Leveraging Transdisciplinary Engineering in a Changing and Connected World
P. Koomsap et al. (Eds.)

doi:10.3233/ATDE230666

Designing Transdisciplinary Engineering Programmes: A New Wave in Engineering Education

Irina LAZAR[1], Laurent LIOTE and Adam COOPER
Department of Science, Technology, Engineering and Public Policy, University College London, Shropshire House, 11-20 Capper Street, London, WC1E 6JA

Abstract. Traditional engineering programmes equip graduates with knowledge and skills that enable them to achieve great technological advancements. However, one of the flaws of current programme design is that what is taught is often compartmentalised into pockets of knowledge potentially leading to a loss of perspective. Engineering students are highly applied and solution-oriented, but many times do not hold a holistic view of other associated professional dimensions. This can be detrimental in fast-paced changing environments, where they are exposed to global challenges spanning multiple disciplines. The question is *how can we, as educators, overcome these flaws*? We argue that providing innovative engineering education programmes that combine technical training and skills with social-scientific and policy knowledge is key. This creates the premises for new generations of graduates who possess a transdisciplinary skillset thus "speaking multiple professional languages" and filling a clear gap on the employment market, as studies have shown. We present a case-study focused on the new engineering programme at University College London (UCL): the BSc Science and Engineering for Social Change. Here, we offer students an authentic learning experience using project and problem-based approaches to contextualise learning in diverse environments. Projects are set in collaboration with community partners who provide real-world socio-technical challenges for students to solve. Students get to simultaneously apply the technical and social science skills they learn, constituting a true transdisciplinary engineering experience enabling them to thrive in the professional world.

Keywords. Engineering education, social change, transdisciplinarity, problem and project-based learning

Introduction

Engineering Education has been under scrutiny in recent years, and it is undergoing a vast process of transformation in the United Kingdom (UK) and around the world [1-4]. In addition to the extensive literature, this statement is supported by the work of several entities for example, in the UK, the Royal Academy of Engineering [5], the Engineering Professors Council [6], the UK and Ireland Engineering Education Research Network [7], or the Engineering Council [8,9], in addition to the work carried out in Higher Education Institutions (HEI), including UCL, which will be outlined later in this paper.

To start with, these conversations have focused on employability from the perspective of industry needs [10]. Students are also increasingly looking for degrees

[1] Corresponding Author, Mail: i.lazar@ucl.ac.uk.

offering value-adding opportunities to improve their prospects on the competitive job market. For example, in their 2021 employability review, AdvanceHE speak about the value of work-integrated learning, from the perspective of students, universities and employers [11]. More recently, these conversations have moved into aspects of ethics and sustainability [12] and embedding the so called 'soft skills' into engineering programmes [13], which is reflected in the latest accreditation requirements introduced in the UK in 2020 [8]. To complete the picture, the COVID-19 pandemic has acted as a catalyst and enabler of educational change across the sector from the perspectives of delivery, skills development and assessment alike [14].

Adding to this complex landscape, the engineering profession is facing a lack of diversity which translates into a talent crisis [15,16], despite engineering often being cited as a discipline which promotes social mobility [17]. Introducing transdisciplinary engineering programmes, supported by inclusive widening participation and recruitment strategies, could improve this trend by opening up to applicants with diverse backgrounds, skills, capabilities and interests.

These premises create an optimal climate for innovation in engineering education, with change being embraced rather than resisted [18,19]. In this paper, we focus on two main areas of change: 1) the design of integrated curricula and 2) the introduction of transdisciplinary programmes. There are multiple advantages to integrated curricula [20], they allow students to connect and contrast information, to create links and access higher levels of the Bloom taxonomy [21], and they enhance student motivation. They also allow for a better control of the curriculum, where any repetitions are carefully orchestrated to enable consolidation instead of creating confusion [20]. Our aim is to go beyond the integration of knowledge or content in a traditional engineering programme and, instead, to create programmes that operate across disciplines and which can generate graduates who can operate in complex and challenging professional spaces. For this, we must integrate knowledge from across disciplines, with transdisciplinarity being at the top of the integration ladder [22]. Transdisciplinary engineering research should translate into transdisciplinary education practice [23-25], thus creating the graduate profile outlined above.

