THE POWERLESS ENGINEER: QUESTIONING APPROACHES TO TEACHING SOCIAL RESPONSIBILITY (RESEARCH)

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ABSTRACT

In recent years there has been growing emphasis on the requirement for engineers to contribute toward the complex socio-technological challenges confronted by society. The need for a more holistic understanding of the societal impact of engineering has been highlighted by government, professional institutions and industry, and has strengthened calls for a widening of engineering curricula. Despite this, there is evidence to suggest that the higher education (HE) sector is not producing socially responsible engineering graduates. This study explores potential barriers to the development of socially responsible, culturally aware engineers. In so doing, it draws upon student feedback and reflections from a UK based engineering

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design course which makes use of the Engineers Without Borders UK Design for People Challenge, and which focuses on human centered, sustainable design. The findings are discussed in the context of theories of reasoned action and planned behaviour. It is argued that engineering culture and curriculum act to discourage alternative modes of thought which leave students powerless in their ability to enact meaningful change. Alternative modes of teaching and learning are discussed.

1 INTRODUCTION

1.1 Motivation

The need for engineers to solve complex socio-technological problems has been highlighted by government bodies [1], professional institutions [2], [3], [4] and industrial stakeholders [5], [6], resulting in worldwide calls for curriculum changes. Within the UK, the latest edition of the Accreditation of Higher Education Programmes (AHEP) framework (AHEP4) has incorporated language around the social dimension of engineering, with one of the five areas of learning being referred to as “The engineer and society”, this including learning outcomes that refer to mitigation of security risks and supporting equality, diversity and inclusion (EDI), in addition to sustainability, risk and ethics [7]. Elsewhere, the National Academy of Engineering [2] call for engineers to “ethically assist the world in creating balance in the standard of living for developing and developed countries alike” (p. 51).

Despite the apparent consensus that the profession should engage more deeply with societal issues, several pieces of work suggest that higher education (HE) is not preparing engineering students to display social responsibility. For example, Bowen [8] describes “a tendency for engineering, as presently taught and practiced, to prioritize technical ingenuity over helping people” (p. 6). Zandvoort [9], Riley & Lambrinidou [10] and Bielefeldt [11] all note the absence of any clear vision of what serving society means for engineers.

Other work has focused on changes in the way engineering students perceive social responsibility, with both Cech [12] and Rulifson and Bielefeldt [13] reporting an apparent decrease in the value students place upon social responsibility throughout their undergraduate degree. Elsewhere, Smith et al. [14] reported that students taking classes with significant corporate social responsibility (CSR) content tended to express a greater desire to work for socially responsible companies. However, this improvement did not usually translate to their next course. Disengagement with societal issues has been claimed to have direct implications for the diversity of engineers [14], with several pieces of work claiming that women and racial/ethnic minorities are more likely to pursue engineering careers with an explicit sense of social responsibility [12], [15], [16]. It also limits the extent to which we can expect engineers to produce socially just and sustainable engineering solutions.

This mixed methods study explores some of the potential barriers to developing socially responsible engineers. Data is drawn from the Engineering Professional Responsibility Assessment (EPRA) tool [17] and a combination of student feedback and reflections from a UK based engineering course which makes use of the

Engineers Without Borders (EWB) UK Design for People Challenge. The findings are discussed in the context of theories of reasoned action and planned behaviour.

