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Opportunities and barriers faced by early-career civil engineers enacting global responsibility

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ABSTRACT

The term 'global responsibility' projects a holistic sense of ethics, sustainability, and obligation. To achieve the long-term viability of human life on Earth, civil engineering must be conducted in increasingly responsible ways, and civil engineers must value and enact global responsibility in their work. Interviews conducted with nine civil engineers in London provide insight regarding engineers' familiarity with the term, how they learned about it, what opportunities and barriers they face, and what might be done by professional and educational institutions to help them practice more responsibly. Results indicate: the term itself is novel but underlying concepts are not; continuing professional development has played a crucial role in their understanding; material selection and Health & Safety represent primary avenues for contributing responsibly at work. This paper provides advice to professional institutions regarding transparencies, procedures, and metrics to enhance the UK workplace and ideas for educational institutions preparing engineering students for practice.

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Sustainability; accreditation; ethics; responsibility; civil engineering; curriculum design

Introduction

Civil engineers' decisions impact society. They influence the world, and life on it, via 'the use of material, energy and water resources, the development of infrastructure, the design of new products and so on' (Dodds and Venables 2005, 8). The construction and operation of engineered buildings, networks, and systems directly affect energy use, carbon emissions, and climate at local and global levels. Although civil engineering improves quality of life via clean water, effective sanitation, public transport, *et cetera*, it carries many negative consequences as well. Engineers – designers, managers, leaders, and decision-makers – with a sense of global responsibility are needed to achieve holistic solutions to the problems facing us all.

Aiming to promote a holistic vision, the United Nations (UN) has, since at least 2005, encouraged use of the term 'global responsibility' (GRLI 2020). Engineers Without Borders (EWB) also promotes the term. A European collective of Professional Engineering Institutions (PEIs) followed suit in 2011. Embracing a sense of global responsibility – and seeking to promote it among all engineers – the European Federation of National Engineering Associations (FEANI) emphasised:

> We can no longer limit ourselves to addressing technical issues as we did in the industrial age. Instead, we need to take a holistic view of the economic, ecological and social impacts of our actions — and always do so from a

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> global perspective. Our objective here must be to ensure that every engineer adopts an international point of view so as to enable him or her to contribute to the improvement of the quality of life for everyone on the planet. (Fuchs and Bochar 2011, 45).

FEANI (2019) aims 'to strengthen the position, role and responsibility of engineers in society' (¶1) and address 'social and global challenges' (Fuchs and Bochar 2011, 42). Although FEANI leaders published the term 'global responsibility' in 2011, adoption of the term 'global responsibility' via engineering speeches, publication, and documents is not evident.

What's in the term? 'Global responsibility' implies concern for environmental and social sustainability as well as financial aspects of construction, as conveyed in the three pillars – environment, society, economy (Purvis, Mao, and Robinson 2019) – that should be given balanced consideration in decision-making (McDonough and Braungart 2010). The term ties closely to 'sustainable development' – the type of construction that would meet 'the needs of the present without compromising the ability of future generations to meet their own needs' (UN 1987, 15). All professionals in all realms should balance these aspects when making choices.

Specific to civil engineering, issues that urgently require attention include

> the poor condition of the infrastructure in many nations, the occurrence of corruption in the global engineering and construction industry, the minimal involvement of civil engineers in the political process, the need to more fully embrace sustainability, the globalization of engineering practice, and the desire to attract the best and brightest to the profession. (ASCE 2007, 1)

At large scale, humanity is not on track to reach agreed performance targets set by the UN (2019). The work of civil engineers directly impacts ability to the UN's (2015) Sustainable Development Goals. Indeed, civil engineering has been linked to mismanagement of resources and large-scale corruption. Even today, bribery, human slavery, and blacklisting of vocal critics are all evident in the production of the built environment (Craven 2020). Ethically irresponsible decisions can pile up with detrimental effects, as evidenced in the United Kingdom (UK) by the tragic fire at Grenfell Tower (Bowsher 2020; Craven 2020; Sanchez-Graells 2020). To help overcome challenges like these, professional organisations develop codes of ethics and agree upon standards of conduct. In civil engineering, protecting health and safety and avoiding corruption and bribery emerged as primary concerns in recent decades; these have been poignant foci in the UK, where significant progress has been made (Health and Safety Executive 2019). To promote desirable values and responsible behaviours among engineering students worldwide, the Washington Accord sought to integrate sustainability and ethics into engineering curricula (International Engineering Alliance 2014). The 20 signatories of the Washington Accord include the UK and nations on every inhabited continent (International Engineering Alliance 2020).

Discussion of ethics and sustainability is now common among civil engineers and PEIs in the UK. In 2004, UK civil engineers adopted a 'Code of Professional Conduct' (ICE 2017). They built on this with detailed 'Advice on Ethical Conduct' (ICE 2012). ICE has periodically updated these, indicating that they are living documents. ICE presidents have promoted sustainable development through inaugural addresses (Jowitt 2009; Leiper 2006) and other highly visible messages to members. PEIs have created guides on sustainability for engineers (Dodds and Venables 2005) and university instructors (Bourn and Neal 2008). To encourage life-long learning on these topics among engineering in the UK, PEIs recently introduced Continuing Professional Development (CPD) requirements that included structured recordkeeping, reporting, and auditing (Engineering Council 2020).

To facilitate shifts in higher education, UK PEIs adopted new accreditation requirements in ethics and sustainability (Engineering Council 2004, 2013). Yet, even though Higher Education Institutions (HEIs) have been working to integrate sustainability and ethics into engineering curricula for decades, the results of such activity are largely unknown. Recognising this gap, Bourn and Neal (2008) called for 'further research on the impact and value of the "global engineer" concept in the contribution of engineering to positive world change and meeting the skills needs of the UK workforce' (3). This study constitutes a first step, seeking to uncover the degree to which target values and abilities are reflected in civil engineering in the UK today. We aimed to determine how early career engineers (who would have entered practice after new accreditation standards for sustainability were adopted) currently understand and enact global responsibility. We wanted to know what they, their employers, and their PEIs have been doing in this realm.

In this exploratory study, requested by Engineers without Borders UK (EWB-UK) and supported financially by the Royal Academy of Engineering (RAEng) and the European Union, our university-based research team has taken a grassroots approach to generating new understanding of engineering practice in the UK. We interviewed nine London-based civil engineers (eight early career and one senior manager) about 'global responsibility' and analysed their interview transcripts inductively to understand what these early career engineers feel they can and can't change and what systematic improvements might be made to support them. We offer what we found as advice to PEIs (regarding procedures, quantification, and transparencies that our data suggest might enhance the workplace) and HEIs (as they work to prepare students for engineering practice).

Literature on global responsibility

'Being globally responsible means appreciating that there is a world beyond us; a world we are a part of and one that we can – and should – play an active role in improving' (Saint Michaels University School n.d., ¶1). Across engineering however, this term is not well known. Literature reviews and interviews suggest concepts underlying the term are well known in engineering, but synonyms and close concepts are used in lieu of the term 'global responsibility' itself.

Emergence of the term 'global responsibility'

The book *Global responsibility: In search of a new world ethic* (Kung 1991) used the term, associated it with both ethics and 'Planetary Responsibility', and asserted 'an ethic of responsibility' (viii) should be adopted in lieu of the prevailing and individualistic success-driven mentality so prevalent in Western societies. The term gained some traction, and a dozen years later, Biefnot's (2003) review of literature identified several clusters of understanding: eliminating poverty, reducing social inequality, respecting human rights, and protecting the natural environment.

The private sector has taken a leading role, initially differentiating itself from other sectors, 'by implying that doing good should also be good for business' (Biefnot 2003, 17). The business sector worked with schools and the UN to launch an initiative in 2005 'to catalyse the development of globally responsible leadership and practice in organisations and societies worldwide' (GRLI 2020, footer). The sector also launched, in 2010, a peer-reviewed *Journal of Global Responsibility* focused on management and governance (Emerald Publishing Limited 2020, ¶ 3). To facilitate assessment and accountability, the business sector adopted the terms 'corporate citizenship' and Corporate Social Responsibility (CSR). The later provides a self-regulating model wherein companies hold themselves accountable for impacting society in positive ways regarding the three pillars, with specific connotations of CSR varying from one industry to the next (Chen and Scott 2020).

To facilitate assessment and accountability across all sectors, the UN (2015) adopted a set of 17 SDGs to be reached by 2030 that built upon Millennium Development Goals (MDGs) introduced by the World Health Organization (2020) in 2000. Like MDGs, SDGs measure contributions toward environmental, social, and economic sustainability. Businesses, including engineering firms, can contribute to achieving the SDGs by using them to guide activity, e.g. identifying goals and benchmarks, monitoring impact, and tracking progress (Preston and Scott 2015; PwC, GMIS, & UNIDO 2017).

Within engineering, a group of engineers and scientists assembled a new organisation in 1991 and included the term in their title (INES 2020). They later defined 'global responsibility':

> First, global responsibility means working for the betterment of humanity. Practically this means using one's talents and skills for constructive rather than destructive purposes. Second, it means speaking out, individually or collectively, against dangerous and destructive uses of science and technology. Third, it means putting the welfare of humanity as a whole ahead of the considerations of any one nation. (Krieger 2007, ¶ 8)

Although principles of 'global responsibility' appeared in seminal documents of the American Society of Civil Engineers (ASCE), the term was mentioned neither in the organisation's vision for civil engineering (ASCE 2007) nor its strategic roadmap for achieving the vision (ASCE 2009). The words 'global' and 'responsibility' were used individually, but not together.

