Incorporated Engineers (IEng) and Chartered Engineers (CEng). Learning Outcomes are included, to guide assessment of the competence and commitment of individual engineers; they can be interpreted in the context of a particular disciplinary or multidisciplinary engineering practice, and level of study.

There have been four iterations of AHEP since its original publication in 2004. The third edition of AHEP is applicable for all accredited modules from September 2016 and the fourth edition of AHEP is to be introduced by the end of 2021, with the learning outcomes implemented by August 2024. AHEP4 reduces the total number of learning outcomes to focus on core areas and it strengthens the focus on inclusive design and innovation, equality, diversity, sustainability and ethics (Engineering Council, 2020a), as evident in the statement below.

> ***The Engineer and Society****: Engineering activity can have a significant societal impact and engineers must operate in a responsible and ethical manner, recognise the importance of diversity, and help ensure that the benefits of innovation and progress are shared equitably and do not compromise the natural environment or deplete natural resources to the detriment of future generations. (Engineering Council 2020a)*

Methodology

This preliminary study explores how the principles of globally responsible engineering are integrated and framed in engineering education accreditation in the UK. This follows on from a previous exploratory study of globally responsible decision-making in civil engineers' day-to-day practice (Chance, et al, 2019, 2020). This paper investigates the social, environmental, ethical and economic considerations in recent updates to engineering education accreditation and the principles of globally responsible engineering, which are central to strategies published by the Royal Academy of Engineering (2020-2025) and Engineers Without Borders UK (2021-2030).

Global responsibility in engineering requires more than solely knowledge and understanding. It requires engineers to have the ability to critically analyse, reflect and critique the role of engineering, its relationship with humanity, and its impact on our past and potential futures (Engineers Without Borders International, 2021). This paper contributes new understandings, extending prior work, by investigating the language surrounding skills development for globally responsible engineering. It uses the framework of Bloom's taxonomy (a hierarchical model that categorizes learning objectives into levels of complexity) to explore how engineering students can most effectively develop skills prior to graduation. Bloom's taxonomy is presented in Figure 1, based on revisions to the original taxonomy made by Armstrong (2010). Lower order skills include Remembering, Understanding and Applying. Higher order skills include Analysing, Evaluating and Creating. This framing is not used to dismiss the lower levels of teaching but rather to understand where accreditation leans more towards building lasting skills to enable change, rather than simply delivering content for students to memorize and remember.

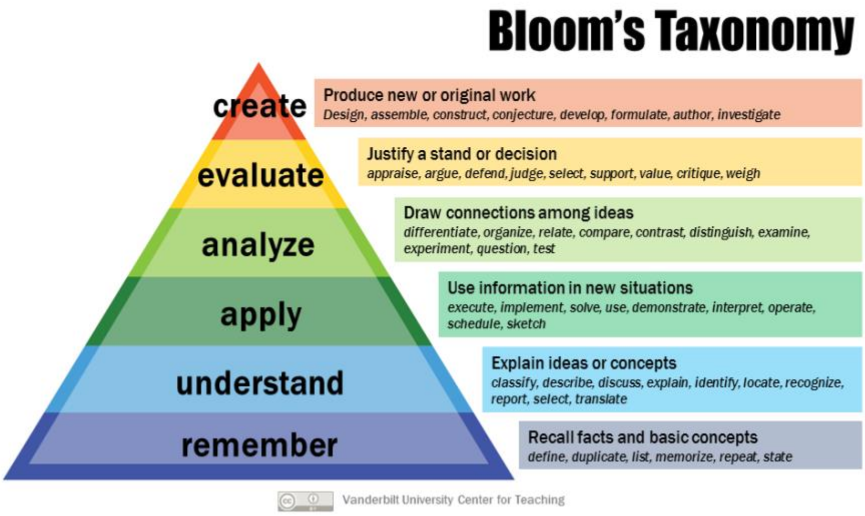

Figure 1: Bloom's Taxonomy, source: Armstrong (2010)

To facilitate comparison and gauge change over time, the learning outcomes of AHEP3 and AHEP4 were coded. The meanings of the words used with regard to globally responsible engineering principles and Bloom's taxonomy were carefully considered and tabulated the results to facilitate comparison of frequencies. Bachelor and Masters degrees that fully meet the requirements for IEng and CEng level accreditation courses were specifically considered in this analysis. This preliminary study is part of a larger body of work in progress by Engineers Without Borders UK, to define and broaden competency frameworks. The subsequent competency frameworks will support the engineering workforce to develop values and competencies in producing globally responsible outcomes.

Results

Table 1 presents the frequency of coded global responsibility aspects within the learning outcomes of AHEP3 and AHEP4. The principles and definitions of globally responsible engineering, as set out in the Engineers Without Borders UK strategy, are also presented. These cover specific goals of the RAEng strategy involving progression towards a 'sustainable society' and 'inclusive economy'.