UCL has introduced novel education programmes in its strategy early on, a milestone being the creation on its BASc in Arts and Sciences in 2012, following on from the 'Transforming Education' Provost White Paper published in 2011 [26]. Moreover, in 2022, UCL opened a new campus, UCL East [27], dedicated to innovative education programmes. The transdisciplinary engineering programme that is the object of this paper, the BSc Science and Engineering for Social Change launches in September 2023 and will be delivered on this new campus. The programme spans civil engineering, public policy, and the wider social sciences and is co-delivered by the UCL Department of Science, Technology, Engineering and Public Policy (STEaPP) and the UCL Department of Civil, Environmental and Geomatic Engineering (CEGE).

Over the following sections, we present the appetite for transdisciplinary programmes as resulting from our market studies and research. We then show how the BSc Science and Engineering for Social Change addresses this appetite and present the programme structure, delivery and assessment plan. We will also look at administrative considerations and their implications. As we make prepare for launch and reflect on the lessions learnt so far, we identify opportunities and challenges to come. Finally, we present the future directions and planned growth.

1. Education and the employment market

The market's need for graduates with transdisciplinary skills combining technical training and social-scientific knowledge is backed by current research and literature [28-33]. Policy illustrates this need quite clearly. With increasing amounts of socio-technical challenges to tackle, like climate change, governments will benefit from individuals who are sensitive to both engineering and socio-political concerns.

This point comes across clearly through Cooper and Lioté's research based on ethnographic studies of the UK's energy ministry [31-33]. Some of the key findings of Lioté's PhD work on engineering advice for instance show that the UK's government actively looks for 'generalist engineers', engineers that are adaptable enough to provide advice on the ministry's multiple energy policy areas. In parallel, the policy advisers working with the engineers have stated that having a technical background is seen as an asset by the ministry [33].

The policy need for transdisciplinary engineering graduates working either as engineers in policy or as policy advisers is driven by the engineering and policy teams' necessity of "speaking the same language" [33-36]. If the engineers are sensitive to socio-political needs and policy advisers are sensitive to engineering concerns, both teams can communicate their expertise and concerns to each other more easily. In other words, engineers and policy advisers are able to adapt to their audience to better collaborate, in-turn generating mutual trust and increasing productivity [33].

However, as senior civil servants, engineers and policy advisers pointed out, this type of 'transdisciplinary engineer' profile is hard to come by. There is a perception, that engineering education remains highly technical [28-30], which is easily verifiable if we look at most engineering programmes offered at undergraduate level in the UK. On the other hand, policy advisors, mostly trained in humanities and political science subjects, have stressed their lack of exposure to more technical ways of thinking during their education [33].

A word cloud generated using the testimonies of civil servants, engineers and policy advisers in [33] is shown in Figure 1(a). It is interesting to note that 'think' is the most frequent word, followed by 'technical', 'engineering', or 'policy'. This suggests that a way of thinking which encompasses the areas or disciplines mentioned above could be the key to connecting the pockets of knowledge reported by professionals.

These points are echoed in wider market studies undertaken by STEaPP, where 209 participants from a wide variety of backgrounds and looking to start university answered a survey commissioned by STEaPP and conducted by YouthSight. Ten participants also took part in a one day focus group. Figure 1(b) shows a word cloud created based on the participants' expressed perceptions of the new programme. The words 'engineering' and 'course' were excluded as these were prompted by the facilitator. As can be seen, the emphasis is again placed on thinking in the context of real world applications. It is also interesting to note how concepts which are not usually linked to engineering education are cited here, for example humanities, anthropology or society. It is not surprising the public policy is not part of the picture, given that it is removed from what pupils experience in their pre-university education. Even if it could not be articulated by participants at this stage, policies play a pivotal role in deploying engineering into society, as reflected in the data collected from specialists [33].

Figure 1. (a) Word cloud generated using the interview data in [6] and (b) Word cloud generated using data in the UCL STEaPP market study.

The market studies also showed that students are increasingly looking for innovative programmes and are highly motivated to embark on altruistic, problem-solving careers in a transdisciplinary space, upon graduation. Their enthusiasm was centred around the wide range of topics addressing participants with both science and humanities backgrounds.

