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A Critical Realist Investigation Into The Development Of Engineering Ethics Education

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A CRITICAL REALIST INVESTIGATION INTO THE DEVELOPMENT OF ENGINEERING ETHICS EDUCATION IN IRELAND

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ABSTRACT

The paper reflects on the use of critical realism as a theoretical lens for examining the provision of ethics in engineering programmes and putting forward recommendations for the development of engineering ethics education. It is based on a large scale 4-year mixed methods study in which 23 engineering programmes from 6 higher education institutions in Ireland participated. The methods used include documentary analysis of programme documents, course syllabus and accreditation reports, interviews with instructors and members of accreditation panels, participant observation at accreditation events and a descriptive statistical analysis of the numerical grade used by engineering programmes to self-assess their provision of ethics. The paper addresses two research questions: 1) what are the key challenges in the provision of engineering ethics education, considering the 23 programmes analysed? 2) what recommendations emerge to address these challenges? To respond to the research questions, given the stratified ontology presupposed by critical

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realism, the research study focused on 4 different levels of analysis: individuals (engineering ethics teachers), institutions (engineering programmes) and policy (national accreditation body). The main insight of the paper is that change strategies need to address all levels and treat them as intertwined in order to develop comprehensively the education for engineering ethics.

1 INTRODUCTION

Traditionally, disciplines such as engineering and exact sciences were regarded as morally neutral [1]. Ethical concerns are a more recent addition to engineering programmes, and the development of engineering ethics education (EEE) has been slow [2]. Moreso, both teachers and programme leaders have reported struggling to make sense of the variety of EEE theories, learning goals, teaching activities, and assessment methods, as to ensure their alignment [3]. There is also a disparity between the perceived importance of societal-related practices by engineering faculty and their actual presence in the engineering curriculum [4].

Accreditation has been mentioned as a factor of change leading towards an enhanced presence of ethics in the engineering curriculum [5]. In Ireland, the accrediting body Engineers Ireland has been actively working on reformulating accreditation criteria aligned with current societal needs and research evidence [6] [7]. The present research study was conducted in collaboration with Engineers Ireland between 2017-2020, with the aim of informing the revision of criteria purporting to societal aspects. When the study was conducted, ethics was already an accreditation outcome, which required that engineering graduates in Ireland show "knowledge and understanding of the social, environmental, ethical, economic, financial, institutional, sustainability and commercial considerations affecting the exercise of their engineering discipline", as well as "knowledge … of engineering practice, and the impact of engineering solutions in a societal and environmental context" and "commitment to the framework of relevant legal requirements governing engineering activities, including environmental" [7].

The study aims to examine the current status and implementation of EEE in Engineering Programmes in Ireland, and on the basis of the findings to identify change measures for enhancing EEE. 23 engineering programmes from 6 institutions in Ireland took part in the study, alongside 16 instructors teaching in these programmes and 6 evaluators serving on panels accrediting the participant programmes. We argue that change measures need to address several levels pertaining to teaching, programme leadership and policy-making to ensure a transformative engineering education oriented at addressing the grand societal challenges of the time. As such, the study provides insights for lecturers and programme leaders, in response to the need for guidance on how to implement EEE and the increased calls for engineering programmes to take on a societal role.

2 METHODOLOGY

The paper reports on two key research questions: (Q1) How is EEE implemented in Engineering Programmes in Ireland? and (Q2) What are the key recommendations

emerging for enhancing the implementation of ethics in Engineering programmes in Ireland?

2.1 Theoretical perspective

When designing the study, an important step was opting for a theoretical paradigm that supports the project aims. As such, we purposefully steer the balance towards describing the theory behind the study. We consider it is important for engineering education researchers to reflect and make explicit how their research is loaded with specific ontological, epistemic and axiological assumptions, which may influence the data collection and analysis. With few exceptions [8], engineering education research is conducted in the absence of such reflections, or these are neglected in the reporting of findings. This carries the risk of acontextual or uncritical research processes, that "limits what can be seen, known and understood." [9]

To address the research questions set for the project, the theoretical stance adopted by this research study is critical realism (CR). This is due to three main reasons:

First, from an ontological perspective, CR is committed to understanding the embedded nature of human action and the interaction of structure and agency [10] .CR acknowledges the existence of different ontological domains [11]. Bhaskar [12] distinguishes between three domains of existence: "the empirical" (comprised of observable or experienced entities and events), "the actual" (events that take place and which may or may not be experienced) and "the real" (comprised of causal powers that generate both actual events and experiences). According to CR, structures exercise causal power over individual and collective agents, but agents can also affect the structures they are part of [13]. In this sense, reality is considered to be socially constructed and emergent.

In light of this layered ontology, the role of the researcher is then "to use perceptions of empirical events to identify the mechanisms that give rise to those events" [14]. This seemed important given Sterling's argument for regarding education as a complex system with a number of different layers [15]. The failure to integrate different layers into models for change has been identified as a gap in engineering education research, with different research communities having focused separately on different levels [16]. More so, higher education research has largely neglected the social context which shapes the activities of individuals [17] [18] [19]. A CR research study on engineering education would thus place the individual in the wider context, as "change based on 'improving' individuals will usually be a disappointment if not done with an awareness of the context individuals operate in." [17] This fits with recent calls for developing change strategies that link different levels in order to generate long lasting and organic transformation [20].

