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Overlap of Ethics and Sustainability for Responsibility Mindset: Insights for an Educational Approach Change in Ethics of Engineering

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Abstract: The mandate of universities and higher education institutes is to shape students' ethical wisdom and catalyze sustainable development. However, everyone does not have equal access to higher education which drives the above mindsets, leading to unequal quality of education. Today, most ethics teaching in engineering schools is narrowly micro-ethics and does not attempt to define macro-ethics' special challenges. Micro-ethics concentrates on concerns related to the individual and the innermost workings of the profession. However, macro-ethics encompasses sustainable development with a focus on the collective social responsibility of the profession and public concerns about technology. This study examined undergraduate engineering programs in 25 major Canadian universities to see if they are adequately prepared to navigate both the micro- and macro-aspects of ethics education. The curricula of the programs show many courses focusing on micro-ethical concepts. The lack of explicit macro-ethical agendas for advancing society invites further work on curricula to enhance the efficacy of the content and delivery modes. This inadequate commitment to socially responsible engineering is conceptualized as a "culture of disengagement". The study introduces important moments of change to strengthen ethics education. These include twinning engineering and computing ethics; embedding overlapped ethics, sustainability, and responsibility mindsets; and promoting the scholarship of integration through research, synthesis, practice, and teaching. By adopting these approaches to curriculum and pedagogy, the students will effectively cultivate a critical understanding of and obligation to the profession's collective responsibility and the well-being of the greater society. These changes provide crucial insights into broadening socio-technical-minded prospects of engineering ethics education.

Keywords: micro-ethics, macro-ethics, culture of disengagement, sustainability, responsibility, scholarship of integration, digital scholarship

1. Introduction

Academic institutions have the potential to produce a signal of positive change, thereby helping to ensure societies prosper. This entails guaranteeing that students within educational institutions acquire the material designated by curriculum planners, encapsulated by authors of academic texts, delivered by educators, and evaluated through examinations [1]. The 2020 United Nations Development Program report [2] highlights that education encompasses more than just imparting scientific and technical skills. It plays a crucial role in advancing critical and imaginative thinking and introducing students to essential human ethical values. Consequently, education possesses the potential to be transformative, not only in its outcomes but also in its process.

Ethics can be understood as "eudaimonia" in Greek, signifying well-being, happiness, and flourishing in the Aristotelian virtue ethics tradition [3]. This may motivate educators to portray ethics as aspirational rather than preventive-only with the fact that the well-being of the public as well as professionals should be boosted in any ethical decision-making agenda [4]. For engineering ethics, the primary objective for students is to learn how to recognize, define, and resolve moral dilemmas that arise in social contexts when one must harmonize conflicting priorities and perspectives.

The current emphasis on engineering ethics education is limited especially involving the wider associations of the profession and public good [5]. Students are often taught to apply ethical codes when making professional judgments. However, such codes primarily deal with technical and professional ethics, such as promoting safety and reliability or acting as faithful agents, with little consideration for social and ethical responsibilities. To this extent, engineering has traditionally been considered rigorous and fit only for those who excel in mathematics and physical sciences. It has been considered objective and disconnected from societal issues [6].

The lack of wider ethics education in engineering, a relatively recent development, is attributed to the profession's perception as primarily concerned with practical matters rather than theoretical ones [7]. The push for broader education peaked around the turn of the century and is closely tied to the interest in promoting sustainability education. In many countries, engineering programs are accredited by professional organizations that sustain codes of

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ethics. Initially, these codes focused primarily on issues related to professional practice (micro-ethics) including moral/ethical concerns that may occur in the professional setting [8].

Several authors, including ethicists Ladd [9] and Herkert [10], have issued critiques, noting that engineering ethics must encompass both micro-ethics and macro-ethics, although there are indications, however, that such a balanced view is gradually taking hold. One way of expanding ethics to address macro-ethical issues is to believe in the collective social responsibility of the profession by considering the impact of sustainable development (SD), digital transformation, and artificial intelligence (AI).

