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Understanding Transdisciplinary Engineering in Public Policy: A Survey of Policy Actors' Perceptions of Engineering Expertise

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Abstract. The transdisciplinary engineering project aims to transform the practice of engineering for more social benefit, and be agenda driven. For this to work, a key community of non-engineering actors needs to be effectively engaged: those working in public policy. Through data gathered for a project exploring interested in a career development scheme for policy officials offered by the UK's Royal Academy of Engineering, we explore the opportunities and barriers to better engagement between engineering and this community. An explorative online survey with policy actors gathered views on the importance of (non-transdisciplinary) engineering to policy in different policy settings. While those who regard technical expertise as crucial to their policy are keen to engage with engineering, others find it more difficult to engage. We suggest this is down to three factors: narrowness in what 'engineering' is (so a failure to understand the ability to apply engineering concepts, e.g. systems thinking, in a variety of areas); organisational arrangements that split policy practice that might more readily connect to engineering from those who do policy design; policy analysis rooted in standard microeconomic forms of analysis. We suggest ways in which these issues might be addressed through education and research to enable the effective deployment of transdisciplinary engineering practice.

Keywords. Transdisciplinary engineering, technical expertise, public policy, survey

Introduction

The idea of 'transdisciplinary engineering' (TE) is relatively new in the academic literature, emerging around 2015-16 with a dedicated journal (*Advances in Transdisciplinary Engineering*) and a new international society (the International Society for Transdisciplinary Engineering). Importantly for this study it is important to recognise that TE sits in contrast to what we might call 'normal' engineering, that is the engineering that most people would encounter today should they work with an engineering firm, for instance, working in areas such as infrastructure, manufacturing design, technology and systems (such as energy or telecommunications). The history of TE and the emerging focus of scholars using the term gives it an almost exclusive focus

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on private sector, product design and manufacturing focus (e.g. [1–2]). As Wognum et al [3] have noted TE, aims to retain the core concepts of transdisciplinarity as imported from the distinct field of transdisciplinary research which is typically focused on sustainability (e.g. [4]). These include being 'agenda driven' (or as Lattanzio et al put it 'undertak[ing] research which has social benefit' [5]), 'integration … of knowledge from different disciplines' and 'involves non-academic participants' [3]. This latter definition, when integrated with the ideas of agendas and social impact, mean that policy actors – i.e., those working in or for public policy institutions such as central or local government and associated bodies – are a key participant in the deployment of TE practice.

An underlying assumption for the effective practice of TE – meaning the use of engineering skills, combined with insights from other non-engineering disciplines, working with non-academic actors for social good – is that these non-engineering actors are interested and able to undertake such a collaboration. While non-engineering disciplinary experts are collaborating, with engineers in different topical areas such as energy policy (e.g. [6]) it is often fraught and the relationship – particular with those parts of the social sciences which might be most help in orienting engineering to 'social impact' is fraught [7] and uncommon [8]. As a consequence, for some areas of 'social impact' such as in energy policy, and likely others (such as transport and industrial policy) the full emergence of TE practice will likely be hindered until these challenges are overcome.

Beyond these interdisciplinary challenges, the basic transdisciplinary challenge – that of engaging non-engineering actors outside of academia – remains largely clouded in mystery. One study exploring the relationship between 'normal' engineering practice and policy actors reveals opportunities and tensions [9]. Normal engineering – with the focus on design thinking, complex problem solving via systems thinking, and a natural tendency to pragmatism – fits well with the observable features of policy-making. However the mindset of 'normal engineering' can likewise generate problems such as the failure to recognise policy ownership, the provision of technology-focused options that fail to include a useful understanding of the social setting, and therefore a tendency towards a problematic 'techno-solutionism' [10–11]. The quest for TE then, can be expressed as working to leverage the positive qualities of engineering knowledge and practice in a way that enables engagement with diverse perspectives and generates objects and processes that genuinely address identified social needs.