Overall, in engineering, the term 'sustainable development' has been used more readily. In civil engineering, greater sustainability is sought to enhance the profession's proud legacy of providing water supply and sanitation systems, transportation systems, and towers and bridges that are iconic, functional, and safe (ASCE 2007; Jowitt 2009; Leiper 2006). With increasing recognition that humans have been using more energy and materials than the earth can replace, civil engineering leaders have called for transformed approaches to improve the world's infrastructure and equitable access to it (ASCE 2007; Jowitt 2009). Major transformation is needed in the realms of construction, transport, energy, and political engagement (Bourn and Neal 2008).

Use of the term 'global responsibility' in research on engineering practice

In engineering, CSR encouraged 'ideas of sustainability, including human rights and environmental issues, as well as a chain of responsibility and duty of care' (Bielefeldt 2018, 42), yet the stated ideals have not been easy to achieve in practice. CRS for sustainable development is typically used as a marketing strategy; it rarely reflects 'a more sustainable long-term commitment to changes in organizational culture and also society' (Richards and Zen 2016, 275).

Regarding sustainability and engineering, two different ideologies emerged in the 1990s, alternately emphasising (1) technological and (2) socio-cultural change (Sakellariou 2018). Looking at socio-technical networks within structural engineering, Chilvers and Bell (2014) asserted that despite pressure to address ethical and normative issues (e.g. sustainable development, climate change, technological advances), there are professional arrangements that limit engineers' reach and the level of impact their work can have.

Chilvers and Bell (2014) conducted an ethnographic study of a case conducted at Arup that used Actor-Network Theory. They found that 'the professional arrangements of the construction sector make the desire to deliver a more efficient and sustainable structure untenable' (338) because the architect serves as the 'central mediator within the actor-network of the design team' (338) and the structural engineer has little voice in driving design decisions. Structural engineers have become disassociated from the design process over time. Other barriers to change are 'practical habits of the construction sector' (Chilvers and Bell 2014, 338) and contract arrangements (that, for instance, allow the client to drive decision-making). The study by Chilvers and Bell is of particular interest because it included similar research questions and focused on sustainability without a specific focus on 'global responsibility'.

The term has been central in some empirical research related to engineering practice, however. These include studies titled 'global responsibility: sustainable development in information and communication technology' (Griese et al. 2001), 'strategies for high risk reduction and management as global responsibility' (Miccoli and Destefano 2010), and 'exploring site roles in global corporations: balancing local identity to global responsibility' (Wiktorsson et al. 2016).

Use of the term 'global responsibility' in research on engineering education

Several engineering education researchers have focused on global responsibility. A journal article by Wilson (2010) focused on 'promoting active citizenship and global responsibility amongst populations in the global north' and a conference paper by Wigal (2007) investigated 'the use of engineering design projects for student understanding of engineering's societal impact and global responsibility'. Tossavainen (2009) identified global responsibility as a primary goal for internationalising the engineering curriculum, and Lappalainen (2011) used the term in the text of a paper on 'cooperation as methodology for teaching social responsibility to engineers' (513). Today, it is quite common for the term to appear in papers on curriculum or course design, for example: the 'GO GREEN' engineering course (Fox et al. 2008); study abroad (de Carvalho and Moore 2011; Songer and Breitkreuz 2014); and an engineering master's degree integrating sustainability (Gustafson, Vieth, and Eagan 2013). Scholars have investigated ways to incorporate global responsibility into first year engineering coursework (Kelly 2002; Reid et al. 2013). The term has also appeared in national overviews of engineering education, including Finland (Takala and Korhonen-Yrjänheikki 2013) and Australia (Dowd 2010).

Implications of 'global responsibility' for engineering education

Today, HEIs are mandated to produce 'graduates and qualified engineers who understand sustainable development and can deliver significantly more-sustainable solutions for society', according to Dodds and Venables (2005, 45), who add that effective change will require intense involvement from practicing engineering, training managers, university leaders, and course coordinators.

The Engineering Council UK (2004) – which is the UK regulatory body for the engineering profession – took action to embed new requirements and enforce uptake via accreditation. Enacting the UK Standard for Professional Engineering Competence (UK-SPEC), the Council began requiring all engineering students to engage in activities related to sustainable development. In civil and structural engineering, the UK's Joint Board of Moderators issued Sustainability Guidelines that apply to bachelor's and master's courses, stipulating graduates should understand drawbacks of the extractive model of development, identify and implement methods to counteract negative impacts, and make design decisions in the context of sustainable development (Dodds and Venables 2005).

To assist HEIs, the RAEng supported development of guidebooks, example curricula, and teaching tools (Dodds and Venables 2005) specifically including model projects, assignment briefs, and the like (Bourn and Neal 2008). The RAEng appointed fellows to develop, pilot test, and refine innovative techniques in the hope engineering graduates would bring awareness, interest, and ability to enact change when entering practice, along with solid understanding of the role engineers can play in facilitating change. Because this initiative launched over 15 years ago, target values and abilities should be evident among graduate engineers in the UK today.

Yet, preparing graduates with a full suite of skills and abilities is a tall order. Making fully ethical and sustainable decisions in complex contexts cannot be entirely mastered in 3–4 years of undergraduate study. Today, there is increased recognition that developing abilities in these areas must start in university and extend into the working years. In the United States, new accreditation criteria have been released via CEBOK3 (Bielefeldt et al. 2019). The new criteria delineate which knowledge- and values-based skills should be developed in sustainability and ethics. The criteria also indicate when and how such skills may be demonstrated effectively. Although specific cognitive and affective abilities are identified for development during university, CEBOK3 recommends the more complex, higher-order skills be developed through guided mentorship in the years following graduation (Committee on Education 2019).

Design and methodology

A primary objective of this study was to assess the degree to which civil engineers practicing in London value and enact 'global responsibility' in their work. Additional objectives were to assess the level of familiarity they had with the term 'global responsibility' as promoted by the UN since 2005 (GRLI 2020) and to gauge the level of saturation the term has achieved within engineering.

The research team aimed to discover how participants defined global responsibility and how they experienced the phenomenon of 'making decisions related to global responsibility'.

We investigated definitions of the term, sources of learning related to it, and the spectrum of experiences participants described from positive to negative, using the following research questions:

(1) *How do early-career civil engineers working in London conceptualise and define 'global responsibility'?*
(2) *How have they learned about global responsibility?*
(3) *What aspects of global responsibility do they feel able to influence in their day-to-day work? What opportunities and barriers have they encountered?*

Analyses surrounding those three questions helped us answer a final, overarching, question:

(4) *How might PEIs, HEIs, and engineering educators better support early-career civil engineers in their efforts to enact global responsibility?*

Participants

EWB-UK identified the topic of global responsibility as well as the size and composition of the sample. The organisation recruited participants – three females and six males – via email and social media. Sampling was pragmatic and purposeful, intended to distill insight into engineers' experiences working in London. Eight participants had been in the profession less than nine years (see Table 1). Only two participants had practiced for more than a decade – one for 12 years and the other for 37. The one with 12 years overall, Jack, had entered engineering by way of a geoscience degree and considered himself an early career, saying 'I'm relatively young and there's still a lot to learn'. Participants' statements suggest they were motivated to provide interviews because they enjoy learning, have desire to share knowledge, and realised they could log CPD hours toward Chartership under sustainability.

The research team acknowledges that limitations exist due to the purposeful sampling procedure. The sub-set of nine London-based civil engineers who volunteered shared specific characteristics. They were are all involved with high-level credentialing (either a PhD or Chartership, which is

Table 1. Participant demographics.

Name	Sex	Degrees Held (Area)	Professional Years	Employment Sector (Type of Work)	Charter Status at the time of the interview
Ava	F	M.A. & M.Sc. (Sustainable Development)	3–5	Sustainable Development (Consulting & Research)	N/A (Ph.D. Underway)
Emma	F	M.Eng. (Civil & Environmental Engineering)	3–5	Structural Engineering (Infrastructure & Building Design)	Underway
Arthur	M	M.Eng. (Civil & Architectural Engineering)	3–5	Structural Engineering (Building Design)	Chartered
Mia	F	M.Eng. (Civil Engineering)	3–5	Structural Engineering (Building Design)	Underway
James	M	M.Eng. (Civil & Structural Engineering)	5–10	Rail (Design Management)	Chartered
Thom	M	M.Eng. (Civil & Structural Engineering)	5–10	Structural Engineering (Infrastructure Design)	Chartered
Charlie	M	M.Eng. (Civil Engineering)	5–10	Rail (Infrastructure Construction Planning)	Underway
Jack	M	B.Sc. (Geoscience)	10–15	Ground Engineering (Construction Costing)	Chartered
George	M	M.A. & M.Sc. (Civil Engineering)	30–40	Rail (Design Management)	Chartered

obtained by only 5% of UK engineers according to Uff 2016). Moreover, they were motivated by the UK's CPD system, but we note that engineers outside the credentialing system might not feel compelled to undertake continuing development in such a conscientious and structured way.

Participants in this sample continued to learn, develop new knowledge, and study emerging concepts and techniques. Moreover, the sample was skewed toward those engineers who had some interest in EWB activities, receiving email and social media posts either directly or forwarded by colleagues in their networks. They may have higher awareness of international and global issues than typical. As such, we apply caution within our interpretation of data. However, common sense tells us that much of what these engineers said is likely to hold true for other UK-based civil engineers – the fact that even these highly conscientious engineers have trouble enacting sustainability suggests many engineers will face similar obstacles.