Building on this observation, the second reason for opting for CR is axiological in nature, due to its commitment to social change. The axiology of a theoretical framework refers to the values directing research or the research output. CR puts forward an emancipatory axiology [21] [22]. According to Danermark et al. [23], CR

research is driven by the belief that the improvement of society is possible. As such, it is considered to offer "exciting prospects in shifting attention to the real problems that we face and their underlying causes." [21] Thus, the ultimate aim of the emancipatory worldview advocated by CR is to identify how the features examined in the research study may be changed in order to ameliorate harmful effects or to enhance beneficial effects [22]. This implies a "strong focus on 'what to do'" to improve the situation under investigation [22]. Godfrey [24] agrees that the analysis of engineering education should focus not only on "characteristics of behaviours and practices", but also on the values, beliefs, and assumptions that underpin "how these came to be," in order to enable the development of strategies for change.

Thirdly, from an epistemological perspective, CR looks beyond the empirical to posit causal explanations that target the underlying mechanisms for current experiences, beliefs, practices and events [12]. As such, our claim is not that the data is representative of the Irish engineering education system in its entirety, but rather that it provides useful insights into the way ethics is being understood and integrated. This is achieved though retroductive explanations, starting from the examination of phenomena registered in the "empirical" and "actual" ontological domains to pin possible causes pertaining to the "real" domain [25]. The aspiration is towards "theoretical generalisation" [26], which means that the data can provide theoretical insights that, if acted on, may have a profound effect on the development of EEE.

Thus, the ultimate goal of the CR research project is to facilitate change in the practices of EEE. To achieve this, after identifying the main characteristics of EEE belonging to the empirical and actual domains, a generative explanation will be sought placed in the domain of the real, followed by recommendations for change targeting the different ontological layers of the engineering education system.

2.2 Research methods

Four research methods have been employed to determine the implementation of ethics: (a) document analysis of the documentation which was either prepared by the programmes for accreditation or is available online on the website of all 23 participant programmes, together with the analysis of 11 accreditation reports and 83 course descriptors; (b) participant observation at the accreditation events of 11 programmes offered by 3 institutions and (c) interviews with lecturers from the participant programmes teaching a professional formation course and evaluators who served on the accreditation panels observed and (d) a non-systematic literature review for identifying strategies for addressing the challenges and deficiencies revealed via the previous empirical methods. These methods are seen as complementing each other for developing a comprehensive insight into the implementation of ethics education in the participant programmes and putting forward relevant recommendations. The scope of the study was limited to Engineering programmes that underwent accreditation between 2017-2019. Twenty-three programmes offered by 6 institutions are included.

The main strategy behind the mixed method research approach is summarized in Table 1, alongside a description of each research stage. Stage 1 was the initial stage and had the longest temporal unfolding, which encompassed stage 2. Stage two aimed to complement the scarce data available in the accreditation reports analysed in stage 1, to better capture the process of evaluating EEE for the purpose of accreditation. The preliminary results obtained during stage 1 and the experience gathered during stage 2 informed the approach to the interviews conducted in stage 3. Then the three stages informed the literature review search for recommendations and change strategies mentioned in engineering and higher education journals and conference proceedings.

Table 1. Summary of research stages

Stage	**Method**	**Data Source**	**Data collected**
1	Document analysis (qualitative)	23 Programme documents submitted for accreditation 83 Course descriptors and syllabus 11 Accreditation reports	The topics and learning outcomes employed in connection to EEE Content used in EEE Method of implementation of EEE in the programme Weight given to the ethics outcome in the programme, compared with other accreditation outcomes Recommended changes for improving ethics, according to accreditors
2	Participant observation (qualitative)	3 Accreditation events that evaluated 11 programmes	The views on ethics, engineering and engineering education verbally expressed when evaluating evidence The evaluators' judgement and criteria of how the programmes meet the ethics outcome The guidelines received by the accreditation panel from the accreditation body for evaluating ethics The amount of time dedicated to the evaluation of ethics compared with other outcomes
3	Interviews (qualitative)	16 Instructors teaching EEE 6 Evaluators on accreditation panels	Motivation to teach ethics Personal views on the role of ethics in engineering education Perception on how ethics is viewed and implemented in the programme Approaches to EEE in terms of content, teaching and assessment Challenges experienced with EEE (teaching, preparing for accreditation or evaluating ethics) Views on support received or needed in the teaching or evaluation of EEE
4	Literature review	Empirical and theoretical research sources	Measures and strategies for curricular change Measures and strategies for EEE

3. RESULTS

3.1 The status and implementation of EEE in Ireland

Through the triangulation of data, the study identified the following findings within a CR frame: within *the empirical domain*, the beliefs, understanding and attitudes of representatives of teachers, programme leaders and accreditors towards EEE; within *the actual domain*, the teaching practices of instructors and the measures taken by programmes and representatives of the accrediting body; while for *the real domain*, the study hypothesizes the existence of a cultural level, characterised by the prevalent view that engineering is mainly a technical discipline. The findings are summed up in Table 2.