To make this kind of TE practice happen, understanding the perspectives of policy actors in relation to engineering is important. Identifying any challenges to engaging with 'normal engineering' can provide clues regarding how 'normal engineering' can change in order to make TE practice happen, and thereby achieve the goals associated with it. There is little doubt that the research challenges for TE still hold as per [12], but these focus solely on TE within a private sector setting. The study here seeks to elaborate the challenges and opportunities facing engineering as practiced in relation to public policy development and delivery, focusing specifically on the views and perceptions of policy actors in a range of different settings.

1. The context for this study

To explore the perspectives of policy actors on engineering as a disciplinary practice, this study takes advantage of – and is funded by – recent work in this area led by the UK's Royal Academy of Engineering (RAEng). The RAEng is a charity that 'harnesses

the power of engineering to build a sustainable society and an inclusive economy that works for everyone'[2]. This expressed goal, and the underpinning focus on engineering, places the RAEng as a core example of an organisation seeking to promote the practice of TE. As a part of this endeavour, the RAEng – and in relation to the public policy actors forming the basis of this study – established two programmes of work that seek to reinforce its role as a policy-oriented engineering organisation. The first was establishing the National Engineering Policy Centre (NEPC) in 2018. The NEPC's goals are to 'policy makers with critical engineering expertise to inform and respond to policy issues of national importance, giving policymakers a route to advice from across the whole profession, and the profession a unified voice on shared challenges'[3]. The second was establishing a career development programme called a Policy Fellowship. We will discuss this further below, as it is this programme which provides the focal point of the research here. Despite the RAEng's practice and goals being aligned with ideas of TE, many outside of engineering who work in policy organisations will not be aware or TE-orientation of the RAEng. This is important for understanding the research and analysis below which hinges on the notion that when most officials in policy encounter 'engineering' the strong assumption we make is that they think of 'normal' rather than transdisciplinary engineering. It is this 'normal' engineering concept that is understood to be problematic in policy.

1.1 The RAEng Policy Fellowship programme

The RAEng launched their Policy Fellowship programme (PFP) in 2019. This programme was targeted at bringing practicing policy officials from government bodies into contact with engineering experts drawn from the RAEng's list of over 1500 Academy Fellows. The PFP is essentially a form of paid-for career and professional development programme, aimed at supporting mid-to-senior level policy officials gaining leadership capabilities, rooted in better understanding of engineering as a mode of thought and networks with engineering experts. It can be seen as a version of the perhaps better-known University of Cambridge Science and Policy (CSaP) policy fellowship programme.

After 2 years of recruiting nearly 40 officials into the programme, the RAEng commissioned a study to explore the market for the programme, with a particular view to extend beyond the policy domains it had previously been successful at recruiting from. These typically included officials in central government, from ministries with portfolios that highlight engineering expertise explicitly (i.e. defence, energy, infrastructure, digital systems and environmental management) – all based in the UK. As a part of the research project that created the dataset being used here, an online survey of these historic and current policy fellows was conducted in January 2022 but these data will not be reported below.

In addition to this online survey of the historic and current policy fellows, the RAEng commissioned the authors (UCL, Technopolis) to gather data from a range of policy actors based in organisations that lay outside the standard community described above. This means, in particular, civil servants (employed directly in central government bodies) and public servants (employed directly in bodies outside central government, including local government and public bodies like the National Health Service) whose briefs do not include an obvious need for engineering input, such as education, social care and

[2] See: https://www.raeng.org.uk/ Accessed 14 March 2022
[3] See: https://www.raeng.org.uk/policy Accessed 14 March 2022

health, and criminal justice. Finally, the RAEng were also interested in whether policy actors from outside the UK would find the offer of the policy fellowship as attractive. This latter point is particularly interesting in the context of TE where the integration of social science perspectives on knowledge for policy would foreground the need for locally-relevant knowledge, implying that a direct RAEng-delivered PFP to overseas participants would not deliver the goals of TE. However, this study was not aimed at evaluating the impact of the PFP, but simply seeking to understand the market for it.

Below we describe the process of gathering data from a public and civil sector actors that aims to capture their views on the role of engineering advice and associated training provided via the PFP. Although the explicit goal was to inform the RAEng plans for the future of the PFP, these data also reveal the perspectives held by policy actors in relation to engineering and, crucially, how important they think it is to expend resources (time, money, effort) in building greater knowledge and networks in with 'normal engineering'.