1.2 Theory of Reasoned Action and Theory of Planned Behaviour

The Theory of Reasoned Action, or TRA [18], [19] and the Theory of Planned Behaviour, or TPB [20], [21] are theories used to understand human behaviour, and have increasingly be used in relation to sustainability research [22], [23], [24], [25] as well as energy, green IT technology adoption, environment-friendly energy use, waste management, and vehicle use [26], [27], [28], [29], [30]. TRA (see Figure 1) offers a conceptual framework which proposes that behaviour is influenced by three factors. *Attitudes toward behaviour* and *subjective norms* are both claimed to inform a decision process which results in the deliberate plan to perform the behaviour, or the *behaviour intention*. Within the framework, the attitude toward a behaviour is influenced by two things: *outcome belief* and *outcome evaluation*. Similarly, *subjective norms* are affected by both *normative beliefs* and *motivation to comply*. TPB is an extension of TRA (see Figure 1) which includes *perceived behavioural control*, which relates to the degree to which people feel able to enact the behaviour in question, this being based on opportunity and/or capability. Such theories are of interest given the existence of work which identified a negative correlation between powerlessness and action on climate change [31], [32]. The same work also describes a relationship between action and the commons dilemma, a term originally used by the economist William Forster Lloyd [33], and which refers to a case when the benefit derived from an action accrues to the individual, but the cost is shared within the community.

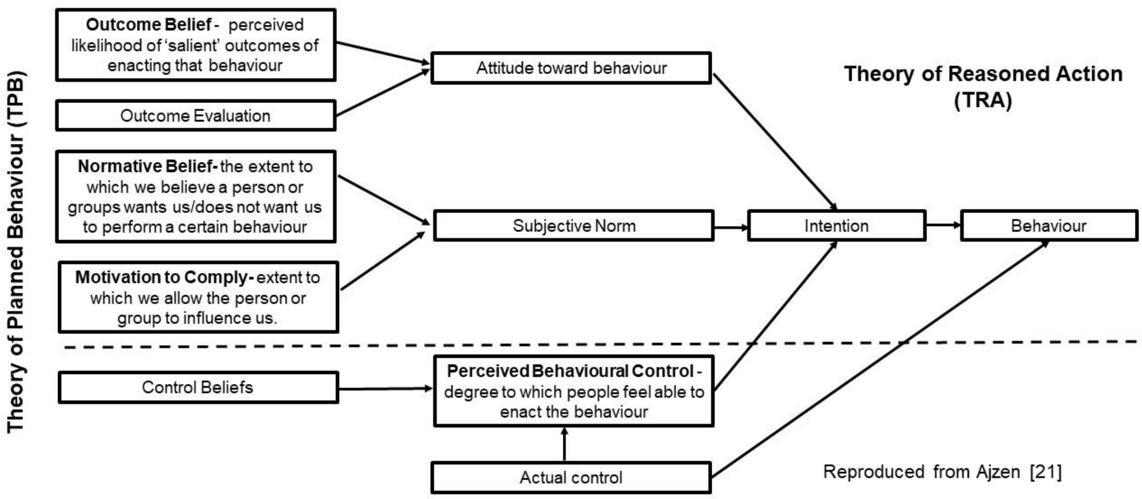

Fig. 1. Schematic showing the dimensions of the Theory of Reasoned Action (TRA) and Theory of Planned Behaviour (TPB) frameworks. Reproduced from [21].

2 METHODOLOGY

Data was obtained from first year (Civil, Electrical and Electronic, Materials and Mechanical) engineering students enrolled on a 10-credit module entitled

‘Engineering for People’. The module ran in the first semester of the academic year, for a duration of seven weeks from late September. The syllabus included: mindset and self-awareness; ethics and professional responsibilities; sustainability; design cycle; teamwork; positionality and personal design perspectives; and reflection. There were 2 hours of contact time per week including lectures and discussion. The module culminated in a week-long immersive design challenge during which all other modules were postponed. Students worked in small groups (5-7 students) to produce a design for the EWB UK Design for People Challenge.

Approval for use of student submissions for research purposes was sought from the Swansea University College of Engineering Ethics Committee. Students were provided with the research information sheet at the start of the module and were asked to complete a consent form to ‘opt in’ to the study. 105 of the 444 enrolled students consented to take part.