Table 1: Frequency of coded learning outcomes associated with global responsibility

Areas of learning global responsibility	AHEP3 (IEng)	AHEP4 (IEng)	AHEP3 (CEng)	AHEP4 (CEng)
Social	1	2	1	2
Environment	4	4	4	4
Economic	1	0	1	0
Ethical	2	2	2	2
Sustainable	0	0	0	0
Responsible	1	1	1	1
Purposeful	1	0	1	1
Inclusive	0	5	0	6
Regenerative	0	0	0	0

The learning outcomes terms associated with global responsibility remain similar between AHEP3 and AHEP4, with the exception of learning outcomes with Social and Inclusive considerations. Although Economic considerations were not mentioned in learning outcomes of AHEP4, they are stated alongside the learning descriptions, which highlight the importance in economically viable designs e.g., "development of an economically viable product, process or system to meet a defined need". While Sustainability is not specifically mentioned within the learning outcomes in AHEP4, it is described as an area of learning that is defined by a learning outcome, i.e.:

- "Evaluate the environmental and societal impact of solutions to Broadly-defined problems." (IEng)
- "Evaluate the environmental and societal impact of solutions to Complex problems (to include the entire lifecycle of a product or process) and minimise adverse impacts." (CEng).

AHEP3 does not cover Inclusive in its learning outcomes, however, there is sharper focus on inclusive design and innovation in AHEP4, as reported in Table 1. Regenerative considerations are not evident in AHEP3 or AHEP4 learning outcomes.

Engineers need the skills to put global responsibility into day-to-day practice as well as their broader engineering culture. Table 2 presents the frequency and proportion of skills to meet learning objectives, coded through the lens of Bloom's Taxonomy. AHEP4 also frames learning outcomes in the context of problem-based learning, addressing varying levels of problem complexity. These include Broadly-defined problems (that involve a variety of factors which may impose conflicting constraints, but can be solved by the application of engineering science and well-proven analysis techniques) and Complex problems (that have no obvious solution and may involve wide-ranging or conflicting technical issues and/or user needs that can be addressed through creativity and the resourceful application of engineering science). Table 3 presents the frequency of problem complexity highlighted in the learning outcomes, as defined by AHEP4.

Table 2: Frequency and proportion of coded words associated with Bloom's Taxonomy

Bloom's Taxonomy		AHEP3 (IEng)	AHEP4 (IEng)	AHEP3 (CEng)	AHEP4 (CEng)
Higher-order	Create	4 (9.52%)	4 (11.76%)	6 (9.52%)	5 (15.63%)
	Evaluate	2 (4.76%)	7 (20.59%)	5 (7.94%)	8 (25.00%)
	Analyse	0 (0.00%)	0 (0.00%)	2 (3.17%)	0 (0.00%)
Lower-order	Apply	18 (42.86%)	8 (23.53%)	20 (31.75%)	10 (31.25%)
	Understand	9 (21.43%)	5 (14.71%)	15 (23.81%)	8 (25.00%)
	Remember	9 (21.43%)	10 (29.41%)	15 (23.81%)	1 (3.12%)
Total		**42 (100%)**	**34 (100%)**	**63 (100%)**	**32 (100%)**

Table 3: Frequency of problem complexity in learning outcomes

Level of problem complexity	AHEP3 (IEng)	AHEP4 (IEng)	AHEP3 (CEng)	AHEP4 (CEng)
Broadly-defined problems	0	9	0	0
Complex problems	0	0	1	10

The frequency of words associated with Bloom's Taxonomy is lower in AHEP4 than AHEP3, which can be attributed to AHEP4 specifically reducing the number of learning outcomes to present a sharper focus on the learning outcomes overall. However, proportionally there is a notable shift from lower-order skills to higher-order skills: IEng (AHEP3: 85.71% lower-order and 14.29% higher-order; AHEP4 67.65% lower-order and 32.35% higher-order) and CEng (AHEP3: 76.92% lower-order and 23.08% higher-order; AHEP4 55.88%% lower-order and 44.12% higher-order). IEng accredited courses predominantly focus on Broadly-defined problems while CEng accredited courses predominantly focus on Complex problems. This supports the distribution of lower-order and higher-order skills between IEng and CEng. As this framing is new to AHEP4, the limited use of these terms in AHEP3 is expected.

Discussion

The changes to AHEP recognise the role of globally responsible engineers in tackling global challenges and make efforts to incorporate such values into engineering accreditation. Global responsibility concepts have been refined between AHEP3 and AHEP4 in how they are presented and taught. Analysing these through the lens of Bloom's taxonomy, it is evident there is a shift from lower-order skills to higher-order skills in approaching learning outcomes, encouraging more critical skill development. The changes to accreditation are also synonymous with recent revisions to the International Engineering Alliances graduate attributes and professional competences (IEA, 2021). However, these share similar scope for improvement and expansion. Particularly around deeper comprehension of ethical issues and complexity in curricula to aid critical thinking and reflection of the role of engineering (Engineers Without Borders International, 2021).