2. Methods

To gather views from public and civil servants both in the UK and internationally about their interest in a career or professional development opportunity rooted in engineering expertise we devised an online survey to gather views from a broad community including the potential to gather perspectives from non-governmental organisations, such as business groups, charities and thinktanks. Below we describe the methods for the data collection instrument, the sampling approach and the style of analysis. The goal of the research was not to reach a 'representative' sample of public and civil servants views on engineering expertise in policy (that would be near enough impossible) but rather to study the relationship between the demands of their professional role, the background training (including exposure to engineering or STEM-related academic training) and their views on the relevance and importance to engineering-like expertise.

What is worth noting here is that the overall strategy for approaching prospective respondents was to avoid using 'engineering' as a term in any of the recruitment material. This was based on the experience of the commissioning team at RAEng and that of the researcher at UCL that doing so would likely prevent recruitment of exactly those officials most needed to understand any challenges in engaging policy with engineering.

2.1 Rationale and hypotheses

The online survey was intended to provide a wider group of respondents, particularly those overseas or beyond the network of the researchers or RAEng, to provide insights. In that sense it should be understood as a kind of automatic interview method, with categorical, rather than qualitative answers. The design of the survey was intended to reveal the internal logic that policy professionals might have for engaging, or not engaging with engineering. For the purposes of the research work for RAEng, we were interested in the pathway to choosing or not choosing to undertake a Policy Fellowship. Here, we use the interest in the PFP as a proxy indicator for interest in engineering for policy in general. For the prospects of transdisciplinary engineering, any disconnect between engineering and policy (e.g. policy officials not seeing engineering as important for their work) reveals challenges for transdisciplinary engineering to overcome. Therefore, we structured the survey to assess the reasons why any policy individual might or might not engage with engineering in the guise of attending the PFP with the RAEng. These included:

1. Understanding the local organisational context in enabling attendance at any training scheme
2. Understanding perspectives on engineering (without mentioning 'engineering' directly) so under the guise of 'technical expertise' (and the reported need for it) or engineering concepts and how important they are for their work.
3. Understanding the quality of interactions with technical experts and whether they could be improved
4. Capturing perspectives on PFPs offered by different bodies, including RAEng, in an attempt to understand the impact of 'engineering' as a term, in this context.

We expand on these points below in the detail of the survey design and deployment.

2.2 Sampling

The survey was designed to capture a broad snapshot of perspectives of civil and public servants (and beyond) on the RAEng PFP. This meant trying to gain as many responses as possible in the time available. In the absence of a readily available sample frame listing contact details of thousands of civil and public servants in the UK and beyond, a simple snowballing-based strategy was devised. This targeted known individuals in the research teams network, to ask them to fill in and distribute the survey link to their colleagues. Respondents who reached the end of the survey were provided with the opportunity to pass it on to others via an automatically generated email into which they needed only to add email addresses. Further the survey was advertised on social media channels (LinkedIn and Twitter) of the research team accounts, and retweeted or shared by our networks that way. In addition, specific public bodies were identified by the research team via analysis of the list of public bodies available on the UK's gov.uk website[4]. A final recruitment strategy was via the publication of an article on the widely-read government- and policy-oriented online community 'Apolitical'.

2.3 Survey design, recruitment and mode

The survey was designed as online, self-completion only using the specialist online survey platform 'Opinio' hosted by UCL. Recruitment to the survey was through emails to colleagues and posting to social media platforms or via lead in articles as noted above. In all recruitment correspondence, as well as in the early pages of the survey, the term 'engineering' was not mentioned, including the project's association with RAEng. As explained earlier this was to reduce the chances of self-selection bias based on perceptions of engineering and the relevance to policy career development in general. The survey was branded 'Developing Policy Leadership with Expertise' to hint at the central topic of interest without alerting prospective respondents to the direct engineering focus. The branding also helped to reduce the chances of the survey accidentally being responded to twice by the same person – something that the cookies on the same browser would stop but not if they used a separate system each time.