A mixed methods approach was adopted with the aim of understanding the attitude of engineering students toward social responsibility. Quantitative data was collected using the EPRA [17] which was administered to the students in the first week of the module. The EPRA has been demonstrated as being a reliable and valid measure of the social responsibility of engineering students and was developed by Canney and Bielefeldt [17] to operationalize their professional social responsibility development model (PSRDM). Their model assumes that, until university, experiences are limited to the personal realm of social responsibility development (realm 1: personal social awareness) when they are heavily influenced by friends and family. It is important to note that data was collected from first year students during their first semester, and it therefore likely that their views and behaviours reflect their personal social awareness. Throughout their degree programme, students learn about the professional realm of social responsibility, this referring to the values of priorities of the engineering profession (realm 2: professional development). The authors claim that students are likely to compartmentalize these two different realms unless they are given opportunity to engage in co-curricular activities that show them how personal and professional experiences can be integrated (realm 3: professional connectedness). The dimensions associated with each realm include: awareness (aw1-aw5), ability (ab1-ab4) and connectedness (co1-co4); base skills (ba1-ba5), professional ability (pa1-pa4), and analyze (an1-an5) and professional connectedness (pc1-pc19) and cost-benefits (cb1-cb4). The original tool therefore had 50 items in total. Following the recommendations of Canney and Bielfeldt [17], the number of items were reduced in the current work. Namely, the number of items related to the professional connectedness dimension were reduced and both the base skills and professional ability dimensions were omitted [17]. Answers were scored with a value of 1 being given for “strongly disagree” and a value of 7 given to answers of “strongly agree”. Negatively worded items (labelled * in Table 1) were reverse scored. For this work, only a basic analysis of data was conducted, and it would be interesting to investigate whether the results varied according to student characteristics, for example by gender, nationality or engineering discipline.

Qualitative data was drawn from several different sources including: written module feedback; lecture discussions; written reaction to the statement "Obsolescence is not only planned but forced and engineered", made by Professor Justin Lewis during a TEDx talk [34]; written reaction to a small extract from [35] which discusses the way in which engineering has focused on the needs of the richest in society, at the expense of other nations. Data underwent thematic analysis [36].

3 RESULTS

3.1 EPRA Results

The mean and standard deviation for each item of the EPRA tool is given in Table 1.

Table 1. EPRA Results

	Item	Mean(s.d.)
Realm 1	aw2: Some community groups within the UK need our (engineers) help	6.11 (0.83)
	aw4: There are members of society who have needs not being met	6.47 (0.97)
	ab2: I can have an impact on solving problems that face my local community	5.79 (1.02)
	ab3: My contribution to society will make a real difference	5.76 (0.99)
	ab4: I cannot have an impact on solving problems that face under-served communities internationally*	5.39 (1.22)
	co1: It is not my responsibility to do something about improving society*	5.80 (1.35)
	co2: It is my responsibility to take real measures to help others in need with problems	5.56 (1.24)
	co3: I feel an obligation to contribute to society	5.56 (1.14)
Realm 2	an1: Cultural awareness/ understanding is important for a professional engineer	6.14 (1.10)
	an3: I would not change my design if it conflicted with community feedback*	5.64 (1.05)
	an4: It is important for engineers to consider the broader impacts of technical solutions	6.26 (0.84)
	an5: It is important to incorporate societal context and constraints into engineering	5.93 (0.99)
Realm 3	pc1: It is important for professional engineers to volunteer and serve others	5.18 (1.14)
	pc3: It is important to me to have a career that involves helping people	5.50 (1.19)
	pc4: Service should not be an expected part of the engineering profession*	4.40 (1.31)
	pc5: I will use engineering to help others	6.05 (0.82)
	pc6: I view engineering and community service work as unconnected*	4.90 (1.45)
	pc7: I feel called to serve others through engineering	4.76 (1.48)
	pc8: Needs of society have no effect on my choice to pursue engineering as a career*	4.45 (1.75)
	pc13: Engineers should use their skills to solve social problems	5.39 (1.12)
	pc14: It is important to use my engineering abilities to provide a useful service to the community	5.70 (0.96)
	pc15: I believe I will be involved in social justice issues for the rest of my life	4.11 (1.61)
	pc17: I think people who are more fortunate in life should help less fortunate people with their needs and problems	5.67 (1.30)
	pc18: I believe it takes more than time, money, and community efforts to change social problems: we also need to work for change at a national or global level	6.10 (0.99)
	pc19: It is important to me to have a sense of contribution and helpfulness through participating in community service	5.27 (1.13)
	cb1: I would be willing to have a career that earns less money if I were serving society	4.48 (1.56)
	cb2: My engineering skills are strengthened through participation in engineering service	5.75 (0.91)
	cb3: I believe my life will be positively affected by the volunteering that I do	5.54 (1.14)
	cb4: I believe extra time spent on community service provides benefits for the community	6.10 (0.75)