Data collection

Participants were recruited by EWB via social media and email. Participation was voluntary and participants were not offered any incentive or reward. This type of purposeful sampling presented several limitations, but data saturation (Guest, Bunce, and Johnson 2006) was achieved with regard to participants' definition of global responsibility and sources of learning.

Hour long interviews were conducted on the University College London (UCL) campus in central London following approval by UCL Ethics (Project ID 14165/001). Ethical procedures were followed and confidentiality was assured. Participants could request copies of their own transcripts and reports of the study allowing us to conduct member checks.

Consistent with grounded-theory methodology, semi-structured interviews with open-ended questions were conducted to assess how participants experienced or perceived the topic (Dudovskiy 2019). This interview type is useful when studying new concepts (Given 2008). The research team developed initial interview protocols and questions, pilot tested them in the first two interviews, and refined them in response (see Appendix A). Data from the two pilot interviews (with Ava and George) were included in final analyses as they held valuable insight.

The primary and secondary authors conducted interviews, often together, and started each interview by asking the participant to discuss 'an instance in your recent work as a civil engineer where you made decisions related to "global responsibility"'. The interviewers resisted providing any preexisting definition of the term – and in fact, had little prior exposure to the term. Near the end of the interview hour, each participant was asked to define the term. The open-ended nature of the questions allowed participants to raise any topics that came to mind.

Data analysis

We conducted a descriptive study using grounded theory methodologies. The interview protocols were designed in such a way that they, and the data collected, would be appropriate for analysis using either grounded theory or phenomenology. We have used both methodologies in the past and have carefully analysed when each is most useful (Chance, Duffy, and Bowe 2020). In this case, since our goal was to influence policy (Creswell and Poth 2017), we opted to use strategies associated with grounded theory. Our overall target was to understand and describe how participants understood and enacted global responsibility. We were not aiming to construct a new theory, rather we found grounded theory strategies useful for producing 'thick and rich description, concept analysis, [and] pulling out themes' (Corbin and Strauss 2008, x–xi). With this inductive analytic approach, we found NVivo 12.0 to be helpful in managing data.

The first two authors, who had co-conducted the interviews, verified accuracy of transcriptions, identified categories and themes using grounded theory strategies, interpreted findings and drafted results for multiple publications, including one on ethics (Chance et al. 2021). During analysis, the authors used constant comparison (Charmaz 2014) following established practices for open, axial, and selective coding by identifying themes and grouping them into categories (Strauss and Corbin 1994). The team analysed data inductively within each theme to make interpretations and to collaboratively identify findings. We conducted member checks at two points in the writing process and received feedback from over half the partiipcants. As with most exploratory studies, the bulk of analyses were conducted by a single researcher (Reiter 2013). Nevertheless, the team took care to ensure trustworthiness by conducting weekly debriefings throughout the process (from interviewing straight through to analysis, interpretation, and reporting). For additional quality control, EWB-UK provided an expert Advisory Panel which advised on design and execution of the study. The Panel also reviewed results and initial interpretations. The research team represented diverse nationalities and fields of expertise and experience, contributing emic and etic perspectives (e.g. from architecture, engineering, psychology, and education sciences). The team critically analysed their underlying assumptions. The research team adopted a constructivist view of reality, where definitions and new knowledge are co-constructed by researchers and interviewees (Charmaz 2014). They used inductive and emergent processes to identify commonalities across interview transcripts (Charmaz 1990, 2014; Strauss and Corbin 1994). Finally, because of our efforts to co-construct meaning with their participants, and the high value these participants placed on metrics for quantifying various types of data, we tabulated many of the results to facilitate easy comparison by engineers.

Results

Results are presented and discussed for each question, sequentially.

Q1 Definition of the term global responsibility

The first research question was: *How do early-career civil engineers working in London conceptualise and define* 'global responsibility'?

Results of Q1

Participants' concepts of global responsibility involved the three pillars: (1) environmental sustainability with a focus on material selection and carbon emissions, (2) social sustainability with a focus on job-site Health and Safety, and (3) economic sustainability having to do with tendering, staying in budget, and providing economic efficiency. To participants in this study, the term itself was nebulous, yet had to do with ensuring longevity, minimising damage, and seeking opportunities to do better. James defined it as making 'conscious decisions, about actions you're going to take, that will have a positive impact on society, and on the planet in terms of sustainability and its longevity' considering 'environmental, social and financial' aspects. The words 'finance' and 'budget' were used in lieu of the term 'economic sustainability' and were described as both barriers and opportunities for efficiency. Core concepts associated with the UN's Brundtland Report (Keeble 1988; United Nations 1987) were evident across all narratives, although participants found it

Table 2. Frequency of environmental mentions.

Environmental topic	Participants	Mentions
Materials	8	89
Carbon or climate	8	49
Water	6	41
Site or land	6	19
Retrofit	4	14
Pollution	4	10
Logistics	3	14
Resourcing	4	7
Electric power	2	8

easier to justify making decisions that were 'less bad' (McDonough and Braungart 2010, 45) than necessarily good or regenerative.

Environmental sustainability

Environmental sustainability emerged as a primary theme related to participants' work and conceptions of global responsibility, as evident in Table 2. The participants' 251 mentions of environment related to: materials, carbon or climate, water, site or land, retrofit of existing, pollution, construction logistics related to environment, resources, and power supplies. Echoing Charlie, whose overall 'understanding of global responsibility links quite closely to environmental sustainability', most participants found it easier to trace the positive and negative impacts of their decisions to the environment than to society. Positive impacts often had to do with 'saving carbon' from being emitted into the atmosphere.

Materials selection, carbon footprint, and impact on climate clearly dominate these civil engineers' work day-to-day; these three comprised 138 of all 251 environmental mentions. Some noted the link between global outcomes and local decisions in regard to environmental sustainability. Arthur summarised that, at a global level, 'the main impact that I will have is climate change, so carbon and embodied carbon'.

Social sustainability

Social sustainability emerged as a second major category, and the ways in which participants discussed it are identified along with frequencies in Table 3. Thom explained, 'in terms of what my work is, the global responsibility is about understanding social implications of engineering, of the work we do … wherever it is in the world'. Likewise, Arthur shared a holistic vision, where he considers 'very local impacts' like 'where they build the building and what impact of that is', the impact a space has on the people who use it, and what its presence implies for 'the society around it'. He considers corruption and forced labour in his decision-making, understanding that his decisions affect 'supply chain, logistics and procurement'.

During interviews, participants mentioned social aspects of civil engineering 205 times. Mentions had to do with community, access, longevity, developing nations, gender and diversity, social benefits related to efficiency, and public health and safety. Based on the way we coded, these mentions (e.g. longevity and future generations) might have more to do with what participants see as global responsibility than what they actually do related to it.

Four participants discussed diversity. James described diversity on design teams as desirable, saying 'a responsibility of the large organizations [like] I work for [is] to make sure we have diverse teams and provide equal opportunities'. George explained how tendering metrics for some recent rail projects have encouraged diversity (i.e. on design teams).

Interestingly, the UN's Sustainable Development Goals were mentioned by only two participants and the earlier Millennium Development Goals by only one.

Health and Safety (H&S) emerged as the social issue of primary focus for participants. We had expected to hear about ethics and anti-corruption as a result of initial conversations with our Advisory Panel, yet participants rarely framed their narratives using these terms. Many of them discussed

Table 3. Frequency of social mentions.

Social topic	Participants	Mentions
Community	7	56
Access	7	44
Longevity / future generations	5	46
Developing nations	4	21
Gender and diversity	4	13
Efficiency having social benefit	4	6
Public health and safety	3	19

Table 4. Frequency of ethics and corruption mentions.

Ethics topic	Participants	Mentions
Occupational health & safety	5 unprompted, 6 total	19 mentions of 'H&S', plus 1 'life safety' and 7 'safe' or 'safety'
Ethics	2 unprompted (Ava, Emma); 9 total	14 mentions of the word by participants
Corruption	1 unprompted (George); 4 total	8 mentions of the word by participants

jobsite H&S without prompting, while others raised the topic when we asked about ethics and if they had encountered the topic in university.

Safety of those working on building sites was the number one concern with regard to 'ethics', and Table 4 identifies how participants discussed the topic. It shows the number of participants mentioning each aspect (occupational H&S, ethics, and corruption), indicating if the point was unprompted (raised by the participant) or prompted by the interviewer.

Without prompt, five of the nine participants associated on-site H&S with global responsibility. However, participants did not inherently link ethics and anti-corruption to the term. Please see Chance et al. (2021) for detailed analysis of participants' responses related to ethics.

Economic sustainability

Economic sustainability did not emerge as a stand-alone theme, although financial considerations did. Money typically constitutes a barrier to implementing more sustainable approaches. The sector is 'driven by cost, programme, and spec' said Charlie, and 'the net effect of that is that we are also trying to do things efficiently in terms of material use'. James added, 'Often capital expenditure will be prioritised, [above] life cycle costs, which I would say is unfortunate'. Arthur echoed these comments, asserting 'The construction industry is always very frantic. There's never a huge amount of money. No one's ever feeling relaxed and comfortable of their own budget'. Five participants emphasised, however, that social and environmental benefits do often accrue from being efficient.