As noted above the landing page for the survey did not contain any reference to the RAEng, nor did the word 'engineering' appear until question 5 where we used the phrase 'technical experts' as a kind of 'soft' entry point to introducing 'engineering' as a concept. Engineering appeared there as one of the choices in a list aimed at gathering perceptions of what a 'technical expert' might be understood to be. Subsequent to that we explicitly

[4] See: https://www.gov.uk/government/organisations Accessed 18 March 2022

defined the term to include anyone holding a postgraduate or professional qualification in engineering, when asking about the relevance and interest in technical expertise for them and their organisation. Finally, engineering appeared explicitly as part of the RAEng being named as one among 5 institutional hosts of policy fellowships when asking for which of them appealed.

The structure of the survey followed this pattern:

1. Access to learning and development resources in their organisation
2. Understanding and relevance of technical expertise
3. Development of expertise – and what is important
4. Policy fellowships what they are and their appeal
5. Professional and demographic background

In total 27 questions were set some of which were only available depending on certain responses to other questions. Five of the questions were solely open ended, allowing for narrative answers, normally in relation to explaining patterns of response in preceding questions. The remainder were either entirely or mainly closed multiple choice responses though 9 such questions also presented respondents with open text boxes to allow for any additional comments they wished to add. For the purposes of limiting the length of this text we have not reproduced the entire survey here. Specific questions which provide the basis of conclusions in the Results will be reproduced alongside the summary data.

The survey was opened for responses on the 14th February 2022 and remained active until April 15th 2022.

2.4 Data handling

All data collection was done with informed consent. Respondents online provided consent via proceeding with the survey, having been provided with a clear statement about the nature of the research and the security of data and anonymisation. All data was handled anonymously – so respondents in the online survey never provided their names unless they wished to be contacted for a follow up interview. Data was stored securely in encrypted drives accessible only to the research team.

Analysis of the online survey data, given the limited sample size was done through simple summary statistics (counts, ratios) and limited cross-tabulations where important distinctions in patterns of response were deemed important. These included: being in central government, vs not; technical expertise crucial vs not; being UK-focused vs not. Decisions regarding whether or not a cross-tabulation should be performed were taken on the basis of their being sufficient (i.e., more than 15) respondents in each group. No further statistical analysis was applied to the data.

3. Results

Below we set out the findings by the two methods before drawing conclusions based on the data from each method at the end. The important questions we sought answers to, that were relevant for this paper are:

1. To what extent can we observe ‘engineering’ as a source of useful intellectual input into policy? This includes:
    a. The degree to which respondents agreed that ‘technical expertise’ was important for their roles
    b. The degree to which respondents recognised the intellectual concepts from engineering as relevant to their role or organisation

2. To what extent officials felt that engagement with 'technical experts' (defined as those with an engineering background) could be improved.
3. The degree to which a career development programme rooted explicitly in the engineering profession was of interest.

Given the background purposes of this survey, and the use of only part of it here to draw insights for transdisciplinary engineering practice in the public sector, we have intentionally refrained from publishing the entire survey, at this point as, an Annex to this paper.

In addressing these questions we aimed to reveal how much engineering concepts are seen as important to areas of policy, especially in those sectors where engineering is not 'foregrounded' (i.e. made front and centre in policy thinking) by being framed in normal engineering terms (ie. energy, transport, cities etc.). Understanding this is central to enabling engineering practice to transition into a more transdisciplinary mode, as it requires active and willing participation of non-engineering communities. This issue is captured by 1. above, in the important questions list. To answer this question we will rely more on the elite interviews on account of their being intentionally chosen to represent parts of the policy community where engineering is not foregrounded, and their wider experience in policy more general.

Questions 2 and 3 provide a space to understand – for those who do see engineering-like expertise as relevant and useful, the goal is to understand whether it is generally problematic (if not, then this reduces the barriers to developing transdisciplinarity). If so, is the engineering profession *as is* (represented by the RAEng association, see section 1.1) seen as a resource to directly address this?