De George, an ethicist, makes a distinction between "ethics in engineering" and "ethics of engineering" [11]. The former focuses on the actions of individuals, while the latter is connected to both relationships internal to the profession and the responsibilities of the engineering profession to society. De George's concept of "ethics of engineering" encompasses both Ladd's micro- and macro-ethics. To achieve education for the entire domain of ethics (micro and macro), it may be needed to adopt "emancipatory research (ER)". This approach requires educators and learners to collaborate in ongoing dialogue to address societal questions and analyze them thoughtfully. It also involves understanding the socio-technological and cultural realities through research for knowledge and acting as critical thinkers. By doing so, it is possible to collectively become aware of the surroundings and transform learning for the better. The challenge of such education may be addressed by following the CARE-KNOW-DO principles founded by Okada [12]. These principles are based on autonomy, humanization [13], and science for responsible citizenship. In this case, the classroom environment becomes a research community that fosters emancipatory practices by facilitating collaboration among learners, including the instructors.

Canadian engineering undergraduate courses must include an ethics component, often as part of the core curriculum. However, the extent to which engineering curricula are aligned with the evolving needs and demands of the global profession is uncertain. Given the growing demand for an enhanced and broader engineering ethics education covering both micro- and macro-ethics, there is a pressing need for a thorough review of current engineering ethics courses. This study addresses this gap by navigating courses at 25 major Canadian universities for the two dimensions, micro- and macro-ethics. The study introduces two important change methodologies to curriculum and pedagogy to increase the breadth of ethics education: twinning engineering and computing (E&C) ethics and adopting the "learn-by-research" approach in teaching and learning. With these changes, students will develop critical and creative thinking skills, fostering a growth mindset to become socially and environmentally responsible engineers.

2. Canadian Engineering Ethics Education

The primary aim of education is to cultivate individuals who are wiser, more knowledgeable, and better informed. This includes fostering ethical, responsible, and critical thinkers capable of continuous learning [14]. Early ethics education in Canada focused on preventing professional issues rather than addressing moral and aspirational concerns. However, at the beginning of the 21st century, there were calls for a shift in focus to address global issues such as SD and social responsibility. As a result, there is growing support for updating the worldwide engineering ethics curriculum.

The broader objective of this study is to examine the ethics curricula of engineering degrees (accredited by Engineers Canada – EC and informed by its code of ethics). The Canadian universities that offer a bachelor's degree in engineering mention "ethics", "professional practice", and/or "engineering and society" in their course description have been investigated. Information was collected from the content of courses in undergraduate engineering programs in 25 major Canadian universities, as shown in Table 1. Canadian universities vary widely in how and when ethics is integrated into engineering courses. Sometimes, it is presented as a specific module or unit of study, while in other cases, it is spread across different modules and units with different teachers incorporating ethical and professional concepts into their subjects. The timing of these courses also varies, with most being introduced in the first and second years as a core module, or in the final year as a capstone unit. Universities emphasize different aspects of ethics. For example, only a few universities include ethics philosophy in their curricula. The aspect that seems to be most emphasized is professional and institutional ethics, which aligns with the early versions of ethical codes from accrediting organizations.

As intelligence continues to play a larger role in political, economic, and social spheres, the relevance of macro-ethical concepts is becoming increasingly apparent. This requires the integration of E&C) for teaching ethics. The preliminary analysis indicates that the engineering programs at Canadian universities mainly include engineering ethics in their courses and focus on micro-ethics with few offering some content related to macro-ethics, but most only cover a couple of aspects. Further research