Table 2. A CR analysis of engineering ethics education in Ireland

Ontological domain / **Actor level**	**Empirical Domain**	**Actual Domain**	**Real Domain**
Individual level (teachers; evaluators)	Ethics is perceived to be a lower status academic subject Perceived lack of motivation to teach ethics Confusion as to what falls under the scope of ethics	Challenges experienced in the teaching and assessment of ethics Challenges in motivating EEE students Popular use of sustainability, health & safety and legislative topics in EEE	The prevalence in society of a traditional conception of engineering as a purely technical discipline
Institutional level	Ethics is perceived as a non-essential learning outcome Ethics is perceived as a curricular add-on to meet the accreditation requirements Perceived difficulties in finding room of ethics in a crowded curriculum	Ethics has the lowest weight in the engineering curriculum of all accreditation outcomes The implementation of ethics is uneven among different programmes The implementation of ethics is unsystematic Few or no staff specialised in EEE	
Policy level	Belief that ethics needs to be part of the engineering curriculum	Increased presence of ethics following the introduction of an accreditation criterion Less time spent at accreditation events on evaluating ethics, compared with technical outcomes Lower threshold for what is considered satisfactory evidence for ethics	

3.2 Recommendations for enhancing EEE

Considering its emancipatory axiology, the CR study set to identify via a non-systematic literature review recommendations for addressing the deficiencies previously identified:

At *individual level*, the actions and example set by individual instructors are powerful means to instil educational change. Effective change in universities is bottom-up, incremental, and often invisible, with faculty and administrators representing “active agents in the curricular change process” [27]. The power of example of committed individuals is crucial in highlighting deficiencies and leading redress strategies. To achieve change, collective action and collaboration are important for fostering the overall reorientation of the programme. It was suggested that this can be accomplished through working groups and faculty learning communities, with open discussions in which instructors are encouraged to think outside their discipline and co-create the course and curricular redesign. Individuals can also enhance their teaching by using educational resources, such as the Online Ethics Center, The Ethics Toolkit or The Surf project.

At *institutional level*, an overall redesign of the programme curriculum is crucial. This can be achieved through staff training, hiring decisions targeting EEE specialists, resource prioritization, incentives internalized in the mission and reward system of the institution, accountability in implementing change. It is also important for programmes to gain an external perspective of their EEE curricular offer and teaching approach through participation in EER conferences and engagement with non-engineers, educational consultants and other institutions.

At *policy level,* it is important to acknowledge that institutional change rooted in the demands set by accrediting bodies risk leading to a culture of compliance rather than of transformative change. The recommendation is a continual update of accreditation requirements in consultations with stakeholders representing different technical and non-technical disciplines, as well as the academic and non-academic environments (major employers, private companies, NGOs, communities affected by engineering developments). It is encouraged that non-mainstream perspectives are brought in the formulation of accreditation requirements, such as humanitarian engineering, engineering for peace, the justice pillar of sustainable development or critical feminism. It is also recommended that accreditation bodies offer additional support to programmes in the implementation and teaching of ethics as well as to members of accreditation panels on evaluating evidence purporting to EEE. Such measures include training sessions, expert advice, the development of pedagogical resources or facilitating stakeholder engagement.

At *cultural level*, it is important to address the dichotomy of the “two cultures”, that sees engineering separate from social sciences. This implies recasting the discourse surrounding engineering as a purely technical discipline and renouncing the dichotomy between the so-called “hard” and “soft” skills. The main recommendation is to promote a language that describes engineering as a sociotechnical discipline

and the development of sociotechnical skills in engineering education. This may begin with reflecting on how the mission of engineering programmes is formulated to pass on the importance of nontechnical content and the aim of producing sociotechnical engineering graduates. It also includes active efforts reflecting through language the role of societal content and non-technical disciplines and striving to communicate this from programme leaders to the teaching staff, and in turn from technical instructors to students. This is a societal effort that aligns with the recent focus and opposition towards unethical practices or climate denial.

3 CONCLUSION

The study examined the status and implementation of EEE in the Irish engineering education system, via mixed methods comprising documentary analysis of programme documents, interviews with instructors and evaluators, participant observation at accreditation events and a non-systematic literature review. It was driven by a critical realist theoretical framing, which guided us into analysing the findings at different layers of the education system and put forward a causal explanation for these findings. From a methodological perspective, the study contributes to the limited number of investigations in engineering education that adopt critical realism [28]. Considering its emancipatory axiology, the study identified several enablers for enhancing EEE, at the policy, institutional and individual levels. The novelty of this study lies in its attempt to explore the interrelationship of different levels belonging to different ontological domains in the context of a national education system. The findings and recommendations are envisioned to be of interest to teachers, programme leaders and policymakers, as to contribute to enhancing EEE beyond the national context examined in the study.

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