3.1 Overview of respondents

In total, 86 respondents had answered the first question, and around 60 answering most questions (branching means that some questions were not available to all respondents), 46 completing all questions. Given the lack of a sample frame and direct use of 'snowball' sampling, it is not possible to generate a meaningful response rate from these data. However, notable gaps in the data in that only 1 respondent reported working in local government. By and large the respondents worked in central government (63%) with a significant minority in non-governmental organisations (17%). Approaching half (43%) recorded that "technical expertise is crucial to achieving the goals of [their] organisation", with only 4% stating it was rarely or never useful. This suggests that the overall sample is skewed towards more 'engineering-friendly' organisations or policy portfolios, in contrast to the elite interviews reported above. Nearly half (48%) self-identified as a 'technical expert' reinforcing the view that this represents an extended community of likely engineering-interested officials, compared to the likely characteristics of the overall public policy population.

This notion of the biased sample may explain the pattern of responses seen in relation to the importance of different engineering-related concepts to their work. These comprised 6 features commonly understood as typical of different kinds of engineering 'habits of mind' (from engineering education) that include: 'systems thinking', 'creative problem solving and resilience, but also more common skills for engineering analysis including: identifying and mitigating risks, logistics, and understanding technology. For all these concepts, except logistics, 60% or more of the sample considered them as 'very important'.

Nevertheless, despite this sample being skewed towards 'engineering-friendly' on account of both context they work in and the background of the individuals, nearly three-quarters (70%, n=47) believed that their "interactions with technical experts could be more effective than they are." This suggests that even in these sorts of settings, there is considerable room for engineering experts to fit better with policy concerns.

3.2 Perceptions of engineering-focused policy fellowships

When considering resources for improving engagement with technical experts, policy fellowships seemed to provide the exact sort of training that many responding felt was important. Primarily, around 9 in 10 respondents felt that "building a network of expertise" and "learning about new ways to analyse policy issues" were appealing. Perhaps importantly, when we consider the largely private sector nature of most engineering experts (in the UK at least), the least appealing was the ability to meet "senior business leaders who have no policy agenda". These appealing aspects identified above are central to the offer from the RAEng PF programme.

However, despite the sample being skewed towards a relatively engineering-friendly community, this didn't translate into a high level of appeal for the policy fellowship programme offered by the RAEng. Table 1 shows the 5 programmes offered, each with different underlying features, giving indicative insight into the underlying features that supported appeal for the programme.

Table 1. Showing the net appeal for actual policy fellow programmes offered by the shown organisations (n=47). For each organisation, respondents were asked: "Based on what you know about the organisation, rate how much a Policy Fellowship with them appeals to you." Respondents could choose 'Appeals a lot', 'Appeals a little', 'Doesn't appeal' or 'Don't know'. They were told to choose the latter category if they had never heard of the organisation. Net appeal was calculated by adding the percent choosing 'appeals a lot' and 'appeals a little', then subtracting the total of 'doesn't appeal' and 'don't know'.

Organisation	**Features**: *Location/Type*	**Net Appeal**	**Rank**
University of Cambridge	UK, Academic	+27%	1st
Oxford Policy Management	UK, Non-academic	+23%	2nd
Bath University	UK, Academic	+13%	3rd
Royal Academy of Engineering	UK, Non-academic	+9%	4th
European University Institute	Non-UK, Academic	+7%	5th

In addition, the RAEng programme had the highest 'doesn't appeal' rate out of all of the responses, suggesting that despite the good match with both the background and demands of the sample of respondents, it was not generally seen as an appealing place to gain the exposure to technical experts that seems to appeal to the respondents. The open text box follow-up, asking respondents who chose 'doesn't appeal' wrote points that matched in with those recorded in the elite interviews: e.g. "not directly relevant to my job role", "topic specific not for me". This indicates that engineering is seen as a very specific sort of expertise, perhaps akin to something like micro-biology or town planning, rather than a more widely applied expertise like economics or project management. These findings suggest that the idea of 'engineering' – even just the term – generates a kind of reaction that prevents civil and public servants from seeking out the very expertise that offers the insights they have identified as important (e.g., systems thinking, risk and resilience analysis and so on). The clearest indication of the 'engineering' effect is in the difference between the Oxford Policy Management PFP and the RAEng PFP, a

14%-point differences despite both bring non-academic organisations, so with a potentially similar perception. One question arising from this is what affects that perception?