Table 1
Survey of engineering ethics domains at 25 Canadian universities

Ethical domains of focus	University
Ethics: Theories and philosophy; Ethical dilemmas; Moral decisions.	Dalhousie; Royal Military College; Ontario Tech; Western.
Micro-ethics: Professional responsibility; Ethical professional practice; Critical thinking; Personal attributes integrity; Honesty; Respect; Trustworthiness; Loyalty to the profession; Honesty; Communication skills; Equity in the workplace; Teamwork competence; Professional development; Compliance with codes; Standards; Legal issues; Intellectual property; Professional knowledge; Project management; Public safety; Safety in design.	Alberta; British Columbia; BCIT; Calgary; Carleton; Concordia; Dalhousie; Guelph; Lakehead; McGill; Royal Military College; McMaster; New Brunswick; Ontario Tech; Ottawa; Queens; Regina; Simon Frasor; Toronto; Toronto Metropolitan; Western; Waterloo; Victoria; York.
Macro-ethics: Global responsibility; Engineering in society; SD; Quality of life; Socio-technical skills; Public understanding of technology; Role of technology; Health and well-being; Awareness of consequences of technologies.	Alberta; British Columbia; BCIT; Carleton; McGill; Ontario Tech; Ottawa; Polytechnique Montreal; Saskatchewan; Simon Frasor; Western; Victoria.

and interviews with course developers are necessary to evaluate these curriculum inclusions' extent and effectiveness.

3. Culture of Disengagement

Understanding the broader cultural and institutional context of dominant engineering education programs is crucial for comprehending the current challenges in teaching engineering ethics to undergraduate students [11]. This is contested by the "culture of disengagement" which refers to a set of beliefs, practices, and meanings that influence how members of a profession perceive their responsibility towards society. According to Cech [15], this culture is supported by three main ideologies: depoliticization, which dismisses non-technical concerns as irrelevant; technical/social polarity, which undervalues social competencies related to public welfare; and meritocracy, which assumes existing social structures are just and fair. More explicitly, disengagement is a trait of the culture that over-stresses technical knowledge, which sometimes refers to the notion of "think like an engineer", and what kind of information is deemed essential for solving engineering problems. Due to this culture of "resistance to change", or "swimming against the concealed cultural tide", students may tend to distance themselves from considering social responsibility as they become engineers.

Sax et al. [16] stated that engineering students in the U.S. had on average, lesser obligations to social engagement as compared to their peers in other disciplines. The author shared this finding with his students who rated their level of agreement with it and attributed that mostly to the reasons given above. Two opinions are provided as given below:

> *"I believe that taking this ethics course allows us to understand and be aware of ways to prevent a culture of disengagement, and to make sure to use our knowledge taught in other courses to solve various problems around the world".*

> *"I think engineers are squeezed by all the math and logic they must do, and their brainpower is limited at the end of the day to worry about societal issues".*

Today's engineering ethics education must go beyond its traditional roles to tackle the increasing number of mindsets contributing to disengagement. This requires a greater sense of responsibility and an ethical approach to engineers' work. To tackle this challenge, professional codes of conduct should be carefully crafted to meet the unique challenges faced by engineering professionals, including their social responsibility to society and the environment. Therefore, professional codes of ethics must adapt to dismantle these new and complex challenges head-on. The author argues that it is essential to integrate engineering ethics with computing ethics and beyond for a better realization of the disciplinary culture of engineering and the ambiguous nature of disengagement culture.

4. Engineering Ethics and Computing Ethics

Ethics in engineering education has been a recent addition, even though its principles mainly focus on professional participants' rights, safety, and welfare. A major challenge in teaching engineering ethics is students' reception of the subject. When exposed to ethical considerations, students tend to show disinterest, resistance, and difficulties [17]. They are often taught to acquire knowledge of ethical codes and apply them when making professional decisions. However, such codes primarily deal with the individual responsibility of engineers toward technical and professional ethics (micro-ethics), such as promoting safety and reliability or acting as faithful agents, with little consideration for social responsibilities. This is a challenging case for faculty with a technical background who consider ethics personal [4] and related to the innermost operation of the engineering profession.