Table 5 indicates how many participants discussed each economic factor and with what frequency. Money, the press for efficiency, fragmentation across the industry, lack of time, and existing habits (including risk aversion and comfort with known ways of working) affect what the early-career engineers in this sample said they could accomplish. These economic limitations are analysed in detail under Q3.

Conclusions for Q1

Synthesis of results allowed us to answer the first research question: How do early-career civil engineers working in London conceptualise and define 'global responsibility'?

It is a nebulous term. Like Charlie, most found global responsibility 'quite difficult to define'. James asked, 'How many times have I heard the term global responsibility? Not loads.' He added 'it's not a buzz word, in the industry'. To Ava, 'It's a very complex, multifaceted issue which you

Table 5. Frequency of economic mentions.

Economic topic	Participants	Mentions
Money	8	46
Efficiency (pressure & benefits)	8	17
Contracts and priorities	7	38
Fragmentation	7	21
Time	7	19
Risk aversion	4	6
Health & safety (related to cost)	3	9

can tackle from really many different angles'. Indeed, for most, the combination of words was ambiguous, multifaceted, and unfamiliar.

An immediate objective of 'global responsibility' is to minimise damage. Participants described doing less harm by 'minimizing the negative externalities of your work' (Arthur) and 'carrying out projects, creating infrastructure, without having a detrimental effect – a lasting detrimental effect – and minimizing that effect on the world' (Jack). This is consistent with Krieger's (2007) statement that the practical side of 'working for the betterment of humanity [involves] using one's talents and skills for constructive rather than destructive purposes' (¶8). Yet, it falls short of replenishing or regenerating the environment (Iverson and Chance 2007; McDonough and Braungart 2010).

Material selection, carbon emissions, and H&S predominate in participants' definitions of global responsibility. We can confidently state that specific environmental topics are of central concern in participants' day-to-day work. This set of engineers is indeed making 'decisions about the use of material, energy and water resources, the development of infrastructure' described in the literature by Dodds and Venables (2005, 8). There was a collective sense that global responsibility involves protecting future generations, working toward environmental and social justice, and protecting those working in construction. Health and Safety were regarded as primary means for acting ethically and achieving social sustainability. Participants were able to identify aspects of global responsibility that the projects they work on impact, although early-career engineers described feeling constrained in how much they were able to influence as individuals, as most decisions are made before their work, or are outside their purview.

Q2 Sources of learning about global responsibility

This section presents results of the second question: *How have participants learned about global responsibility?*

Results of Q2

Participants described learning about global responsibility as part of their jobs and through formal education.

Jobs

Learning at and for work were participants' main ways of coming to understand 'global responsibility' and enact it in practice. Civil engineering requires research, participants explained, for design as well as construction optimisation. Since these are considered a core part of their jobs, they can justify doing a fair amount of learning in these areas. 'CPD is daily for me', explained Jack, because 'any job that comes through would require a certain amount of research for me, in order to come up with the best solution'. This could involve reading books and papers, or talking with others, in order to 'come up with our best solution'. Popular forms of CPD included lectures, networking events, and symposia, as well as intensive day-long or multi-day workshops in the UK and beyond. Events sponsored by 'the Building Center, the ICE [Institution of Civil Engineers] of course, the IStructE [Institution of Structural Engineers]' helped direct Mia's attention. 'The precedent that's being set,' Mia explained, is 'that these materials are the sustainable options and are the industry best practice'. Although PEIs provide many of these events, others like lunch-time seminars are sponsored by companies seeking business, and thus the content may not be as reliable. Participants do their best to assess accuracy and implement recommendations they hear from trusted sources.

Discussions with colleagues are seen as important – and hearing diverse voices is valued. Sharing ideas across disciplines and sub-fields is also appreciated. Ava explained, 'I have a lot of discussions with people from different disciplines, to shape each other's views, or debate this topic and see, what is the bottom line'. Doing pro bono work, mentoring student engineers, and providing educational outreach to schoolchildren were seen as ways to learn new things and help others learn as well.

Conducting research helped participants generate new knowledge for their companies and themselves. Doing research is necessary to respond to project briefs, client requests, and their own desire for innovation and improvement over time. They have shared their research with colleagues and clients via meetings, office forums, showcases and portfolios, and conference presentations.

Mia provided a detailed example. To reduce the negative impact of her company's reliance on concrete, she conducted research at the Concrete Center. After reading 'Specify Sustainable Concrete' she promoted it 'around the rest of the office as well to make sure people were reading it'. Mia re-wrote her office's standard specifications for concrete, got buy-in at various levels, and succeeded in getting the changes adopted office-wide. What she produced is now 'a company standard document, that's used throughout all of our concrete projects'. She recorded this work as part of her CDP toward Chartership.

Formal education

For most participants, quality assurance procedures at their offices, combined with their own aspirations for Chartership, have provided impetus to engage with global responsibility topics. 'I keep a log for Chartership', explained Jack. 'To apply and then to maintain it, you have to keep a CPD log'. Working toward Chartership has required meeting specified objectives, involving 'work-based technical things or management type things,' according to Thom, but also including 'legal context and understanding aspects of sustainability'. He described how he had been 'tested on that, in an interview' to obtain Chartership.

Narratives indicate that other realms of formal education had not been very effective for developing knowledge and skills related to global responsibility. Of the six with undergraduate degrees in engineering, only three could recall learning about sustainability. One of these said her only experience was via a non-required module she selected in her final year. Two found it embedded in required coursework: Arthur indicated sustainability and social justice were integral themes of his Architectural Engineering course, and Charlie encountered various engineering 'scenarios' and also a final-year project that had threads of sustainability. The three others who had earned undergraduate degrees in engineering (Thom, Emma, James) explicitly stated that they could not recall encountering content relevant to global responsibility in their curriculum.

Across the board, participants who had studied geography indicated this was far more important to their understanding of global responsibility than anything they encountered in an engineering course. For Emma, 'Geography at A level' provided 'a really good foundation to bringing up both physical and social issues that exist on the globe.' The engineering course she chose at university was called 'Civil and Environmental Engineering. I thought that would be engineering from a sustainability perspective, but it wasn't. It was more from a sewage-treatment perspective!'

Several participants insisted it was possible to graduate from their engineering programs when they did without encountering the environmental and social pillars of sustainability, or discussion of ethics.

Conclusions for Q2

From the results presented above, we conclude that job-related learning and the incentive to log credits for Chartership have been primary motivators for participants to engage with global responsibility. They have learned through research, discussion, organised events, and information available online and in books and magazines. Civic engagement provided an additional avenue for learning. In general, participants did not see their time in university engineering courses as helpful in understanding or practicing global responsibility beyond H&S and some environmental issues. Global responsibility content had been largely absent from their degree coursework.

Q3 Spectrum of experiences enacting global responsibility

Third, we asked: *What aspects of global responsibility do participants feel able to influence in their day-to-day work? What opportunities and barriers have they encountered?*

Here, we sought to understand and assess the range of experiences described, from good to bad. In analysing interviews, we considered opportunities engineers have encountered that helped them succeed as well as barriers that caused frustration. To develop this section, we identified the tone conveyed with each participant's narration of events. We mapped these to a spectrum from positive to negative, as a way of helping ourselves and others understand what experiences are desired by early career engineers, and which are harmful or detrimental to their success. This helped us distill recommendations for Q4, our final, overarching, research question.

Results of Q3

Positive experiences of 'global responsibility' involved an underlying sense of purpose, satisfaction, accomplishment, collegiality, and/or support.

Learning and growing. Mia asserted there is interest in global responsibility 'from our side because we like to learn, as engineers'. Following on from Q2, many learning activities were described by participants as being positive and satisfying (for example, learning via CPD, collegial discussions, professional events, emails from colleagues about interesting issues). As described in Q2, the process and outcome of generating new knowledge – via (a) developing new specification templates for the office, (b) presenting research internally and at conferences, and (c) teaching others – also provided a sense of pride and satisfaction. Many participants projected a sense of fulfilment when describing instances where their research was supported, celebrated, shared, and/or adopted to inform future practice. James felt positive 'just by using semi-sophisticated software … because you're developing [and] learning about the digital innovation and you're applying technology [and this] will have, a positive impact'. The discoveries they made on any given project, he said, can transfer over to other projects as well. In this way, Jack, and two others (George and James) discussed how their organisations learn through experience and use it to grow.

Building 'community'. Descriptions with a positive undertone often had to do with building or uplifting a community, such as engagement with new forms of participatory design and new ways of organising contracts to foster collaboration. New contract types had improved participants' experience by decreasing fragmentation and enabling collaboration around shared aims and goals. Many, like Charlie, valued good 'communication within the project' as well as careful optimisation to ensure all the parts work together.

Being part of member-owned firms gave two participants clear voice in decision-making and was a point of pride. Both Emma and Mia described enjoying collegial office culture, where ethical dilemmas could be openly discussed. Both described employee discussions regarding which projects to accept and being able to opt-out of work they did not find palatable. Although both sometimes faced discouraging situations and ethical dilemmas, their narratives indicate they did not feel isolated or alone in grappling with thorny issues.

Other examples provided on the theme of 'building community' included conducting and coordinating office outreach, mentoring interns, raising funds for Engineers for Disaster Relief, engaging with EWB and various pro-bono projects. James and Arthur both described feeling satisfaction in achieving innovative school designs with 'long-term durability' that can have positive 'impact on the students and the learning environment' (Arthur).

