A Comparative Analysis of Embedding Responsible Innovation in Integrated Engineering Curricula: A case study of Established vs Emerging Universities

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Abstract

As engineering education evolves to meet the demands of an increasingly complex world, especially in times of a climate crisis, universities must prepare students to develop technologies that are ethical, sustainable, and socially responsible. Responsible Innovation provides a framework for achieving this by integrating ethics, sustainability, risk mitigation, and equity, diversity, and inclusion into engineering curricula. Engineers have long influenced society through innovation, acting as agents of change. Given the lasting impact of engineering decisions, future engineers must be equipped to anticipate risks, uphold ethical standards, and design inclusive solutions that serve diverse communities. Many institutions are shifting toward integrated education models that emphasise real-world applications through project-based learning (PjBL). This paper compares how RI is embedded within two academic frameworks: (a) the established Integrated Engineering Programme at University College London (UCL), an interdisciplinary approach that works within that a discipline-based departmental structure (e.g., mechanical, electrical, chemical engineering) by combining project- and lecture-based learning, and (b) the Interdisciplinary Global Design Engineering Programme at emerging institutions like The Engineering & Design Institute London (TEDI-London), which employs a fully project-based learning approach. By examining these programmes, through an auto-ethnographic study, by interviewing two early-career academics from these institutions, capturing their reflections on the challenges and opportunities of embedding RI in engineering curricula. Ultimately, this paper offers recommendations for strengthening the integration of RI within engineering curricula, tailored to each programme's unique characteristics. It contributes to ongoing discourse on preparing engineers to navigate global challenges, emphasising inter- and trans-disciplinary competencies as essential for future demands.

Keywords: Responsible Innovation, Project-based Learning, Interdisciplinarity, Auto-ethnography

1 Introduction

Engineering innovation has long prioritised technological advancement without fully accounting for its ethical, social, and environmental impacts. The climate crisis, a stark consequence of unchecked innovation, is one of the most urgent and existential threats to our planet (Sveiby, Gripenberg, Beata, Eriksson, & Aminoff., 2009; Biggi & Giuliani, 2022). Engineers, as the architects of industrial progress, hold a profound responsibility in this crisis (Stilgoe, 2013). They have shaped the world through technological advancements, but too often at the expense of people and the planet. At the same time, engineering also has the means to resist - by working across disciplines and challenging extractive systems, engineers can help shift priorities toward sustainability and collective well-being and contribute to positive transformative change (Alwi, Manan, Klemeš, & Huisingh, 2014). Given this capacity for change, there is a growing recognition that universities must play a central role in equipping engineering students with the skills and competencies necessary to address the climate crisis (Filho, 2011). To support this shift, the United Nations' Education for Sustainable Development (ESD) framework has been widely adopted, shaping curriculum revisions to embed sustainability within higher education (Rieckmann, 2017).

In this context, the latest edition of the UK Engineering Council's Accreditation of Higher Education Programmes (AHEP4) underscores the growing recognition of the eco-social dimensions of engineering (Engineering Council, 2020). AHEP4 highlights key aspects of Responsible Innovation (RI) - encompassing Ethics, Sustainability, Risk mitigation and Safety, and Equity, Diversity, and Inclusion (Owen, Bessant, & Heintz, 2013). This shift acknowledges that engineers must be equipped not only with technical expertise but also with the values and critical awareness necessary to make ethical, sustainable, and inclusive decisions. In response, engineering programmes are deliberately adopting an integrated approach that fosters interdisciplinary education, recognizing that today's global challenges cannot be addressed by any one discipline alone (Van den Beemt, et al., 2020).

This interdisciplinarity is reinforced through active inquiry-based learning methods, such as Project-Based Learning (PjBL), which immerse students in real-world challenges and encourage collaboration across disciplines to develop socially responsible and innovative solutions (Kokotsaki, Menzies, & Wiggins, 2016). Adapting to its unique context and institutional goals, some programmes have focused on blending multiple engineering disciplines within a single curriculum while other programmes have brought students from different disciplines to develop solutions to interdisciplinary challenges (Richter & Paretti, 2009).