The programme structure and content, outlined in the following section, were cemented based on the feedback received from prospective students and employers alike, with the latter reflecting on the alignment of the offering with the transdisciplinary skills needed at all levels in governments, global and national businesses or consultancies.

2. Programme vision, ethos and structure

The programme's vision is that the global challenges of the 21st century cannot be addressed using a unidisciplinary approach and that education is a vehicle needed to deliver innovation and societal change. As evidenced in the introductory section, engineering education finds itself at a turning point post-pandemic. Transdisciplinarity, which is often discussed in the context of the United Nations Sustainable Development Goals [23,37,38], is at the core of the BSc Science and Engineering for Social Change. The programme aims to equip graduates with technical and social scientific knowledge such that they work effectively towards identifying, understanding, and managing complex global issues. The transdisciplinary nature of the programme enables the integration of knowledge from engineering and the physical sciences with a deep understanding of government and decision-making practices. Noteworthy, the programme is conceived to be equally topical in the UK and internationally, by carefully balancing content relevant to the Global North and South, thus enabling an appreciation of global perspectives and ensuring that the programme is inclusive by design.

2.1 Programme structure

The programme proposes four thematic strands, spanning across the three years of study, as seen in Figure 2. The context strand focuses the social and technical infrastructures in society, the conversation stream looks at the ways in which engineers and policy makers think and make decisions, and the culture stream presents concepts of design in science and policymaking.

The professional practice stream acts as a programme-level component which draws on the other streams and enables students to apply their knowledge and skills in authentic settings by proposing three year-long project modules (Figure 3). These projects are carefully scaffolded, with the first one focused on identifying real-world problems inclusively, in collaboration with all the relevant stakeholders, a step which can often be invisible to engineers. Building on this, the second project looks at approaches for addressing real world problems. The third module focuses on solution implementation whilst consolidating the students' employability skills and prospects through a part-time placement component.

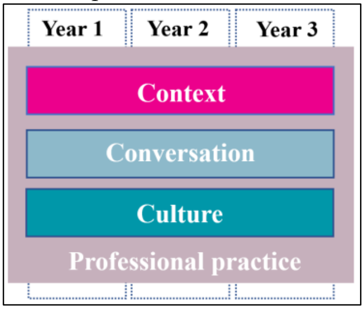

Figure 2. Programme structure.

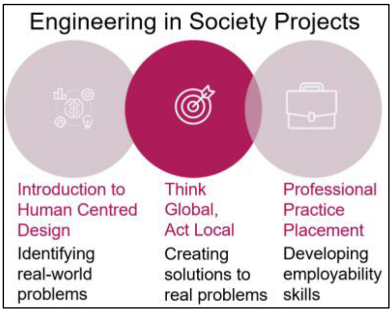

Figure 3. Professional Practice stream.

The Programme-level Learning Outcomes can be seen in Table 1.

Table 1. Programme-level Learning Outcomes.

Area	Programme-level Learning outcomes
Subject-specific knowledge	Integrate practical knowledge from engineering and the physical sciences with an understanding of how policy decisions are made and implemented to address global, local and individual challenges.
	Apply knowledge of engineering in the policy making process; apply this knowledge inventively and inclusively to meet the needs of society.
	Demonstrate a sophisticated understanding of the nature of change and the ways government, populations or other stakeholders do or do not want it.
Intellectual, Academic and Research Skills	Demonstrate research, analytical and management skills to create practical solutions to complex global challenges for present and future generations in eng.
	Recognise and respond to the concerns of professional engineers, their modes of reasoning and their priorities, effectively, inventively and inclusively.
	Demonstrate mastery in how eng. problems move from problem to different solutions in the context of teamworking and interdisciplinary contexts drawing on design cycles
Practical and Transferrable Skills	Apply engineering thinking to a wide range of policy practice and manage the inputs of engineers to get the best of their expertise
	Create cultures in which the benefits and importance of supporting equality, diversity and inclusion is promoted and critically engaged with
	Demonstrate the value of reflective and self-directed learning as key lifelong and professional learning approaches in engineering

2.2 Content integration, delivery and assessment

As mentioned in the introductory section, the programme is co-delivered by STEaPP and CEGE, both part in the Faculty of Engineering Sciences at UCL. Despite both departments holding a portfolio of modules that could have been slotted into or adapted for delivery on this programme, it was decided against it and in favour of all modules being created specifically for it. This decision reinforces the programme's coherence and enables the creation of a strong degree identity which the team believe is vital for its success. It also eliminates the disadvantages of traditional joint degrees, where students have to deal with multiple frameworks and bureaucracies and risk being exposed to a disjoint content [39]. To give a flavour of the programme, Table 2 shows the modules delivered in year 1.