Moving toward sustainability. Core job responsibilities with benefit society – mentioned in nearly all interviews – included selecting materials in a more purposeful way with greater consideration for sustainability, optimising designs to eliminate unnecessary overages or environmentally hazardous materials, and highlighting responsible choices to others, including clients. James likes to assess 'where we can make savings'. This helps his team 'highlight the issue … and discuss with the client what the options are going forward.'

Quantifying benefits. Mia was able to compare and measure benefits on a concrete frame her team designed. 'We did quite a lot of work internally on reducing the embodied carbon', and without increasing time or cost, 'saved 30 tons of embodied carbon'. They achieved this by 'looking at concrete grades, levels of reinforcement, aggregate mixes, and things like that'.

Overall, five participants described benefits of quantification, noting that tools for measuring and tracking various aspects of construction are important. Several discussed creating or using such models. When they can measure alternatives, they are able to see, explain, and advocate better solutions. Engineers in smaller firms often use models and resources created by larger engineering companies, Mia said.

User experience is also something that can be quantified, Arthur explained. His firm seeks to quantify efficient and effective use of space, so people benefit. Measurement is important, he argued, because 'when you start quantifying, it's easier to put targets on that. Then, it starts to become more of your day job, but until then, you can't'. Arthur was not alone in stating that his ability to influence sustainability had to do with the range and reliability of tools available to him as well as the scope of what he is asked to do, design, or calculate. Only the senior engineer, George, is regularly involved in such discussions. He conveyed an air of confidence in being able to affect social outcomes that early career participants did not. For all, being able to back up claims with data seemed important.

Honoring their code and protecting H&S. Areas where most participants had not experienced negative feelings or stress involved jobsite H&S, professional codes of ethics, and current anti-corruption procedures. In most discussions, protecting H&S conveyed implied a sense of satisfaction. It has been easy for most of these early career engineers to avoid corruption, and most insist they haven't seen it (although Ava's contrasting situation will be discussed below). George's assertion that corruption has been declining over time was supported by others. Jack agreed, 'I don't think it's just common place as it used to be'. Today's rules are very clear, they feel, and straightforward processes are in place. Offices have codified their expectations and established standards for reporting gifts. Most of the early career engineers in our sample have been surrounded, Emma explained, by 'people and environments that naturally mean I don't get exposed to that sort of thing'. It appears that where expectations have been well-defined, they feel confident to watch for and uphold expectations. Yet, emerging research on what went wrong at Grenfell suggests many problems may still be going on within UK engineering projects, undetected, or ignored. This brings us to the negative end of the spectrum.

Negative experiences ranged from feeling resistance and discouragement (Mia) to the case where one participant's former employer was operating in globally irresponsible ways (Ava). In this section, we begin by characterising the less intensely negative situations before summarising the most harmful situations narrated to us. First, we consider times participants experienced resistance and felt discouraged or encountered barriers – vis-à-vis limited scope, limited resources, fragmented processes and systems, habits and other social and psychological barriers, and lack of tools. Even more detrimentally, we heard about instances of 'greenwashing', a company that enabled false green building certifications and other, even more overt, forms of corruption.

Limited scope. Six participants said the scope of their job limited their ability to influence environmental and social outcomes. Entering practice as graduate engineers, participants found limitations within their remits and little personal authority to make globally responsible decisions. Arthur explained, 'When I was more junior, I was more involved in the output side of it. Decisions were made and then I carried them through'. Thom added, at 'junior levels, you're doing what you're asked to do'. Working as early-career engineers often involves running calculations rather than designing systems holistically, they explained. As an entry-level engineer, Arthur explained, he was able to push back and provide 'suggestions when I felt something was wrong' but the most he could do was try to 'persuade, convince, let [clients] know that this is the right solution'.

Limited resources. Money and time are crucial resources in this industry. The amount of time they can spend considering alternatives is limited by budget and know-how (their own, and their firm's).

Decisions affecting environment and society require new learning and this takes time. Sometimes this is not billable to a specific project. Frequently, their ability to incorporate – or even research and consider – innovative solutions ties directly to what clients are willing to fund. Participants made clear that demanding timeframes prevent in-depth analysis.

Financing is a major constraint, as indicated in Arthur's prior comment about feeling 'frantic' about the budget. For Jack, the quick pace and high stakes of planning and bidding cause stress. Learning to use new materials and techniques not only takes time, it also introduces new risks and new unknowns – which clients typically seek to avoid.

Most clients still operate on an extractive, rather than re-generative, model (Iverson and Chance 2007; Empson, Chance, and Patel 2019). Up-front costs often dominate decision-making. James has found 'capital expenditure' is often prioritised above 'whole life cycle costing'. Cost is 'definitely the biggest barrier for us' Mia explained, because you can try as you might to 'promote alternative materials, different construction methods, prefab brought in on the site, but if there is not a monetary positive, it'll get beat down'. At the end, she asserted, 'cost is always the thing'. Jack agreed, stating that at the construction stage, 'There are some areas where we can influence' but an idea generally gets accepted 'only if it's cheaper, or if it's quicker or more efficient.' In his experience, 'it's very client driven' and 'it just depends on the client.' Where the idea tends to succeed is

> if you can tick the box of either of those two [being quicker or more efficient], plus a reduction in carbon, something that has greater social responsibility, then that's going to get the go ahead. But if you propose something that's going to take longer, cost more [the answer will be no].

It is clear that in the UK, the client controls the agenda, and many private clients will not spend more than they deem essential. Participants agreed: where the more environmentally or socially responsible option either costs more or takes longer, it will rarely be supported by a private client. Participants had often faced situations when their ideas were not adopted, and this led to feelings of discouragement, at the level of the individual as well as the team. On the other hand, large-scale public projects had provided opportunity to protect public wellbeing and enact values of global responsibility. According to interview data, such opportunities were much more common on large-scale public projects than smaller, private ones.

Fragmented processes and systems. Four participants described feeling locked in by 'decisions … made years ago' (Charlie). Five participants raised the issue of fragmentation, citing it as a barrier to global responsibility. Ava and George cited the need for systems thinking. Ava identified problems that happened when stakeholders weren't sufficiently included in planning – or lacked understanding of how innovative systems were meant to operate. George discussed major problems with London's Crossrail – a complex railway construction project currently underway in London, that has been delayed several times – where 'They've forgotten it was a railway system because it was sliced up. They built the tunnel, the tunnel is fine, but how do you run a train through it?' He noted, 'fundamentally it was a lack of preparation for integrating the railway systems. It's also quite complex. The control system for the tunnel is quite complex.' A challenge for Thom is 'making sure you're aware of the wider context when you're doing something – rather than just looking at the problem that's in front of you – and taking the time to understand the wider issue.' New forms of contract, like Design-Build, are helping overcome the fragmentation typical on projects with standard design-bid-build projects, said Jack. There's often a lack of coordination between the Architecture, Engineering, and Construction (AEC) components of a project.

Habits, social and psychological barriers. Setbacks where good ideas and research-backed solutions are not accepted by clients can lead a team to be less optimistic over time, as Mia had experienced. Good ideas can be overlooked or can fall by the wayside for a variety of social and psychological reasons. Habitual routine, fear of the unknown, and resource limitations can all have such effect (Hoffman and Henn 2008). They can limit change and deter success. Such barriers, according to Hoffman and Henn, exist on individual, organisational, and institutional levels. Thus, they can apply to engineers, their firms, and their clients. When clients reject values held by the design team, it discourages them from making the effort to learn and to pursue alternatives in the future (Mia). Resistance to change at the socio-political level also represents a significant barrier (George).

Emma sensed a kind of generational divide, saying the industry ‘is quite backward and quite slow moving, and it doesn’t respond to global issues as fast as it perhaps should and could’. Many people are locked into outdated ideas, and ‘some of the people at the top and the influencers in my company don’t share necessarily the same views as some of these younger groups’, Emma explained. There is a risk of ‘being trapped by decision-makers [who] make decisions based on what [they] know rather than what is right.’

Early career engineers sometimes overlooked problems that they noticed – such as flawed tools for calculating environmental impacts – when they did not see clear avenues for addressing them. Although ‘I’d like to think I don’t bury my head in the sand’, said Emma, its sometimes easier to accept the way things have always been done or what is presented as the best way to go.

It also can be easier to say nothing, Charlie explained, than risk being ‘pigeonholed as a bit of a tree hugger, which has a negative connotation’.

At the extreme of discouragement and psychological inhibition, Ava had experienced an unhealthy work environment, riddled with blame, shouting, and sexism, where she felt belittled. Her narrative reflected a tense and hostile situation specifically intended to maximise profit and stifle innovation. Refusing to yield her values, she felt compelled to change career paths and move into academic research.

Lack of tools. Participants asserted that current tools for quantification are not very robust. Arthur described the lack of quantification as one of the largest impediments to being globally responsible in his structural engineering work, saying that the things he associates with global responsibility are rarely quantified. Without measuring, the outcomes remain unknown. As an early-career engineer, Arthur ‘can’t point to what’s a better decision’ and he insists

> there needs to be an agreed methodology for measuring these things because, certainly, if you can’t measure it, you don’t know what’s there. … The main one, that I pick up on as I talked to other people, is embodied carbon – and material usage. The other ones are less well-defined in what is safer … but again, you can’t measure it.