Despite the diversity of approaches, many programmes still face significant challenges in effectively integrating RI in their respective interdisciplinary contexts (Foley & Gibbs, 2019). In many cases, curriculum changes are not sufficient; faculty members lack the experience or training required to manage interdisciplinary team projects or to guide students in addressing the social and ethical implications alongside technical expertise (Summers, Childs, & Corney, 2005).

While much of the existing literature focuses on student experiences, there has been insufficient exploration of the challenges faced by faculty in adapting to these new roles. Without adequate institutional support, many educators struggle to integrate these critical topics on RI into their courses. There is little guidance on how to navigate this transition effectively, particularly for early-career academics who must balance disciplinary traditions, institutional expectations, and novel pedagogical approaches.

This paper seeks to address the question: *What are the challenges and opportunities faced by early-career academics in embedding responsible innovation within interdisciplinary engineering curricula, and what institutional support mechanisms are needed to facilitate this transition in their unique contexts?*

By answering this question, the authors aim to highlight the key skills required for successful implementation for enhancing institutional support structures for (early-career) educators undertaking this transition.

2 Methodology

To explore the research question, the first two authors employed an auto-ethnographic approach. The paper took direct inspiration from a similar auto-ethnographic study carried out for reflections on leading Large-Scale Interdisciplinary Team Project Modules (Truscott & Smith, 2024). Auto-ethnography, especially in education paradigm, enables a reflexive analysis of personal and professional experiences, offering rich, contextual insights (Denshire, 2014; Dyson, 2007). These two authors drew on their personal experiences and reflections as early-career academics, each working in distinct interdisciplinary engineering programmes with a focus on teaching social responsibility in engineering education. By positioning themselves as both researchers and participants, they critically examined their own challenges, strategies, and institutional contexts in integrating RI within engineering curricula. In this context, auto-ethnography served as a valuable method, enabling them to systematically translate their experiences into a broader understanding of the opportunities and challenges faculty face. The third author, serving as Programme Director of the IEP (IEP), provided critical oversight and analytical perspective to the study. They provided the institutional context and programmatic insights that was necessary for this autoethnography.

The two institutions - University College London (UCL) and TEDI-London - both emphasise interdisciplinary, project-based learning as a core component of their engineering curricula, adopting different pedagogical methods to match their unique contexts while sharing similar values that drive them. Similarly, the first two authors also share the same commitments to fostering socially responsible engineering education as part of their individual practice. Therefore, this study is created to elicit the ways in which the different institutional contexts and pedagogical approaches shaping their experiences and the challenges they face as being representative of other early career academics in similar positions.

At UCL, the Integrated Engineering Programme encompasses most of the flagship engineering undergraduate degrees offered by the departments within the Faculty of Engineering Sciences. The IEP emphasises interdisciplinary learning in which students collaborate with peers from other departments/disciplines. The programme complements project-based learning with skills-training in topics such as technical communication, academic research, teamwork, project management, and responsible innovation. Students engage with engineering challenges in single- and multi-disciplinary problems while considering the social impact of their solutions. Combining lectures and hands-on projects, the IEP cultivates both technical proficiency and societal awareness within its diverse annual cohort of approximately 1,000 students. At TEDI-London, the Global Design Engineering programme is an innovative programme that adopts an interdisciplinary and project-focused approach, with flipped classroom model, and emphasis on emerging topics like smart cities, sustainability, and user-centred design. With an annual cohort size of about 50 students, the programme offers immersive, hands-on projects supported by online learning and strong industry collaborations. This encourages students to apply their learning directly to contemporary global issues in each module.

The first author, based at UCL, is an early-career academic specialising in social responsibility within engineering education. Their role involves supporting students in interdisciplinary teamwork, helping them navigate ethical dilemmas and develop a broader awareness of engineering's societal implications. In addition to teaching, they contribute to curriculum development, ensuring that social responsibility is meaningfully embedded across the IEP's interdisciplinary projects. The second author is also an early-career academic at TEDI-London, where they play a key role in embedding social responsibility and sustainability within the curriculum. Their teaching centres on interdisciplinary, project-based learning that blends technical and socio-environmental considerations. Through industry and community collaborations, students engage with authentic engineering challenges that mirror real-world complexities.