Table 2. Programme structure reflecting the year 1 modules delivered on each strand.

Strand	Module title	
	Term 1	Term 2
Context	Society Systems and Change	Engineering Impacts and Context
Conversation	Introduction to the Science Policy Interface	Engineering Thinking 1
Culture	Engineering Design	
		Policy Co-Design 1
Prof. Practice	Engineering in Society Project 1: Introduction to Human Centred Design	

The authentic delivery methods are matched by authentic assessments. As opposed to traditional engineering programmes, where many modules are assessed using written examinations, all assessment on the BSc Science and Engineering for Social Change is coursework-based, including, for example, essays, design portfolios, reflective reports, blogs and vlogs, or posters. Individual and group presentations are also part of the assessment menu. Assessments are carefully scaffolded to enable students to succeed without building excessive anxiety or stress, which can be highly detrimental in their educational experience [40].

An advisory board with non-academic members working in areas relevant to the programme has been formed to support the programme team in ensuring that the curriculum remains authentic and relevant in the years to come.

2.3 Learning environments

Learning environments play an important role in the student experience and learning journey [41]. The programme being delivered at UCL East, on the Queen Elizabeth Olympic Park in East London, which hosted the 2012 London Olympic games, is optimal as it provides a live lesson on London's efforts to uplift one of the least affluent areas in the city, which constitutes a strong example of positive social change.

The new campus proposes a suite of innovative undergraduate and postgraduate degrees delivered using facilities including hi-tech, multidisciplinary research labs and studios exploring areas like ecology, robotics, urbanism; and various teaching areas, fabrication workshops, collaboration spaces to enable transdisciplinary education. Importantly, given the inter, multi and transdisciplinary nature of the degrees offered, students will have an opportunity to study alongside likeminded colleagues and staff, whilst immersed in a developing community.

3. Administrative considerations

No programme can exist or be delivered in isolation from the associated administrative tasks and processes. In this section, we include apects related to recruitment and admissions, management of placements and the economy of scales on the BSc Science and Engineering for Social Change. These have been picked out of the multitude of administrative considerations in an HE setting because of their links with the programme's transdisciplinary nature.

3.1 Recruitment and admissions

A conscious decision was made not to require any specific subjects upon entry. This decision reinforces the inclusive and transdisciplinary nature of the programme, where we aim to admit students from a wide variety of backgrounds and with a wide variety of strengths and interests. We believe this is very important in creating the right learning environment, where students are able to work in diverse teams and appraise a multitude of perspectives. This does not come without challenges in that we may need to provide tailored support to students, depending on their weaker areas, for example by offering technical or social sciences focused modules in the first year, whereby students can complement the skills and knowledge they acquired during their A-levels. This support will ensure students reach a common knowledge and skill base by the end of their first year of study, which gives them the premisses to successfully complete the programme.

In recent years, admissions processes have been streamlined to ensure fairness and consistency, and keep workloads under control [42]. There is a wider question on how current quantitative criteria work in transdisciplinary area. This is something we are monitoring in real time with support from the admissions team and will be revisited before the next admission cycle. For 2023/24 we have made 45 offers aimed at filling 15 places; 27 offers have been accepted, but given the UK admissions systems, we will not know the final numbers until later this Summer. However, these numbers represent a great success and exceeded our targets.

3.2 Planning for the final year placements

In a climate where students are increasingly looking for credentials that enhance their employability prospects, offering a placement is an attractive selling point. As part of their final year, students take a part-time placement, ideally in East London. This depends on the availability of opportunities and interest match. We are working with our Partnerships and Careers teams and leveraging existing STEaPP connections into industry, to create a portfolio of opportunities. Research-focused students will have the possibility to carry out a research placement instead, working alongside UCL staff. The possible overshoot in the number of admitted students may pose challenges here, but we will monitor the situation closely and plan ahead for 2025/26, when the first cohor reaches the final year of study.