There are calls for engaging E&C and beyond to better understand the disciplinary culture of engineering and the blurry aspect of disengagement culture. According to Herkert [18], integrating macro-ethical perspectives is an effective mechanism. While computing is less grounded in practice compared to engineering, computer ethics has been more successful in incorporating both micro-ethical and macro-ethical perspectives in research and education so far [19]. The importance of macro-ethical models is rising as E&C programs are increasingly associated with political, economic, environmental, and social life. Ethical concerns surrounding emerging technologies are gaining more significance, especially with the rise of AI and digital transformation and apprehensions about their far-reaching effects on people and communities.

Ethics education is a long-lasting transformative process, which aims to challenge existing conventions and values to liberate any practice from habits that perpetuate inequity. The key to curriculum design for mindset change is to examine the role of each dimension in the socio-technical professional alignment through the overlap of ethics and sustainability mindsets. This involves incorporating a broader conception to expand towards a hybrid educational model that twins E&C practices for ethics with sustainability as context to professional practice.

5. Overlap of Mindsets

The education system is a suitable domain to promote ethics, sustainability, and responsibility (ESR) mindsets because it can shape the views and attitudes of students towards social change. Competences from each of the ESR disciplines feature distinct characteristics. Therefore, each discipline may influence a different set of competencies in the education system.

Ethics competencies are mostly built on the education ethics domain's three streams of normative (moral) ethics, behavioral ethics, and organizational and managerial ethics [20]. The sustainability mindset encompasses both factual and value-based components, as noted by Carew and Mitchell [21]. It is more than the sum of these components; it is a way of creating knowledge and learning that goes beyond. Sustainability in education and research should be a key philosophical endeavor, grounded in the concept of "eudaimonia" from Aristotelian virtue ethics [3, 22]. The responsibility mindset involves maintaining integrity by acknowledging that we are all interconnected. This notion of ownership stresses the importance of aligning organizational cultures and community-building competencies, social issues awareness, and finding solutions for society's problems [23]. D'Souza et al. [24] add professional ethical responsibility to the discipline competencies.

An effective way to incorporate ERS aspirations into education and research is by adopting the 17 interweaving goals that make up the United Nations 2030 Agenda, the SD goals (SDGs), as an aspiration to achieve a more equitable, inclusive, and healthy world. To directly contribute to advancing SDG 4 (quality education), higher education may utilize its major functions of knowledge acquisition, creation, and transfer to support all the SDGs [25]. When it comes to the SDGs, universities have a crucial role to play in teaching, collaboration, and advocacy [26]. Among those who may impact this development are the upcoming cohorts of E&C graduates who can play a crucial role in shaping sustainability for socio-technical development. This requires the education system to consistently impart the necessary pedagogies

for envisioning sustainability as an ethical value to guide action in knowledge production. Among the principal spaces for knowledge production are universities. In this regard, the International Engineering Alliance has reviewed the Graduate Attributes and Professional Competencies to ensure that they reflect contemporary values and employer needs. This covers diversity, inclusion, and ethics to reflect current and emerging thinking, addressing the intellectual agility, creativity, and innovation required for engineering decision-making. It also aims to equip engineering professionals of the future with the ability to incorporate practices that advance the SDGs [27]. The CDIO (Conceive, Design, Implement, Operate) framework has been updated to include new educational practices such as research experiences, SD, digital learning, entrepreneurship, internationalization, mobility, and industry engagement, in addition to the core CDIO standards [28].

Sustainability as a concept is transversal across disciplines, education, and professions which may be anchored in the analysis of social, economic, environmental [29], and ethical dimensions. It is important to consider ethics in sustainability when considering all potential stakeholders in an issue when finding a solution, considering the challenges or implications that may arise [30]. Including ethics in sustainable decision-making makes the process more diverse by bridging the communication gap between stakeholders. It has become clear to contemporary humanity that E&C is one of the primary platforms for achieving sustainability, however, it remains unclear how ethically E&C serves this goal [31]. Therefore, there is a need for focused education and research to responsibility reassess and evaluate practices from the perspective of sustainability [28]. Utilizing ESR mindsets to address problems is one way to ensure that all voices are heard, including those that may be more difficult to consider, such as those of future generations. When linking ethics to sustainability challenges, a rational mindset and systems thinking are valuable strategies to ensure that collective decision-making considers everyone's needs.

