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Embedding Ethics Throughout a Master's in Integrated Engineering Curriculum*

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The New Model Institute for Technology and Engineering (NMITE) in Hereford UK is a higher education start-up established to deliver a new age of engineering education. Because humanity's pressing problems are inherently interdisciplinary, NMITE's first degree, the Master's in Integrated Engineering (MEng) integrates conventionally separate strands of engineering and goes still further – integrating engineering with other disciplines such as arts, humanities, business, and ethics. The intentional and strategic process by which the course content was developed enabled the creation of an ethics curriculum that maps onto and is embedded within each of the MEng's 27 engineering modules. NMITE's ethics curriculum has several distinctive components including an ethics spine approach that is scaffolded according to stages of ethical learning development and is embedded in problem-based learning pedagogy. This paper will describe the ethics interventions within NMITE's MEng curriculum and will present autobiographic and self-reflective data from a pilot study of trial learners that contributed to an iterative process of improvement and acted as a guide to decision-making. NMITE's thorough and robust approach to embedding ethics within and throughout its Master's in Integrated Engineering has the potential to enable engineers to promote social responsibility and sustainability, to fulfil their public duty, and to engage in lifelong learning and reflection.

Keywords: integrated engineering; engineering ethics education; ethics pedagogy; curriculum development

1. Introduction

In the past ten years, the movement for rethinking and reforming engineering education to better incorporate the social, environmental, and ethical contexts of engineering has been complemented by broad global initiatives like the UN's Sustainable Development Goals, and the National Academy of Engineering's Grand Challenges which are formulated around "sustainability, health, vulnerability, and the joy of living" [1]. Meeting these priorities requires an ethical approach to engineering practice, so academic and professional institutions as well as individual engineers have recognised the need to embed more comprehensive ethics learning within engineering education [2–4]. This recognition has spurred efforts around the world to more effectively integrate ethics across engineering curricula, which range from small-scale interventions at the lesson or module level to large-scale overhauls of programmes or accreditation requirements [5].

With the founding of an entirely new engineering institution, the New Model Institute for Technology and Engineering (NMITE) in Hereford, UK, the opportunity arose to create from scratch an intentional and holistic approach to embedding ethics throughout an entire degree programme, the Master's in Integrated Engineering (MEng). The MEng was created with the philosophy that engineering innovation requires a wide variety of perspectives from the world beyond STEM. This ethos of weaving technical and non-technical considerations together enables a logical and natural way for ethics to become central within, rather than tangential to, engineering learning. The MEng's spine of ethics learning appears across the programme and is aligned to the UK's Frameworks for Higher Education Qualifications (FHEQ) Levels. Because the MEng is a combined Bachelor's/Master's degree programme, it comprises FHEQ Levels 4–7, Level 4 being equivalent to undergraduate first year and Level 7 to Master's-level.

This paper describes NMITE's initial approach to ethics education within and throughout the MEng and provides three contributions to literature on integrating ethics throughout engineering curricula: a model of an ethics spine curricular approach, a method for integrating engineering ethics education at the graduate level, and an opportunity to study systematic integration. NMITE welcomes its first students in September 2021, and via the institutional quality assurance processes of review and reflection, these initial plans will be evaluated and improved upon.

2. About NMITE and the MEng

NMITE is one of several higher education start-ups being established in the UK and was founded to address the need for more engineering graduates, and specifically the need for more diverse, creative, and innovative engineers. These founders believed

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that the established and accepted model of educating engineers is not as effective as it needs to be in order to address humanity's most pressing problems. To achieve these goals, NMITE developed the MEng as its first and flagship programme. This section describes NMITE's development and the MEng's distinctive curricular structure and pedagogical features.