The slightly higher values obtained for the awareness dimension, compared to ability and connectedness is perhaps unsurprising given the fact that statements are based on observation and general knowledge, as opposed to obligation [17].

When considering the professional connectedness dimension, the highest value was obtained for pc5, and it is possible that students assume that engineering, by its nature, helps society (e.g., by developing new technology) [17]. Lower values were generally obtained for items which referred to the individual (e.g., pc7, pc8, pc15) as opposed to the profession. One of the lowest values within the dimension was obtained for pc4 suggesting students feel they should have a choice in how they behave as engineers. In comparison, the highest value recorded for the dimension was for pc18. This perhaps indicates that students are aware of limitations in their ability to behave as socially responsible engineers.

It is interesting to note that one of the lowest mean values was obtained for one of the 'discriminating' [17] items, cb1.

3.2 Qualitative Results

Most students considered societal challenges such as climate change, energy security, water availability, over population, and poverty, to be the most pressing issues faced by the profession. Despite this awareness, it was possible to identify several potential sources of resistance to the inclusion of social responsibility in the context of the engineering curriculum. Table 2 presents representative excerpts organized by interpretive theme, alongside associated dimensions within the TPB.

Table 2. Representative excerpts and associated TPB dimensions organized by interpretive theme

	Subtheme	**Excerpt**	**TPB dimension**
Tensions between economic and social sustainability	Incentives	engineers focus on "how they can make the most money"; "…if we do not generate a profit then we will lose business and cliental"; if companies are "not releasing new products often enough a different company will"; "…the driving force of the modern world is economic growth and getting things done as quickly and cost-effectively as possible"; "isn't it weird that jobs helping people get paid less?"; "it's like we are being motivated not to help people"; Incentives are "predominately financial"; "…the majority of people will pursue monetary gain rather than social gain"; "…we live in a world where money is a huge factor in our thoughts and decisions making... in an ideal world…perhaps then an engineer would be more willing to pick a lower paying job which benefits the lower class of society"; preoccupation with "monetary gain or personal career development" means "the engineering profession does not attract people with humanitarian interests"; challenges within engineering include "Technology vs. Humanity, Economy vs. Environment, Globalisation vs. Community".	Outcome belief and outcome evaluation (perceived opportunity cost /commons dilemma, and influencing the career path that a student takes).
	Engineering Mindset	"…an engineer should be striving to be efficient in their solution and the cost of the solution" Reduction in financial incentives would lead to "far slower rates" of innovation "… best way to progress is to prove there is profit to be made"	Subjective norm (engineering culture)