As argued above, the degree to which the RAEng programme is seen as appealing can be used as a proxy indicator to estimate the degree of relevance of 'normal engineering' to policy practice. We have seen that in general, across this group of respondents, the programme is not highly appealing, reflecting issues with the perception of engineering. But we can see how that perception varies according to different subgroups self-identified in the data. The first is to test the implicit hypothesis above, that a 'technical' orientation increases appetite for (normal) engineering input, and less decreases it. Table 2 shows the outcome here: comparing the list order for each programme for those self-identifying as working in an area where 'technical expertise is crucial' (n=20) vs the rest (i.e., not crucial, n=26).

Table 2. Showing the net appeal of the different policy fellowship programmes for those respondents who chose 'crucial' in response to the prompt 'In relation to achieving the goals of your organisation, would you say technical expertise is…'. The 'not crucial' group is a combination of those who chose 'useful at times', 'potentially useful but often not recognised as such', 'rarely or never useful' or 'hard to say'. See text for more background.

	Net Appeal	
Organisation	**Technical crucial**	**Technical not crucial**
University of Cambridge	+16% (1st)	+12% (=1st)
Royal Academy of Engineering	+14% (2nd)	-4% (5th)
Oxford Policy Management	+12% (=3rd)	+12% (=1st)
Bath University	+12% (=3rd)	+2% (3rd)
European University Institute	+8% (5th)	0% (4th)

Table 2 shows the strong effect of a self-identified 'technical expertise' is crucial has on the perceptions of 'engineering' as represented by a policy programme offered by the RAEng. What is interesting here of course is that the overall understanding of what 'technical expertise' is, doesn't strongly include 'engineering' in a distinctive way – something explored below. Nevertheless, the general association between the presence of engineering, and ideas of what 'technical expertise' is may overlap sufficiently to promote the programme 2 places up the merit order.

The second is to see whether different parts of government or policy communities makes a difference. Here we might expect that the further from central government, the higher the appetite for engineering expertise. In Table 3 we see those who report working in central government (n=28; including here, those who work in what we call 'devolved administrations' in the UK, i.e., the central governments for Wales, Scotland and Northern Ireland) vs not working in central government (n=18, that is, in local government, public bodies, NGOs or businesses).

Table 3. Showing the net appeal of the different policy fellowship programmes for those respondents who chose 'Central government (department, ministry, or body)' or 'Devolved administration' in response to the question 'Which of the following best characterises the kind of organisation you currently work for?'. The 'Not Central Govt' group is a combination of those who chose 'Local government', 'non-departmental public body', 'private business' or 'NGO, charity or thinktank' or 'Other'. See text for more background.

	Net Appeal	
Organisation	**Central Govt**	**Not Central Govt**
University of Cambridge	+14% (1st)	+14% (2nd)
Oxford Policy Management	+8% (2nd)	+16% (1st)
Royal Academy of Engineering	+6% (3rd)	+4% (5th)
Bath University	+4% (4th)	+10% (3rd)
European University Institute	+2% (5th)	+6% (4th)

The results in Table 4 follow a similar pattern as in Table 3 but in an unexpected direction. We anticipated that non-central government policy actors, being closer to delivery, might have a stronger appreciation of engineering, and thus show a higher ranking than in central government. However, the reverse was observed. Importantly, the effect may be more due to changes in the appeal of other programmes for these groups than changes in appeal of the RAEng programme, since the net appeal difference for the RAEng programme is negligible. Instead, we see a stronger appeal from non-central government actors for Oxford Policy Management and Bath University in particular, which might relate more to the relevance of their offer to those kinds of actors – perhaps less 'pure policy focus'.