Integrating ethics into curriculum and education for sustainability is invaluable for addressing various issues and avoiding irrational and indefensible SDGs. This means that faculty and professors should play a crucial role in transforming curriculum and education to meet these needs. To achieve this, value-based educational experiences should be designed [23]. For this, Figure 1 integrates competencies from the ESR mindsets into one interdisciplinary framework that includes major domains of such competencies, namely knowing (ethical literacy), acting (skills), being (attitudes), and interacting (responsible relation).

The Sustainable Development Solutions Network is a valuable source of information and tools for universities interested in prioritizing the SDGs. It has produced a guide for higher education [32], highlighting the significance of the SDGs for universities and providing detailed steps to assist them in leading the SD movement.

6. Scholarship of Integration

The fourth SDG with a focus on quality education is crucial for higher education institutions. It aims to safeguard equitable quality education and promote lifelong learning opportunities for all. In this regard, universities play a crucial role in enabling students to acquire knowledge and imbibe a wide range of ethical values in a learning environment. However, most teaching in engineering ethics, including online resources, has had a "micro" focus with a minor focus on collective social responsibility. Despite increasing recognition of the significance of social responsibility in the role of engineers and changes in accreditation requirements, engineering culture often marginalizes these issues as being unrelated to the technical aspects of the field. This requires a change in teaching methodologies that integrate various teaching strategies and assessment methods to ensure that students have a comprehensive learning experience.

In the groundbreaking 1990 publication Scholarship Reconsidered, Boyer challenged the "teaching versus research debates" by promoting the scholarship of discovery, teaching, integration, and application, and recently digital scholarship (DS). The scholarship of integration is dominant because it is best prepared to answer contemporary problems at both individual and societal levels [33]. It involves bringing insight to bear on original research with integrative, and interdisciplinary approaches. It involves combining information from different disciplines, topics, and periods. This materializes by connecting teaching and research. To achieve this goal, the curriculum should have a strong emphasis on ethics and sustainability, as well as the application of knowledge to real-world problems through experiential learning. For an undergraduate ethics course, it is important to identify key ER knowledge and skills and incorporate them into the curriculum, as shown in Figure 2. Students should be able to learn and practice these skills early on, as they attend modules with research skills. Faculty may use their research expertise to enhance their teaching.

Students find all exposure to research-teaching connections valuable. However, they believe that certain approaches have more impact on their learning and future careers. It is not surprising that students who conduct individual research projects, usually in their final year of studies, consider this type of research experience to be the most valuable. Engaging in research within a team allows students to be part of a research community. Students who participate in work placements, typically in the later stages of

Figure 1
Funnel path of ESR mindsets into education

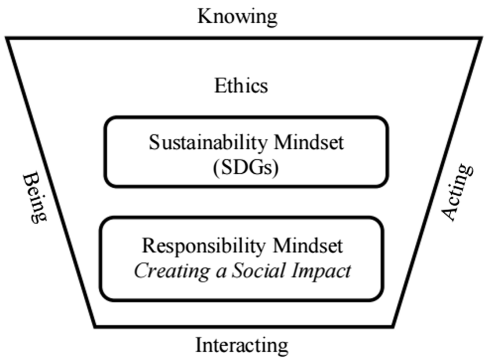
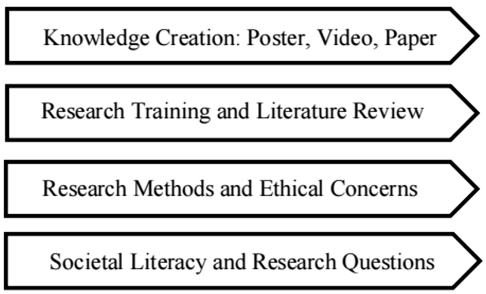


Figure 2
Building undergraduate research experience



a program, express a greater understanding of the impact and value of research on practice and their future careers. In terms of learning to conduct research, modules focused on developing research skills have the most impact when students can apply their skills in a real-world context and on time.