Stratford (2016) describes how accreditation can provide a process to aid reflection on embedding complexity within design project delivery. Implementing AHEP4 will be slow, however, the newly announced AHEP4 provides educators an opportunity to reflect how learning outcomes are currently being delivered in engineering curricula and where more complexity and critical reflection of the role of engineering is needed. It is recommended that accreditation should not be framed as the ceiling for acrredited modules but rather educators should view it as the starting point to go further. For example, a CEng learning objective associated with sustainability, is to ‘Evaluate the environmental and societal impact of solutions to complex problems (to include the entire life-cycle of a product or process) and minimise adverse impacts’. While this learning objective aligns with the Purposeful principle of globally responsible engineering, it needs to go further to question the impacts in the first instance. Minimising the adverse impacts to society and planet is insufficient, as evident from the privacy and security implications with Artificial Intelligence (UNESCO, 2021), the urgency of the climate emergency as it exceeds the tipping point (Ripple, et al., 2021) or the four overshot planetary boundaries (Steffan, et al., 2015). Additional reflection is also required when considering the levels of problem complexity. Confining Broadly-defined problems to IEng accreditation and Complex problems to CEng accreditation could potentially be narrowing and restrictive in practicing the higher-order skills required to tackle global challenges. Much of the curricula success will be attributed to how problems are identified and defined in education and professionally.

Embedding the principles of globally responsible engineering explicitly and relevant global challenges into the learning outcomes of engineering education is another opportunity for accreditation and accredited modules to go further to tackle the global challenges emerging graduates will face. For example, while not specifically embedded in the learning outcomes, a call for Regenerative approaches and use of the UN SDGs are mentioned and encouraged in the Engineering Council's guidance for sustainability in accredited programme design and delivery (Engineering Council, 2020b). This guidance closely aligns with the strategies and principles of globally responsible engineering as set out by the RAEng and Engineers Without Borders UK. This is also supported by the Joint Board of Moderators (a group licenced by the Engineering Council who coordinate accreditation activities for educational programmes in the built engineering sector) which recognises that the climate emergency should not only be learnt but embedded in the culture of how engineers are taught.

> *In particular, we see the extraordinary challenge of the Climate Emergency as a very necessary central cultural feature in the education of civil engineering students, and our guidelines should be read with this strongest intent in mind. (JBM, 2020)*

Addressing the global challenges and SDG benchmarks requires complexity within engineering curricula to recognise the responsibility and skills needed of engineers to create positive change to society and global challenges. AHEP4’s use of Broadly-defined and Complex problems in its learning outcomes has the potential to provide holistic delivery of multiple learning outcomes within a programme while also developing the critical thinking, skill set and professional commitment required in tackling global challenges such as the climate crisis. This is reflective of the already well-established problem-based learning approach (and supported by UNESCO (2021), which encourages educators to move from a knowledge based approach to a knowledge and a problem-based approach), allowing further complexity in a student's learning process that has a positive impact on professional competencies and increasing awareness of sustainability throughout the process (Kolmos, et al, 2020). The Engineers Without Borders UK Engineering for People Design Challenge is an example where this has been successful. The undergraduate design challenge, delivered as an accredited module, enables students to explore ethical, environmental, social and cultural aspects of engineering design, while providing an avenue to put critical thinking skills into practice. Existing approaches, such as accredited design challenges, can enable educators to facilitate the complexity needed to develop globally responsible engineering graduates, align with the teaching and learning objectives required of accredited modules, and embed globally responsible engineering values and commitment for emerging graduate engineers to take into their professional roles and continued professional development.

Conclusion

There is growing momentum towards including globally responsible engineering principles in engineering education accreditation. It's clear accreditation for higher education won't be the sole solution to tackling today's global challenges, but opportunities and recommendations for transforming traditional lecture-based education into approaches (such as problem-based learning) that incorporate complex and critical reflection on the role of engineering are evident. Between AHEP3 and AHEP4, the areas of learning remain largely unchanged but do present a stronger focus and clearer communication around areas and skills of global responsibility. Furthermore, the guidance to the learning outcomes covers valuable information that should not be ignored for accredited module development. The key update to accreditation is moving from solely understanding of the areas of engineering to identification and critical evaluation of engineering solutions and how engineering solutions affect society. For educators looking to AHEP, a crucial aspect of success will be viewing accreditation as a starting point to go further, to improve the culture of engineering and a professional commitment to be more globally responsible. Following this preliminary study, the next steps are to define and broaden competency frameworks to support the engineering workforce develop and embed their values and competence in global responsibility from the classroom learning outcomes into the professional workplace.

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