3.3 Scaling up

Most of the traditional engineering programmes tend to admit 100-200+ students a year. Our initial target is to admit 15 students, with a projected increase to 55 over the next 5 years. The small scale enables us to dedicate time to supporting students and their learning journey individually and monitor the programme closely. However, in an era where pressures on the HE system are building, it is difficult to anticipate how numbers may evolve. The main challenge brought by potentially increasing numbers would be the scaling of final year placements, where significantly more opportunities will need to be secured.

4. Looking ahead: the first year of delivery and future directions

The most important aspect to focus on will be our transdisciplinary curriculum and the interplay between its parts. This will be crucial for its success and the programme team will be on this journey alongside UCL staff, our external examiners, the advisory board and wider external collaborators.

One limitation of the programme's layout is that, at the moment, it is operating on a fixed structure, with no electives. This is currently under review with a portfolio of final year electives to be introduced in the academic year 2025/26, the time when the first cohort will reach their third year of study. Some of these electives will be offered by STEaPP and some by other departments with a presence at UCL East. Beyond expanding our offering, the introduction of electives will offer students an opportunity to interact with and study alongside other cohorts on the same campus.

There is also a question of how students will cope with the transdisciplinary nature of the programme. We anticipate students may require additional support and, thanks to the low student numbers, we have factored that in and are ready to provide it. The language barrier has also been identified as an important challenge in engineering [43]. We anticipate this will be exacerbated by the social scientific content and the skills necessary to successfully engage with it. For this, we enforce higher English language requirements upon entry, compared to other engineering programmes and we are ready to provide additional support at cohort or individual level as and when needed.

5. Conclusion

In the context of global challenges, such as the climate emergency, and post COVID-19 pandemic, educational change is happening at a fast pace in engineering and beyond. In this paper, we presented the journey of a transdisciplinary engineering education programme to start at UCL in September 2023 which aims to bridge the gap between engineering and the successful implementation of engineering work in society. We presented the context in which the programme was developed, together with considerations around its structure, delivery and associated administrative implications.

New programme models bring with them challenges and opportunities alike, which we reflected on in terms or recruitment, support and scales. It remains to be seen how the programme will adapt to sector-specific limitations, or whether, in contrast, it is time for the sector to adapt and, in turn, enable the smooth delivery of transdisciplinary education.

As we prepare to embark on an exciting journey and deliver our new BSc Science and Engineering for Social Change on a new campus, we are keen to proactively assess the programme and the student experience, with support from our staff, students and advisory board. Inevitably, in time, changes will be required to fine tune the curriculum and delivery, but we remain commited to the programme's vision to deliver leaders of social change. This is just the beginning!

Acknowledgement

Lioté's data is taken from his PhD study titled 'How is engineering advice deployed in energy policy practice? An ethnographic look at the UK's energy ministry', kindly supported by a UK Engineering and Physical Sciences Research Council grant (EPSRC Grant #2264956).

The authors would like to wholeheartedly acknowledge the UCL team working on the development of the programme, from inception to approval and implementation.