Even where tools exist, they aren’t always used. Although ‘we’ve got embodied carbon calculations, a lot of them’, Arthur explained, ‘they’re not always used on every project.’ Moreover, the tools that do exist for measuring environmental benefits are not necessarily comprehensive, accurate, or reliable enough, Emma’s narrative suggests. This can lead to greenwashing, as described below.

Thus, there is a clear desire for tools that more accurately predict carbon, safety, energy performance, and building fabric – to quantify various qualitative aspects so they can be measured, assessed, compared, and defended. ‘Embodied carbon is an easy one because you can measure it,’ Mia noted, so you can clearly explain to clients ‘This design here has taken out 10% of that.’

Participants also noted the emergence of methods for measuring social impacts or using metrics to advance social causes in their work, but they have encountered few ways to identify, measure, predict, and influence social outcomes.

> “I would suggest that if I had time or if there were budget for whatever, all projects should have an embodied carbon tool, or should have some metric for social sustainability,” Arthur advised. It’s important to consider, for example, “How many people are we employing? How many jobs are we creating? What is the impact on the supply chain? A lot of [the green building rating programs] try to do it, but they’re often not as effective and don’t capture information that you necessarily want”.

Greenwashing. The lack of reliable metrics and tools for predicting future performance, quantifying and comparing available options can exacerbate and enable false advertising, or what we coded as ‘greenwashing’. Systems for certifying ‘green buildings’ are not consistent or reliable enough with either performance predictions or follow-through during installation, Ava and Emma explained. Clients often use green building ratings disingenuously, ‘because they know it sells well’ explained Mia. ‘It’s like an advertising sticker that they can kind of put on their structure’ but, she felt, many clients in the private sector 'don't really care' about environmental, social, or health-related outcomes.

Although a company may have constructed its own spreadsheets for estimating environmental impacts, they may not be accurate enough. Several years back, Emma had identified shortcomings in embodied carbon calculations her firm had run. She noticed the omission of data related to long-haul transportation and chemical processing that outweighed the benefits that had been calculated and widely advertised. Thus, the calculations provided to clients and the public were false. 'The message we were sending out, which was all the grand carbon offsetting benefits, were actually completely invalid, by the fact that you've got transportation costs and you're using chemicals.' When she voiced concern, her project manager acknowledged knowing about the problem but did nothing to address it. In the end, 'nothing was really done, or said, about how it was slightly manipulated, the information.'

Ava had witnessed many similar situations working in a consulting firm. Often, she said, 'if you try to look into the details of what this sustainability means' in the way it is carried out by many companies, she noted, 'you very often find' it is not genuinely sustainable.

Participants' narratives of greenwashing involved errors and omissions as well as outright corruption.

Overt forms of corruption. Ava discovered the consulting company where she had worked was essentially 'replicating the same studies in consecutive research' meaning that 'they were securing funding and a source of income, but they were not, you know, scientifically and academically, doing any leaps to genuinely contribute to the knowledge source, which I felt very disappointed with.' That same company was not reporting where building owners failed to install agreed components when they conducted final green building audits. Ava explained:

> They didn't do it because then your building contractors would not give you the next job. So, it's kind of an ugly reality of the world, where you have a responsibility which you don't fulfill because you don't want to lose your contracts,

Participants described awards that were politically motivated and instances where the winning contractor was allowed to cut corners. Mia had observed cases where 'shortcuts taken on the site in relation to health and safety, poor quality construction. But at the end of the day, the client was only really worried about the bottom line,' she believed, 'and not necessarily—if you talk about the global responsibilities—providing something that's usable.'

For a junior engineer, it's not always easy to stand up and confront bullying or implicitly corrupt situations like the greenwashing described above. The two most likely ways to deal with problems, errors, and omissions are to look past them, by normalising and rationalising corruption (Ashforth and Anand 2003; Anand, Ashforth, and Joshi 2004), or leaving the situation. Although participants felt constrained in what they could change, most of them nevertheless worked in places where they felt they could give input and highlight better alternatives. The exception to this was Ava, who could not find the support she needed inside her company. She left the consulting firm as a result. Ava explained.

> If this is rather obvious to me, how is it not obvious to them, and how come that I'm the, seemingly, only one who's questioning this?" I was closer to some of my colleagues and we had discussions about this, and it turns out that they were aware as well but they somehow, some way, justified themselves that it's okay, or they don't have other option to work for a company who are more ethical, or more genuine, or that every company is the same. There is a set of excuses that you can come up with, but I couldn't agree with any of this, basically. And when I concluded that, "Yes, it is what it seems to be," I just made a decision that I do not wish to work for an employer like that, and I don't want to believe that every company is like this—because someone has to start making changes if we want the world to be a better place.

Ava's testimonial shows there is not always a safe way to confront problems and challenge existing systems. Her colleagues exhibited 'denial of responsibility'. They rationalised corruption in ways described by Anand, Ashforth, and Joshi (2004) wherein 'the actors engaged in corrupt behaviours perceive they have no other choice than to participate in such activities' (41). On the other hand, Ava refused to rationalise corruption. As Ava's narrative demonstrated, it can require time and distance from the situation to be able to see and understand how the parts have been working together. Perhaps having a mentor outside the company could have provided perspective and support to help her through this difficult time? She has now left engineering practice in favour of academia, and this could be seen as a loss to the profession; a conscientious observer with a critical perspective has left for safer ground.

Conclusions for Q3

All early career participants in this study expressed feeling limited in what they could achieve. Yet, they had persevered against challenges and various forms of discouragement, to discover their decision-making authority had grown. Interviews suggest carbon reduction and embodied energy of materials were the primary concerns early career engineers in this study felt able to affect. When Ava found herself unable to affect enough, she shifted focus so her work could make a difference. Those who stuck with engineering practice focused on highlighting responsible options. Many sensed frustration and discouragement when clients ignored good ideas.

Economic concerns were described in the context of either social or environmental concerns. Financial considerations were typically seen as conflicting with social and environmental aspirations of early career engineers. For many participants, economy represents a barrier – whereas environment and society provide opportunities for doing better.

Enacting global responsibility is more than any one engineer can accomplish individually. An engineer can identify what actions are feasible, but collective actions often sweep them along. Change is enabled via 'the power of the group, united vision, united thoughts and united strategy on these things' Emma explained, but for her, being part of this change starts 'from a place within'. Individual perspectives work together to create shared vision and achieve collective action, and some firms have incorporated global responsibility into their work environment more than others. The engineers in this sample have contributed to sustainability by participating in this research and co-constructing new knowledge with us (Charmaz 2014). It is worth noting that those who chose to participate all now work in settings where they feel comfortable and safe.

Q4 Supporting early-career engineers

Answering the final question of our study required synthesising the results and findings from Q1-3 and revisiting the literature review. Q4) *How might PEIs, HEIs, and engineering educators better support early-career civil engineers in their efforts to enact global responsibility?*

We have formulated conclusions for each major strand of our study – definition, sources of learning, and experiences from good to bad – as related to global responsibility.

Conclusions regarding definition

Regarding how engineers understand global responsibility, this study indicates a need to:

- Utilise terminology that underscores responsibility and supports the SDGs
- Focus on 'public welfare' to complement values and systems existing to protect job-site H&S

Utilise clearer terminology. From the data these nine engineers provided, we induce that, in civil engineering, global responsibility implies protecting the natural environment through the design and construction of structures and systems that improve living conditions across the globe in ways that promote social equity and economic fairness at local as well as global levels. As such, global responsibility can and should serve as a moral compass to help regulate ethical behaviour, prevent corruption, and promote the common good. However, the term global responsibility is not well understood. Among these civic-minded civil engineers there was weak shared conception of the term and almost no explicit link to the UN's SDGs.

The three pillars identified in the literature (environment, society, economy) were widely recognised by participants in this study. However, the term 'global responsibility,' which the UN has been promoting since 2005 to encompass a wide range of concerns including and beyond environmental sustainability (GRLI 2020), was not widely recognised or in common use across this sample. The term 'sustainable development' seemed far more familiar to this sample group than the term 'global responsibility'. If PEIs and HEIs were to encourage wider use of this term – and use it in speeches, publications, written materials, lectures, and course materials – it could help build a common concept of responsible behaviour across the UK engineering community.

Promote public wellbeing to complement existing focus on occupational health and safety. We see a need to shift the priorities shared by the profession to embed wellbeing in addition to 'health and safety' as it is currently conceived in the UK. UK participants told us the main area where cost does not reign central is H&S. However, when participants mentioned H&S, their comments typically focused on the job site. They did not necessarily extend their conceptions of H&S to the whole of the public. Moreover, one part of Krieger's (2007) description of global responsibility was not clearly evident in participants' understanding of H&S: 'speaking out, individually or collectively, against dangerous and destructive uses of science and technology' (¶ 8).

In contrast to the UK, in the US, the sectors of AEC all use the term 'Health, Safety, and Welfare' (HSW) reflecting a purposeful effort to protect wellbeing of individuals and the public. The National Council of Architectural Registration Boards [NCARB] (2018), for example, 'protects the public health, safety, and welfare by leading the regulation of the practice of architecture through the development and application of standards for licensure and credentialing of architects' (¶11). For this organisation, public wellbeing tops the list of professional obligations. HSW is designated as its own category for CPD. Architecture and engineering institutions in the US, as well as professional licensing bodies in each state, often mandate minimum annual thresholds for CPD in both HSW *and* sustainability. Engineers and architects are required to hold state licensure in order to sign off on most projects larger than a single-family house.