	Culture/ "group behaviour"	"…the public's demand for newer things" which engineers don't "have control over". "…society aren't satisfied unless we see progression and improvement" "…a problem many people face is the inward view of success…our view of success drives us to be who we are, thus, in today's society, the brand-new, the fancy, the item everyone 'needs' is the message portrayed by every business, company, and store. We need to be better than we already are, all through physical items and price tags." "…the modern world is so consumed with economic growth and profitability that sometimes we lose sight of real reasons we should be striving to improve what we currently have".	Subjective norm (societal culture)
Sense of powerlessness	Limited impact	"…as an individual there is very little he can do". "…is this challenge one we will be realistically and physically taking action upon and possibly providing to their community or is it just another written assignment sort of thing?".	Perceived behavioural control
	Constraining factors	"…it is up to local governments and charities" "…many engineers…do not have the luxury to fully decide what industry they want to work in" "…empathise with engineers who feel trapped in an industry controlled by profiteering corporations" "…management as they control what products are being sold" "…just carry out orders from people higher up".	Perceived behavioural control
Inter-disciplinary	Respect for other disciplines	"Lads, we are doing engineering not political science" "Bruh, imagine failing an engineering course because you didn't revise social sciences" "RIP those of us that just wanted to build engines"	Subjective norm (engineering culture) Perceived behavioural control (expertise)
	Lack of understanding of systemic social issues	"…with a large population comes large differences…an inevitable inequality" "…the reason most engineering solutions have been developed for the richest people is because they have the knowledge and money to do such a thing… this doesn't mean engineering is only for them, this is just where solutions are developed. That doesn't matter to society though, who cares where or how it is developed?" "…poorer societies also experience large scale engineering…the fact they are poorer (means) they have a limited amount of what they can do.".	
	The self and personal motivations	"…future engineers may have different priorities…international students may focus on the problems facing poorer communities globally" "…the biggest issues I felt, were that many of my peers who have mostly come to Uni straight from school were not engaged in (the module content) the same way" "…the whole looking inside yourself…responsible engineering talks are preaching to the converted…we all know what we can and can't do at this point when it concerns the environment and climate change. University students are all too aware of the risks of climate change considering that we'll be the generation that has to deal with the consequences."	

4 SUMMARY AND ACKNOWLEDGMENTS

This paper has identified several possible sources of resistance to social responsibility. For example, it appears as though some students feel limited control over their ability to contribute towards social issues, something exacerbated by both existing within a consumer society and economic pressures. It therefore seems appropriate to equip engineering students with an awareness of alternative business models and no growth economics. This powerlessness seemed to be emphasised, for some, by the nature of the design challenge which focuses on theoretical solutions for distant communities, and in future it may be suitable to focus more on societal issues within the context of the local community.

In common with the themes identified during this work is a misalignment between personal and professional experiences and a lack of consideration for the 'whole' self, something which may not be surprising given both the early specialisation within the school system and valorization of STEM (science, technology, engineering, and mathematics) subjects that takes place in the British context, and the way in which our education systems utilise grades as a measure of student success. As Heywood [37, p.4] reminds us, the person is the base of the engineering process, saying that "Understanding how our beliefs and values (moral and otherwise) are formed is important to our conduct as engineers and individuals but it belongs primarily to the domains of philosophy and theology which are different languages". In the absence of a 'well-rounded' education, students are unlikely to be aware of alternative modes of thought which may allow them to enact meaningful change in the face of complex problems such as climate change and social injustice, and which may allow them to "conceive a way of being outside this neoliberal worldview" [38] and they may, instead, be likely to become agents of cultural reproduction [39].

In what ways can we encourage students to explore their beliefs and motivations in a system, and indeed a society, which values academic success and how much money they make? Perhaps more importantly, to what extent should we try and address these issues? As Pawley [38] points out, as educators, most of us "indoctrinate students into neoliberalism" and fail to make students aware of alternative modes of thought which allow them to "conceive a way of being outside this neoliberal worldview". Shor and Freire [40] describe how student resistance to liberative pedagogies was rooted in job anxiety and Freire [41] argues for the need to prepare students for the current (neoliberal, capitalist) state of the world.

It is clear we need to help students navigate complex tensions and feel comfortable sitting with uncertainties. This involves allowing ourselves to be vulnerable and admitting we do not know the answers. It necessitates us providing students with space and time, away from pressures of grading, to understand their beliefs and values, and to feel safe to express feelings of anger, guilt or confusion. It also means we need to understand how values and attitudes depend upon cognitive and ethical development [42]. How we best do this in a system which focuses on the cognitive domain over the affective domain, and which encourages disciplinary specialisation, is unclear and involves raising questions about our own learning and development, our own understanding of society and culture and of our selves. This may seem challenging for many of us trained within engineering and involves making choices which affect the way we are perceived by students, colleagues, and management. However, the benefit of the socially constructed nature of engineering is that it does allow us this choice.

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