References

[1] R. Graham, *The Global state of the art in engineering education*. Massachusets Institute of Technology, 2018, Accessed: 05.03.2023. https://jwel.mit.edu/sites/mit-jwel/files/assets/files/neet_global_state_of_eng_edu_180330.pdf.
[2] M. Berge et al., In search of the new engineer: gender, age, and social class in information about engineering education, *European Journal of Engineering Education*, 2018, Vol 44, pp 650-665.
[3] M.M.N. Megat Johari et al., A new engineering education model for Malaysia, *International Journal of Engineering Education*, 2002, Vol 18, pp 8-16.
[4] R. Adams, et al., Multiple Perspectives on Engaging Future Engineers, *Journal of Engineering Education*, 2011, Vol. 100, pp. 48–88.
[5] RAE, 2018, Engineering education systems that are fit for future, *RAE Website*, Accessed: 03.04.2023. https://raeng.org.uk/media/3c0l1oyl/engineering-education-systems-that-are-fit-for-the-future-conference-report.pdf
[6] EPC, 2023, Engineering Academics Netweork Annual Congress 2023: New models, *EPC Website*, Accessed 03.04.2023 https://epc.ac.uk/event/engineering-academics-network-annual-congress-2023-new-models/.
[7] UK EERN, 2023, Annual Symposium 2023: The Student Experience from Envolution to Revolution, *EPC Website*, Accessed 03.04.2023 [Online], Available: https://epc.ac.uk/event/uk-and-ireland-engineering-education-research-network-annual-symposium/.
[8] Engineering Council, 2020, Accreditation of Higher Education Programmes (AHEP), Accessed 03.04.2023 https://www.engc.org.uk/media/3464/ahep-fourth-edition.pdf .
[9] P. Xavier et al., A Snapshot of How 'Social' Considerations Are Currently Being Interpreted and Addressed Within Engineering Education and Accreditation, In: Christensen, S.H. et al. (eds) *Engineering, Social Sciences, and the Humanities. Philosophy of Engineering and Technology*, Vol 42. Springer, Cham, 2023, pp. 65-92.
[10] C. Arlett et al., Meeting the Needs of Industry: The Drivers for Change in Engineering Education. *Engineering Education*, 2010, Vol 5, pp. 18–25.
[11] R. Dalrymple, et al., Employability: a review of the literature 2016-2021, 2021, Accessed 04.03.2023, https://www.advance-he.ac.uk/knowledge-hub/employability-review-literature-2016-2021.
[12] EPC, RAE, 2021, Engineering Ethics Toolkit, Accessed 03.04.2023 https://epc.ac.uk/resources/toolkit/ethics-toolkit/.
[13] F. Almeida, J. Morais, Strategies for developing soft skills among higher engineering courses, *Journal of Education*, 2023, Vol. 203, pp 103-112.
[14] R. Graham, Coolaborative Engineering Education in the Digital Age report, Crisis and Catalyst: The impact of COVID-19 on gobal practice in Engineering Education, MIT, 2022, Accessed 03.04.2023, https://www.rhgraham.org/resources/Crisis-and-catalyst.pdf.
[15] R. Sevo, The Talent Crisis in Science and Engineering. In B. Bogue & E. Cady (Eds.). *Apply Research to Practice (ARP) Resources*. Accessed 03.04.2023, http://www.engr.psu.edu/AWE/ARPResources.aspx.
[16] L. Archer, *Social Call and Higher Education, Chap. 1 in Higher Education and Social Class: Issues of Exclusion and Inclusion*. Taylor & Frances e-library. 2015
[17] J. Rich, S. Fowler, 2021, What does Engineering tell us about social mobility? Accessed 03.04.2023, https://www.hepi.ac.uk/2021/05/25/how-far-does-engineering-support-social-mobility/.
[18] J. Miranda, et al., The core components of education 4.0 in higher education: Three case studies in engineering education, *Computers and Electrical Engineering*, 2021, Vol 93, pp 1-13.
[19] F. Bailey, et al., Changing the narrative on Covid-19: Shifting mindsets and teaching practices in higher education, *Policy Futures in Education*, 2022, Vol. 20, pp. 492–508.
[20] L.J. Everett et al., Integrated Curricula: Purpose and Design. *Journal of Engineering Education*, 2000, Vol. 89, pp. 167-175.
[21] M. Forehand. Bloom's taxonomy: Original and revised. In M. Orey (Ed.), *Emerging perspectives on learning, teaching, and technology*, 2005, accessed July 6 2023, https://textbookequity.org/Textbooks/Orey_Emergin_Perspectives_Learning.pdf