Over six months, the authors met regularly in semi-structured reflections, examining their motivation and roles, teaching methodologies, challenges, and institutional contexts. By systematically comparing the reflections, the authors identified key themes on personal motivations (why), institutional context and support (where), instructional strategies (how), and challenges & opportunities (what). This approach not only provided insight into their own pedagogical practices but also contributed to a growing conversation about the evolving role of engineering educators in shaping ethically and socially conscious engineers

3 Results and Discussion

In this section, we delve into the identified key themes that emerged during our exploration of the two engineering education frameworks.

3.1. Motivation and Institutional Context

How do your personal motivations align with your institution's pedagogical approach in embedding RI, including sustainability, ethics, and inclusivity into the engineering curriculum?

For the first author, the appeal of the IEP at UCL Engineering was compelling for multiple reasons. What stood out was its bold trailblazing approach - pioneering a shift in engineering education despite resistance. Unlike traditional programmes that are isolated by discipline, the IEP prioritised interdisciplinarity from the outset, embedding responsible innovation at its core. Having studied at large universities, the first author had faced similar challenges of departmental isolation and a lack of exposure to social responsibility topics in engineering curricula - issues they had been passionate about since their undergraduate days. Joining the IEP felt like an opportunity to bridge that gap and teach the socially engaged engineering education they had longed for. The programme's reputation for producing graduates who challenge norms and drive change reinforced their belief that this was the right place to be.

For the second author, their personal multidisciplinary background aligned very well with TEDI's interdisciplinary global design engineering programme. In contrast to the large, academic institutions where they previously studied - characterised by slow-moving, bureaucratic processes that often stifled innovation and student agency - they found TEDI's project-based learning approach refreshingly direct. The absence of artificial disciplinary boundaries meant that real-world problems were tackled in collaboration with industry partners from the outset, an approach that strongly aligned with their personal interest in applied engineering skills. With a small, tight-knit community, they had the opportunity to shape the programme in meaningful ways, ensuring that sustainability, ethics, and inclusivity weren't just abstract ideas but embedded in tangible projects. As someone with experience running both an NGO and a company, she found that her personal entrepreneurial spirit aligned well with TEDI's agility, entrepreneurial nature, and applied focus, viewing it as a place where she could make a real impact.

3.2 Institutional Support

How have the availability of resources, administrative support, and institutional training influenced the success of integrating sustainability and ethics into your curriculum, and what gaps have you identified?

At UCL, the vastness of the institution provides both opportunities and challenges in integrating RI into the engineering curriculum. While there is a wealth of expertise and resources available, such as the Higher Education Development and Support Institute (Arena), the sheer size of the university can make it overwhelming to navigate, with unclear signposting for whom to approach for specific needs. The IEP team works collaboratively with faculty from all engineering departments to co-teach modules throughout Years 1-3, ensuring students are exposed to diverse disciplinary perspectives. In recent years, UCL has driven the

development of teaching and research toolkits at the university level through its Grand Challenges initiative, reflecting a growing momentum to engage more deeply with RI themes. Nonetheless, gaps remain in providing clear, centralised guidance and ensuring broader, more consistent institutional support for embedding sustainability and ethics education across departments in each faculty.

At TEDI London, the small and new academic team (the institute is only 5 years old), with only 2-3 educators per discipline, has ensured coherence and consistency in the delivery of these topics. However, this structure also means that perspectives can be limited or biased, as there is little room for diverse viewpoints within each discipline. As the team grows, sustainability and ethics are increasingly embedded in a bottom-up approach, where each educator, administrative member, and institutional policy plays a role in fostering these values. This growing inclusivity makes it easier to introduce new teaching topics, methods, tools, and industry practices. On the administrative side, the small team, though limited in terms of resources, personnel, and facilities compared to larger institutions, has allowed for more direct interaction with staff and fewer bureaucratic hurdles. While this means there is limited access to extensive institutional resources, the direct and flexible support system allows for quick access to necessary resources, whether it's access to VR tools or makerspaces, when needed. This allows an easier way to introduce new interdisciplinary methods and quicker access to industry real-world applied projects and support.