Ensuring every student can participate in research addresses implicit bias and educational inequity. Several university faculty members tackled this issue by developing alternative methods to involve all students in research and extend these educational benefits to a larger number of individuals [34]. This inequity of traditional research experiences may be addressed by what is called a course-based undergraduate research experience (CURE). There are two main categories of CUREs: "network" and "independent". In a network CURE, faculty often receive training alongside individuals from other institutions to implement a CURE based on an established structure [35]. Its primary goal is to support networking and resource-sharing among faculty using the CURE as a pedagogy. In contrast, an independent CURE typically arises from a faculty member's research interests or discipline.

7. Digital Scholarship

Over the past few decades, approaches and computational and multimodal approaches to research have empowered learners to explore creative ways of investigation, embrace new methodological approaches, and scrutinize information in innovative approaches [36]. These approaches, known as DS, emphasize the importance of an open model for scholarly communication, a new teaching and learning approach, and a research style.

DS introduces new forms of academics' professional practice linked to the changing cultural, social, and working context of the digital age [37]. It refers to the research and teaching facilitated by digital technologies, as well as the utilization of these technologies to explore and address inquiries in innovative manners. It encompasses a wide range of research tools and mediums, such as the Internet, emails, blogs, posters, portfolios, videos, data visualization and manipulation, metadata generation, and digital publishing.

As a communication model, the use of posters and videos has revolutionized the way we learn by providing an interactive experience that goes beyond just conveying information. Educational videos offer pedagogical value by presenting knowledge consistently and attractively, making it suitable for in-class, blended, and online learning. It entails the instructor and student collaborating on solving an open-ended problem, probably related to a case or project that is new to both [38].

Incorporating video creation into case studies or projects can be an extremely effective way of creating and translating knowledge and engaging learners. The students may produce and present a video in the class that should include the project research questions and possible generated ideas. The video may include text, figures, pictures, animation, voice, and/or music. It is recommended to use a conversational, enthusiastic, and debate style to enhance engagement [39].

DS involves more than using digital technologies for research, teaching, and collaboration. It includes the open values, ideology, and ability of technologies derived from peer-to-peer networking to benefit both academic institutions and society. Undoubtedly, the fast evolution of digital technologies facilitates new patterns of research, forms of collaboration, and channels of publication. DS adopts novel research questions without limiting approaches, resources, and disciplines, in any kind of endeavor.

8. Conclusions

Teachers can help students develop awareness of "professional social power consciousness" by encouraging them to understand their social responsibilities and opportunities. The content taught in classes can influence how students perceive responsibility, but the challenge lies in the deeply ingrained cultural nature of this education. To address this, it is necessary to shift towards ER, which involves rethinking academic discourse beyond just updating or explaining content and instead focusing on how students can learn to change it. A good starting point is to prioritize student learning by offering ER opportunities that place students at the core of the learning experience. This participatory and transformative task begins with self-learning through reading, using online resources, discussion, and attending conferences. Transformation often requires innovative practices that emerge through interdisciplinary research and updated pedagogical methods. These practices expand the socio-technical-minded prospects of ethics education. Participants, including teachers, need to be passionate and comfortable discussing ethical and social responsibilities in their environments, recognizing the interconnectedness of their work with other professions and the large society.

Ethical Statement

This study does not contain any work with human or animal subjects performed by the author.

Conflicts of Interest

The author declares that he has no conflicts of interest to this work.

Data Availability Statement

Data sharing is not applicable to this article as no new data was created or analyzed in this study.

Author Contribution Statement

Riadh Habash: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data Curation, Writing – original draft, Writing – review & editing, Visualization, Supervision, Project administration.

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