[22] R.M. Harden, The integration ladder: a tool for curriculum planning and evaluation. *Med Educ*, 2000, Vol. 34, pp. 551-7.
[23] S. Kubisch et al.. From Transdisciplinary Research to Transdisciplinary Education—The Role of Schools in Contributing to Community Well-Being and Sustainable Development. *Sustainability*, 2021, Vol. 13, pp. 306-15.
[24] B. Nicolescu, The Transdisciplinary *Evolution of Learning. Proceedings of the International Congress on What University for Tomorrow? Towards a Transdisciplinary Evolution of the University*, Locarno, 1997, pp. 1-11.
[25] N. Pinfold, M. Mokhele, Foundation of transdisciplinary education at Caoe Peninsula University of Technology, *Journal od Transdisciplinary Research in Southern Afrika*, Vol. 16, 2020, pp. 1-18.
[26] University College London. (2011). UCL Council White Paper, 2011–2021. Accessed 24.08.2015 https://www.ucl.ac.uk/white-paper/provost-white-paper.pdf.
[27] *UCL East Website*, Accessed 03.04.2023 https://www.ucl.ac.uk/ucl-east/ucl-east-0.
[28] K. Anderson et al., Understanding engineering work and identity: a cross-case analysis of engineers within six firms, *Engineering Studies*, 2010, Vol. 2, pp. 153–74.
[29] D. Michelfelder, N. McCarthy and D. Goldberg, *Philosophy and Engineering: Reflections on Practice, Principles and Process*, Springer, Netherlands, 2013.
[30] C. Mitcham, R. Mackey, Comparing Approaches to the Philosophy of Engineering: Including the Linguistic Philosophical Approach, In: I. Poel and D. Golberg (eds),*Philosophy and Engineering*, Springer, Netherlands, 2009, pp. 49-59.
[31] A. Cooper et al., Engineering advice in policy making: a new domain of inquiry in evidence and policy, *Evidence & Policy: A Journal of Research, Debate and Practice*, 2020, https://discovery.ucl.ac.uk/id/eprint/10094114/3/Cooper_Final%20print-ready%20Manuscript%20-%20Engineering%20advice%20v4%20Jan%202020%20Clean.pdf.
[32] A. Cooper et al., We need to talk about engineering policy, *Technology in Society*, 2023, Vol. 72, 102196.
[33] L. Liote, Modelling for the UK's Utility-Scale Solar Regulation Change: Lessons for Transdisciplinary Engineering in Policy Practice, *Advances in Transdisciplinary Engineering*, 2022, Vol. 28, pp. 187–96.
[34] H. Collins and R. Evans, *Rethinking Expertise*, University of Chicago Press, Chicago, 2008.
[35] N. McCarthy, Interdisciplinarity, Incommensurability and Engineering in Policymaking: Using Philosophy to Understand Challenges at the Engineering-Policy Interface, In: D. Michelfelder et al. (eds), *Philosophy And Engineering: Exploring Boundaries, Expanding Connections*, Springer, Cham, 2017, pp. 139-50.
[36] N. McCarthy, Engineering Practice and Engineering Policy: The Narrative Form of Engineering Policy Advice, In: D. Michelfelder and N. Doorn (eds): *Routledge Handbook of the Philosophy of Engineering*, Routledge, 2021, pp. 630–44.
[37] United Nations, Department of Economic and Social Affairs, *The 17 Sustainable Development Goals*, Accessed 03.04.2023, https://sdgs.un.org/goals.
[38] UNESCO, Education for Sustainable Development, *UNESCO Website*, Accessed 24.03.2023, https://en.unesco.org/themes/education-sustainable-development
[39] S.O. Michael, L. Balraj. Higher education institutional collaborations: An analysis of models of joint degree programs. *Journal of Higher Education Policy and Management*, 2003, Vol. 25, pp. 131–145.
[40] E. Howard, Ofqual, *A review of the literature concerning anxiety for educational assessments*, 2020, Accessed 12.03.2023, https://dera.ioe.ac.uk/35045/1/A_review_of_the_literature_concerning_anxiety_for_educational_assessment.pdf
[41] M. Hanrahan, The effect of learning environment factors on students' motivation and learning, *International Journal of Science Engineering*, 2007, Vol 20, pp 737-753.
[42] C. Variawa, S. McCahan, Identifying language as a learning barrier in engineering, *International journal of engineering education*, 2012, Vol. 28, pp. 183-191.
[43] S. Schwartz, Admissions to Higher Education Review: Fair admissions to higher education: recommendations for good practice, 2004, Accessed 12.03.2023, https://www.voced.edu.au/content/ngv%3A12058.