3.3. Instructional Strategies

Based on our teaching experience, which specific teaching methods, tools, and strategies have proven most successful in helping students grasp and apply sustainability and ethics in their engineering education?

According to the first author, they implement direct classroom instruction through the "Engineering Challenges" and "Design and Professional Skills" (DPS) modules in Year 1. In Engineering Challenges, multidisciplinary teams tackle real-world problems such as setting up a tuberculosis vaccine plant in Uganda, with students encouraged to consider the premise and social impact of the project. In DPS modules, content is tailored to different disciplines, connecting engineering practice with social justice issues like the climate crisis and industry responsibility, effectively making these topics relevant to students' fields of study. The author also supports scenario-based learning - an immersive, week-long experience where students from the same discipline apply their DPS knowledge to real-world projects. Additionally, the author provides support to scenario teaching leads in integrating RI through tailored pedagogical and curriculum development, including lectures and assessment design. These complementary approaches have proven effective in helping students recognise their responsibilities in engineering projects.

In the experience of the second author, at TEDI-London, all modules have integrated industry-linked projects, group assessments, stakeholder workshops, presentations, and site visits, engaging students with real-world challenges and develop understanding of the social and environmental implications of their work. In the “Ecological Design” module that they run, students gained hands-on experience with sustainability tools such as Life Cycle Assessment and engaged in mechanical engineering simulations using digital tools like MATLAB. Additionally, systems thinking was incorporated through interactive modules, encouraging students to consider the interconnectedness of engineering systems and the broader impact of their decisions. Key skills such as communication, portfolio design, and project management were also emphasized, fostering the ability to lead projects with an ethical and sustainable focus. Furthermore, in modules like “Smart Cities” and “Global Design Engineering”, students were encouraged to design inclusive and accessible solutions, with varying assignments that fostered both individual and collaborative work, ensuring they were well-equipped to navigate the complexities of ethical and sustainable engineering in diverse contexts.

3.4. Challenges

What significant challenges have you faced as educators in embedding sustainability and ethical considerations into your teaching model, and how have you worked to overcome them in practice?

The isolated nature of first-year RI lectures limits long term engagement, with only a small cohort (30 students) continuing to the second-year Engineering Design for Society module. At a faculty level, embedding RI into engineering education programmes like the IEP presents specific challenges, that include institutional resistance, curriculum constraints, student engagement, and faculty preparedness. Disciplinary silos can create inconsistencies in how RI is addressed - some departments see RI related accreditation requirements as a box-ticking exercise, while others embrace RI as central to their subject. Time constraints exacerbate this issue, with faculty members either lacking the time to prepare content on social responsibility or struggling to fit it into an already packed curriculum. Additionally, many first- and second-year students enter with rigid expectations about their disciplinary identities, often anticipating a traditional, technical focus.

At TEDI-London, the limited size of the academic team and the constraints of time are the key challenges. Additionally, there has been limited training of educators in interdisciplinary methods, which further complicated the integration of these critical topics into the curriculum. Balancing structured, meaningful sustainability education within the project-based model of the curriculum posed another challenge, particularly when it came to assessing individual contributions in team projects while also integrating ethics alongside technical learning. Furthermore, maintaining student engagement across diverse cohorts, each with varying levels of prior knowledge and interest in sustainability, added another layer of complexity.

3.5. Opportunities

What further institutional changes or support do you feel are necessary to improve sustainability education and better equip engineering graduates with the skills they need to address pressing global challenges?

At UCL Engineering, a growing transdisciplinary interest could be enhanced through cross-faculty collaborations with RI-focused units and local community partnerships for service-learning. The priority should be to weave RI themes into existing courses by critically evaluating existing content e.g. by developing meaningful assessment methods that measure sustainability competencies effectively. Many educators struggle to integrate RI due to limited training and institutional backing, thus, the university must provide resources and professional development opportunities that empower faculty to navigate these complex topics and embed RI across the curriculum.