3.3 Defining features of 'technical expertise'

A further unexpected issue observed by the survey was the understanding of how 'technical expertise' itself is defined by respondents. The assumption of the research team is that a basic precondition for being considered a technical expert would be having some kind of academic or professional training in engineering. When we asked respondents how they would define 'technical expertise' the tended to see the presence of a higher engineering degree as no more particular to technical expertise than a social or physical science degree. Table 4 below shows the categories offered for defining technical expertise and the most commonly chosen ones by the respondents.

Table 4. Showing the defining features of 'technical expertise' as understood by respondents (n=64). Respondents were asked 'In my view, 'technical experts' definitely include those with…' and were instructed to 'Check all that apply'. The range of response proportions for each category shows that respondents were paying attention and discriminated strongly the categories, suggesting that the differences seen here are not an artefact of the method. The order of each category of response was randomly varied between respondents to control for any order effect. The categories are presented here in order of most to least often chosen, not the order they were necessarily presented to respondents.

Suggested feature of technical expertise	**% of respondents**
...extensive professional experience of particular technologies	78%
...a professional background in a specific area (eg. doctor, lawyer, project manager)	70%
...a postgraduate or professional qualification in engineering	55%
...a postgraduate qualification in physical sciences	53%
...a postgraduate qualification in social sciences (including economics)	50%
...a background in consultancy, management or business leadership	23%
...a background in entrepreneurship	17%

4. Discussion

These data show that while engineering clearly has a lot of important potential to inform policy for helping society, deploying transdisciplinary engineering approaches into standard policy arenas is likely to be challenging. In part this appears to be due to a perception among non-engineers about what engineering is relevant to, which is those topics on infrastructure or technology such as energy or transport. It is possible to trace this to at least three different likely sources from the data: the background of participants and their exposure to engineering (or even wider STEM) concepts; the organisational arrangements of government bodies; the processes and methods of policy analysis. At the same time is also possible to see some issues with the epistemic or ontological basis of engineering thinking: too great an emphasis on deterministic systems, too little agency afforded 'users' as part of the problem-solving system, too great a focus on novel technical approaches rather than smaller, pragmatic means of achieving goals.

This implies that a transdisciplinary approach – one in which the social sciences may play a critical role – is likely a beneficial, perhaps even necessary step in integrating the benefits of engineering approaches in policy. This integration of social science practice in to engineering practice may – or perhaps *should* – result in modes of thought that are less directly dependent on or driven by mathematical models of reality, but can incorporate more qualitative, narrative understanding. Such integration can help both by transforming the image of engineering in the eyes of non-engineering policy actors, but also making it more relevant to policy challenges and the kinds of systems they are working with.

At the same time. There is a clear need to rethink the way policy operates as well: both in terms of the way policy portfolios are understood and domains of specialism are segregated between different managerial units, but also how officials think about policy challenges – the tools they use. In the UK – as in most OECD countries – the emphasis is on the use of impact assessments, which themselves typically use cost-benefit analysis from micro-economics. While it is possible to see this practice as little more than a performative practice of analysis to legitimise political decision-making [13], it nevertheless frames the way in – and perhaps the disciplinary source of – which policy is analysed, that is with economic modes of thought – what Oliver has recently termed the 'appetite' for evidence and expertise [14]. Opening up the approved means by which problems can be analysed and choices made using tools of engineering could potentially provide a means to open the door to engineering practice in policy domains that may not otherwise see it as relevant.

The transformation that brings transdisciplinary engineering practice into the heart of policy making is likely to be extensive. A key part of this transformation will be in the education of engineers and the creation of new kinds of degrees as entry points into policy jobs. A move away from the 'Politics, Philosophy and Economics' degrees to ones that integrate engineering thinking into these programmes will be a significant step. But the change also applies at master's and executive training level too. Alongside that, research into new policy appraisal methods that integrate transdisciplinary engineering methods – and are shown to be a better process for more effective policy – is necessary to ensure take up of any new policy analysis method among policy organisations.

The transdisciplinary engineering programme is an extensive and transformative one, as well as a necessary one if society is to successfully – and fairly – address the major challenges facing countries globally. Working across engineering, social sciences and professional policy spaces is key to its success.

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