The UK has weaker systems of professionalism, but change mechanisms exist, nonetheless. UK engineering has very clearly embraced job-site H&S, vividly demonstrating that change is possible. The levers (policies, procedures, messaging systems, and communication practices) used to operationalise this change could be replicated – to widen the shared conceptualisation of H&S. We recommend promoting conceptions that include more people under H&S (to include people off-site) and more holistic understandings of 'health' and 'safety' (to encompass communities and the planet).

Conclusions regarding sources of learning, learning approaches and continuous professional development

Results of this exploratory study suggest how to improve delivery of educational programs to better encompass global responsibility. Our recommendations are to:

- Integrate environmental, social, and ethical issues into the development of engineers in increasingly memorable ways
- Provide more exposure to the SDGs and support engineers and firms in realising them via benchmarking and holistic thinking
- Evaluate how engineering mentorship works in the UK and identify how it could be structured more effectively
- Require CPD among all engineers in the UK, not just those who choose Chartership

Integrate environmental, social, and ethical issues into the development of engineers in increasingly memorable ways. Our analysis suggests the need for more authentic and noteworthy integration of environmental, social, and ethical issues in engineering courses. The literature identified accreditation requirements in place in the UK since 2004. The Engineering Council UK (2004) listed many possible ways that graduates could demonstrate the required levels of global responsibility: considering environmental, social, and economic outcomes in decision-making; designing products and services that support environmental, community, and financial quality of life; or integrating a range of stakeholder viewpoints and activities in their decision-making processes.

Since these expectations were stated in 2004, one would expect all interviewees to have experienced these. Yet, only a few participants could recall university activities related to considering environmental, social, and economic outcomes. As a result, we encourage educators to make these lessons more relevant, memorable, and 'sticky'. This might involve reinforcing them through clubs, competitions, and other extracurricular activities (Polmear, Chau, and Simmons 2020).

Overall, it is important to provide students with opportunities as well as clear impetus to engage with people and the environment – to explore social and environmental sustainability topics – and to encounter ethical questions and effectively confront ethical dilemmas, through both the formal and informal curricula offered by HEIs. Students must have hands-on engagement with engineering to bring abstract concepts to life at a scale and texture students can relate to and make part of their vocabulary. Engineering programs can, and must, seek to positively influence the values – as well as the skills and behaviours – of students before they graduate.

As for undergraduate learning, results suggest that most curricula experienced by engineers 3–9 years out of university had little memorable coverage of ethics and sustainability. This appears consistent with findings by the ASCE Committee on Education (2019) that resulted in a recent shift to expect high-order abilities in the realms of ethics and sustainability to be demonstrated by early career rather than student engineers. This would allow individuals to be mentored by experienced professionals outside their employing organisations, to provide wider perspectives and an impartial 'sounding board'. This type of program can help individuals as they learn to grapple with complex and slippery issues. The Committee on Education has determined that the university years alone cannot yield sufficient proficiency in dealing with ethical conundrums and complex sustainability challenges. The Committee has written new expectations for accreditation of engineering programs into CEBOK3, specifying where and how engineering can reasonably convey complex high-order abilities in sustainability and ethics. We believe the UK should draw from this resource and the research that underpins its development (e.g. Bielefeldt et al. 2019).

Provide more exposure to the SDGs and popularise SDG benchmarking and tools. The lack of reference to either 'Sustainable Development Goals' or 'SDGs' by these civil engineers – working in a profession with some of the most direct, tangible, and measurable impacts on climate, provision of clean water and sanitation – was striking. In a 2015 survey, respondents from Engineering and Construction saw their work positively impacting: (1) industry, innovation and infrastructure (SDG 9); (2) decent work and economic growth (SDG 8); (3) climate action (SDG 13); (4) sustainable cities and communities (SDG 11); and (5) responsible consumption and production (SDG 12) (Preston and Scott 2015, 11). This was one of the few sectors selecting sustainable cities and communities, highlighting the important of this sector in realising UN goals.

Although mentions of the SDG were surprisingly infrequent during our interviews, the clusters of understanding Biefnot (2003) had identified all surfaced in conversation, including the desire to eliminate poverty, reduce social inequality, respect human rights, and protect the natural environment. Being more conscientious and intentional can help all stakeholders focus their efforts on the common good. Shared goals and benchmarks can be of particular benefit to early career engineers as these professionals contribute in new areas and learn to navigate increasingly complex situations (Preston and Scott 2015; PwC, GMIS, & UNIDO 2017). This may be occurring in some of the participants' firms, especially those with 'sustainability portfolios', yet SDG benchmarking was not mentioned by any participant. All firms seem to have implemented policies and procedures to help avoid bribery, and several of the participants' firms have created systems and set benchmarks and goals to enhance their performance in sustainability, but the SDGs themselves were not mentioned.

Thus, the opportunity to align with efforts of global scale and to contribute more specifically to a vision shared beyond the profession is being under-utilized.

In particular, more attention should be given to systems thinking and life cycle analysis over upfront capital costs and students should be exposed to these at the bachelor's level as part of the required curriculum. It appears that today, some civil engineers never receive training on these topics.

Overall, early career engineers felt limited by the scope of their jobs, project assignments, and client budgets. Existing measures of success also limit them: 'The benchmarks that you're measured [against] as an engineer don't necessarily line up with global impact', Arthur asserted. Tools to quantify a wider array of benefits would help.

Although many engineering firms do run calculations (on aspects like embodied carbon) they don't make calculations for all of their projects because doing so carries 'extra' cost that many clients deem unnecessary. These days, demand must come from clients, they say, if they are to calculate environmental and social benefit and enact global responsibility. When they can quantify sustainability and efficiency, it helps them justify decisions – and achieve decisions more astutely.

We believe government policies should go further to *require* consideration of social and environmental sustainability in order to align with existing international agreements. George explained that about ten years ago the mantra in civil engineering started to change from 'harnessing the environment' to serve the 'will of man', and this shift

> allowed you, as a civil engineer, to make the case for environmental responsibility and global sustainability, against the hard-nose finance and quantitative surveyor's people who were looking at the bottom line when constructing things, because it became a national and government agenda item.

The national agenda can do more to support responsible development. Building performance must not only be predicted – it also must be monitored – so that buildings and systems can be maintained and operated more effectively over time. Most of today's green building programs do not require the types of post-occupancy analysis and building performance tracking that we believe are essential to sustainable performance. Harvesting and pooling data on how buildings are actually performing can also help society develop better and more effective tools, policies, and practices (Chance 2012). As noted by participants, Life-Cycle Analysis (LCA), systems thinking, and use of reliable tools and models can help public and private clients set priorities and optimise their decisions.

Evaluate how engineering mentorship works in the UK and identify how it could be structured more effectively. Participants fortunate enough to work in firms that encouraged internal dialogue, reflection, and critical discussion, all experienced informal mentorship; their narratives underscored the importance of having critical colleagues to consult during times of doubt and dilemma. Participants did not mention having trusted advisors outside their firms. This was somewhat surprising as it is a common feature of mentorship programs in the US, for example, the Architectural Experience Program (AXP) of NCARB (2016). In US civil engineering, the ASCE's Committee on Education (2019) relies on structured mentorship and uses it to help early career engineers navigate ethics and sustainability. Surveys of engineers conducted by Bielefeldt et al. (2019) indicate recent graduates need further development in these areas.

Require Continuing Professional Development among all engineers in the UK, not just those who choose Chartership. Creating change will require new knowledge, skills, and values. CPD represents an important tool for innovating across a profession. In the UK, engineers 'have a duty to become and remain competent to deliver the concept and practice of sustainable development in their day-to-day work, and may need actively to seek out courses and other development support to achieve this objective' (Dodds and Venables 2005, 45). To help individuals develop new knowledge and skills, the Engineering Council organises CPD events and programs. Very recently, this Council started requiring members of all 35 PEIs in the UK (all under its umbrella) to record their CPD activities. It now requires its PEI members, including the four related to civil, structural, highway and transportation engineers, to conduct systematic audits of members' CPD records (Engineering Council 2013; ICE 2020).

Limiting entrée and requiring all new entrants to demonstrate current knowledge, skills, and values is another way to shift outputs of a profession. To become Chartered in the UK, early-career engineers are required to engage with topics of sustainability and ethics. Only about 5% of UK engineers gain the credential of Chartered Engineering (Uff 2016), although the percentage is a bit higher within civil engineering specifically. 'There is no restriction on the right to practise as an engineer in the UK' beyond a few safety-related signoffs (Engineering Council 2020, ¶3). This indicates relatively few UK engineers will be mandated to update their knowledge, leaving probable gaps in knowledge on ethics, sustainability, and global responsibility.

Nevertheless, the CPD system seemed to be working related to the engineers in this sample group. Our literature review highlighted that UK Professional Bodies have implemented increasingly clear requirements for engineers to engage with sustainability and codes of ethics in order to become Chartered, ensuring their own engineers have some level of proficiency in 'global responsibility.' New CPD requirements in the UK represent a step forward. Yet, because just 5% of engineers in the UK choose to become Chartered, we believe many practicing engineers will not have a direct impetus to develop knowledge, skills and abilities around sustainable development, social equity, ethics, and the like.