TEDI-London should continue expanding its industry and global academic partnerships to diversify the types of projects available to students. Additionally, strengthening and pushing the boundaries of disciplinary contexts to evolve new fields, such as responsible robotics and ecological design, will help broaden students' understanding of how sustainability and ethics intersect across various domains. It is also crucial to increase support for specialized training and qualifications for interdisciplinary educators. Furthermore, leveraging digital technologies responsibly - such as through projects involving robots used for educational purposes - would help students see the potential for innovation to address global challenges.

4 Conclusion

This study addresses the key challenges early-career academics face in embedding responsible innovation, such as institutional resistance, curriculum constraints, and insufficient faculty training—while also highlighting opportunities for improvement through interdisciplinary collaboration, institutional support, and industry partnerships. At UCL Engineering, the challenges include navigating disciplinary silos and

inconsistent faculty engagement, whereas TEDI-London's smaller, agile structure allows for quicker adaptation but faces limitations in resource depth and faculty diversity. Despite the differences in experiences, authors believe that at both institutions, RI need to be viewed and embedded as a set of values, not merely a set of skills. The study highlights actionable pathways for improvement, including faculty development programmes, and centralised guidance. For early-career academics, institutional backing is critical to overcoming resistance and ensuring that sustainability, ethics, and inclusivity are not treated as add-ons but as foundational pillars of engineering education. By prioritizing these changes, universities can empower educators to cultivate a new generation of engineers who are not only technically proficient but also ethically and socially responsible- equipped to address the urgent challenges of our time.

5 References

Alwi, S. R., Manan, Z. A., Klemeš, J. J., & Huisingh, D. (2014). Sustainability engineering for the future. *Journal of Cleaner Production, 71*, 1-10.

Biggi, G., & Giuliani, E. (2022). The noxious consequences of innovation: what do we know? *In The Dark Side of Innovation*, 12-34.

Denshire, S. (2014). On auto-ethnography. *Current Sociology, 62*(6), 831-850.

Dyson, M. (2007). My story in a profession of stories: Auto ethnography-an empowering methodology for educators. *Australian Journal of Teacher Education, 32*(1), 36-48.

Filho, W. L. (2011). About the role of universities and their contribution to sustainable development. *Higher Education Policy, 24*, 427-438.

Foley, R., & Gibbs, B. (2019). Connecting engineering processes and responsible innovation: A response to macro-ethical challenges. *Engineering Studies, 11*(1), 9-33.

Kokotsaki, D., Menzies, V., & Wiggins, A. (2016). Project-based learning: A review of the literature. *Improving schools, 19*(3), 267-277.

Owen, R. J., Bessant, J. R., & Heintz, M. (2013). *Responsible innovation.* Chichester: Wiley.

Richter, D. M., & Paretti, M. C. (2009). Identifying barriers to and outcomes of interdisciplinarity in the engineering classroom. *European Journal of Engineering Education, 34*(1), 29-45.

Rieckmann, M. (2017). *Education for sustainable development goals: Learning objectives.* UNESCO publishing.

Stilgoe, J. (2013). Foreword: Why responsible innovation. In R. Owen, M. Heintz, & J. Bessant, *Responsible Innovation.*

Summers, M., Childs, A., & Corney, G. (2005). Education for sustainable development in initial teacher training: Issues for interdisciplinary collaboration. *Environmental Education Research, 11*(5), 623-647.

Sveiby, K.-E., Gripenberg, P., B. S., Eriksson, A., & Aminoff., A. (2009). Unintended and undesirable consequences of innovation. *In XX ISPIM Conference, "The Future of Innovation".* Vienna, Austria.

Tait, J. (2017). From responsible research to responsible innovation: challenges in implementation. *Engineering Biology, 1*(1), 7-11.

Truscott, F., & Smith., L. (2024). Do You Need To Be Mad To Work Here? Reflections On Leading Extremely Large-Scale Interdisciplinary Team Project Modules. *52nd Annual Conference of SEFI.* Lausanne.

Van den Beemt, A., MacLeod, M., Van der Veen, J., Van de Ven, A., V. B., Klaassen, R., & Boon, M. (2020). Interdisciplinary engineering education: A review of vision, teaching, and support. . *Journal of engineering education, 109*(3), 508-55.