Conclusions regarding the spectrum of engineers' experiences

In this section, we consider how to encourage and enable responsible action. Until there are clear and appropriate systems for flagging concerns, reporting failures, and amending future practices and behaviours, organisations and societies cannot benefit to the fullest. Results indicate that firms and the profession overall could benefit from enhanced systems for 'organizational learning'. Possible avenues for this are:

- More rigorous and frequent discussion of ethics across the profession
- Higher engagement of engineers in politics
- More discussion of how individual engineers can contribute holistically
- Higher levels of collectivisation across engineering in the UK to promote infusion of best practices
- A way to collect and pool ideas for improving systems
- Better mechanisms for flagging concerns and reporting errors and omissions without fear of personal retribution

More rigorous and frequent discussion of ethics across the profession. There is an opportunity to expand ongoing conversations within professional organisations (e.g. on anti-corruption) to encourage public deliberation of what it means to be ethical, to construct a code of material ethics, to develop a stronger code of social ethics, and to acknowledge that ignoring these topics represents a form of unethical conduct. Mentoring programs like the ones mentioned above could help, particularly for early career engineers. Public discussion of factors contributing to the Grenfell tragedy (which could have been avoided with more transparent decision-making) and continued investigation of similar cases (to prevent another such disaster) can help remind professionals of the dangers of errors and omissions (Craven 2020).

Higher engagement of engineers in politics. ASCE (2007) and ICE (via Jowitt 2009) issued calls for engineers to get more involved in politics. Yet community forums for discussing design and political forums for allocating resources often aren't in the purview of early-career engineers. Interviews suggest early-career engineers hear about public debate and policy changes, but they observe rather than give input into such discussions, as these fall outside their remit or scope of work.

Thom noted that, overall, engineers are not very involved in the political and community-participation parts of the design process, 'Which is probably a bit of shame.' He added, 'It would be good to be more involved with that. I think that's probably something that we can develop.' The senior engineer, George, emphasised the importance of policy that changes practice and enables decision-making down the chain. He also described the power of political messages to the public, referring to them as 'The game.' This is a game that engineers can, and should, do more to shape.

More discussion of how individual engineers can contribute holistically. Interviews provided evidence to support the claim that individual engineers make important 'decisions about the use of material, energy and water resources, the development of infrastructure, the design of new products' (Dodds and Venables 2005, 8). However, interview data also suggest that early-career engineers lack the tools, authority, and impetus they need to influence much beyond material choices. What participants told us about limitations is likely to be true of early-career engineers working elsewhere. They struggle to achieve buy-in and often cannot implement their ideas for sustainability and global ethics. Their successes are small and incremental. As a result, there is a huge divide between the utopian visions articulated by ACSE and ICE, and the actual ability of these young engineers to alter the status quo. Yet, it is increasingly evident that more must be done, and that we cannot continue to operate using extractive models from the first Industrial Revolution.

Higher levels of collectivisation across engineering in the UK to promote infusion of best practices. Reviewing literature on engineering Chartership highlighted the limited reach of the UK to govern and regulate engineering. Professionalisation is not required for most decision-making (Engineering Council 2020) and 95% of UK engineers do not achieve Chartership (Uff 2016). Thus, there is no assurance in the UK that engineers are upskilling in sustainability and ethics as required among engineers in the US by their state credentialling systems.

Kung (1991) encouraged shifting from individual expression and contemporary emphasis on personal success to 'an ethic of responsibility' (viii). Such ethic of responsibility was evident among the engineers we interviewed. They wanted to succeed in engineering by gaining Chartership, which compelled them to participate in this study and thus contribute to the greater good. Collectivisation is supporting responsible behaviour among those who go that route.

How could the UK encourage greater involvement in professional development? For one, the UK government could do more to legally require credentialling and ongoing education. PEIs could create high-quality mentoring programs. They could make it even more interesting and enticing for engineers entering the profession to stay engaged with professional development. The government could promote channels into Chartership and to help increase PEI membership. PEIs could develop more ways to engage individuals while they are still students and retain them after they graduate.

We believe many of these suggestions are already reality in London, yet we do not understand the overall lack of uptake in Chartership and we ponder why no participant mentioned being mentored. On the other hand, participants in our study joined engineering-related groups during university and many have stayed active in engineering groups and PEIs.

A way to collect and pool ideas for improving systems. Development is needed of more tools for predicting and measuring actual outcomes of environmental and social sustainability in various realms of AEC. Better mechanisms for contributing new ideas and procedures for implementation industry-wide in engineering meet the SDGs would benefit all. Indeed, the accuracy and reliability of the existing tools can't and won't improve without people using them and making them better over time.

Better mechanisms for flagging concerns and reporting errors and omissions without fear of personal retribution. Interviews showed how problematic it can be when safe avenues for raising concerns are not present, even in firms where ethics and sustainability are held in high regard. Having support and a receptive audience for voicing concerns is of particular importance for emerging professionals. Today, graduate engineers have been educated to uphold ideals, but they are not provided adequate policies, procedure, and tools for confronting unsustainable practices and challenging the status quo. Grenfell provides a poignant example of what can go wrong when no one speaks up (Craven 2020). Errors, omissions, and ethical breaches of various magnitude can compound to create a recipe for disaster (Bowsher 2020; Sanchez-Graells 2020).

Discussion

We hope this paper will provide useful insights and a helpful baseline for readers. It offers food for thought to those at HEIs developing courses and curricula and at PEIs developing lectures, CPD requirements and programs, and written materials. It provides a foundation for further study by members of HEIs and PEIs alike.

In considering what individual readers might consider doing after reading this article, we suggest that all those involved in engineering education and accreditation might reflect upon our conclusions and consider implementing recommendations identified above. Those with research capacity might build on this exploratory study, using it as a foundation for further work. Those involved in curriculum design, or in teaching engineering, might help ensure that their program's curriculum and overall set of courses cover essential topics noted above. For example, a person designing a final year civil engineering design course could seek to include crucial topics:

- The pillars of sustainability (economic, social, environmental) and triple bottom line reporting
- Sustainable Development Goals
- Ethics, including individual and collective responsibilities and obligations
- Use of reliable tools and models to help clients set priorities and optimise decisions
- LCA and systems thinking
- Greenhouse emission reduction schedules along with strengths and weaknesses of carbon accounting methods and tools
- Corporate Social Responsibility and/or the social license to operate (Shinglesplit Consultants Inc. 2020)

We recognise that our sample did not necessarily represent the norm – this group had challenged themselves to achieve advanced credentials beyond required in the UK. Moreover, the type of person who would volunteer to travel to our university campus and discuss 'global responsibility' for an hour is likely to have a higher level of concern for these topics than the typical professional. Additionally, half the participants were or had been involved with EWB, and we believe they represent those engineers most likely to engage in globally responsible ways. Yet, even within this proactive group, the ability to affect change was quite limited.

In finale, we compare our participants' narratives with Krieger's (2007) report of what the International Network of Engineers and Scientists for Global Responsibility considered to be responsible behaviour. The report stressed a need to work 'for the betterment of humanity [and to use] one's talents and skills for constructive rather than destructive purposes' (¶ 8) and indeed our participants mentioned these aims. Even this group of self-motivated and self-selecting engineers faced challenges, and felt constrained, when trying to implement change by 'speaking out, individually or collectively, against dangerous and destructive uses' (¶ 8) of engineering technology. One way this group found to 'speak out' was to participate in this study. They lent their voices, knowledge, and experiences to the cause of global responsibility. However, it is clear that even these engineers need help speaking out. They need support individually when they see various forms of greenwashing and corruption going on, and they need help collectively so that they can contribute in clear, measurable, and meaningful ways to achieving larger societal goals, such as the SDGs.

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Appendix

Interview Protocol with Questions

- *Introduce the interviewers; explain purpose of the study and potential benefits.*

I'm ___ and this is ___ and we are researchers here at UCL. We've been asked to talk with you about the idea of 'global responsibility' and how it connects with the work you do as a civil engineer. Learning more about your experiences can help the engineering profession support engineers better and also serve society better. Getting to talk about these issues should also be enjoyable since all three of us here today will get to learn new things.

- *Give consent form, remind of confidentiality, anonymity, right of withdrawal, compliance with legal provisions and the transcription process.*
- *Turn on the audio recorder.*

Interview Questions

1. Please tell us about an instance in your recent work as a civil engineer where you made decisions related to 'global responsibility'.
   Probe any of the following, as appropriate:
   - WHAT happened?
   - WHAT was the context of the experience?
   - WHO was involved?

- WHEN did this happen?
- WHERE did this happen?
- WHAT influenced your decisions?
- WHY did that topic matter to you?
- WHAT was the outcome?
- HOW did you see 'global responsibility' relating to that situation?

2. HOW did you learn about global responsibility?
3. WHAT attracted you into civil engineering?
4. With regard to global responsibility:
   - WHAT barriers have you faced? Anything particularly stressful or corrupt?
   - WHAT opportunities do you see?
5. You mentioned earlier that you … [faced a specific challenge]. What prior experiences helped prepare you to meet this challenge?
   Probe any of the following, as appropriate:
   - HOW did you learn about that [topic you mentioned]?
   - HOW did that affect your decisions?
   - HOW did you resolve that?
6. At this point, can you please SUMMARISE how you define 'global responsibility'?
7. Do you have any other examples of times you considered 'global responsibility' in your work? Or, Do any other examples come to mind with regard to 'global responsibility'?
8. Before we conclude, is there anything you would like to add that you haven't had a chance to talk about?
   Probe: Is there anything else you'd like to say, for example, about …