2.1 Institutional Background

NMITE is located in the UK county of Herefordshire, where the government has designated 32 districts as "Low Super Output Areas" in terms of children's and young people's education and skills; indeed, it is also one of the only counties in England without a university [6]. Thus, NMITE's founders were spurred by a strong agenda of justice in terms of social, economic, and educational "levelling up." Widening participation in engineering is also at the forefront of NMITE's mission, not only for people from social and economic backgrounds typically less likely to become engineers, but also in terms of closing the gender gap in STEM. Additionally, an ethic of place-based learning and being rooted in the community was central to NMITE's institutional and curricular design. This is evident in operational decisions such as making use of existing facilities near the city centre rather than constructing a purpose-built campus, but this ethic is also crucial to the practice of using industry and community partners for the learning provision in ways described below. NMITE's vision also responds to industry calls to develop "work-ready" graduates who are broadly prepared for the kinds of complex engineering projects that require a wide range of professional skills and behaviours including teamwork and creativity [7].

During the development of the MEng, NMITE's academic leaders were inspired by global exemplars including educational institutions like Swinburne University of Technology (Australia) and Quest University (Canada), the values of organisations like Engineers Without Borders, the Service Learning and Corporate Social Responsibility movements, and the use of a student co-design year as pioneered by Olin College (USA). These efforts have enabled NMITE to emerge as an innovator in engineering education, recognized within the UK for its new approaches to curriculum and pedagogy and globally as a "place to watch" in engineering education innovation [8, 9].

2.2 NMITE's Curricular Structure and Pedagogical Approach

The MEng is designed so that students can achieve a Master's degree in three years and is therefore an accelerated programme of learning where modules are delivered 46 weeks a year in a sequential and block style. There are four types of modules: Toolboxes (focused on liberal arts and professional skills), Engineering Sprints (focused on the technical topic areas of Electronics, Dynamics, Control, Flow/Heat, and Materials), Community-Based Challenges (focused on design and prototyping), and Advanced Projects at FHEQ Levels 6 and 7 (a combination of individual projects and the broad subject areas of Health, Security, Energy, and Infrastructure). Modules are either 2 or 3.5 weeks in duration and are divided into "Clusters" of learning which are meant to integrate conventionally separate strands of engineering as well as integrate engineering with disciplines such as art, business, and rhetoric. Indeed, Liberal Arts components comprise nearly 30% of the programme, and in the Toolboxes, these liberal elements are explicitly intertwined with technical topics like CAD and Metrology. Thus, the MEng in Integrated Engineering is truly *Integrated*, and at the heart of integrated engineering is inter- and multidisciplinarity.

Interdisciplinarity has been recognised as a high-impact pedagogy because of its ability to cultivate thematic and collaborative learning, to embed communication, ethics, and numeracy skills across the curriculum, to encourage community-based learning, and to encourage capstone learning experiences [10]. As Balsamo and Mitcham acknowledge, this recognition and reinforcement of different modes of knowing is an ethical approach to learning, and the negotiation of and crossing between disciplinary boundaries requires ethical habits and the embodiment of virtues such as generosity, humility, and integrity [11]. Additionally, modules which require interdisciplinary collaboration between faculty, as those in the MEng do, have been shown as sites where ethical behaviour is modelled via the give-and-take of the team-teaching environment [12]. Students taught by interdisciplinary faculty teams have been shown to value the opportunity to observe the multiple perspectives of their teachers as *they* made ethical decisions, which then improved the students' cognitive skills [13].

Problem-based learning [PBL] is one pedagogical approach to interdisciplinary learning; it also models how engineers work in practice [14, 15]. Therefore, NMITE has adopted PBL throughout its Engineering Sprints, Community-Based Challenges, and Advanced Sprints. All learning activities in these modules, including seminars, practical tasks, and assessments, are centred around a real-world challenge posed by an industry partner or community organization. PBL's emphasis on the context of problems has been shown to cultivate critical thinking about ethical aspects of engineering by revealing its social and environmental contexts [16]. In NMITE's iteration of PBL, ethics is therefore core to learning because effects on stakeholders and users are made visible to students and have immediate, real-world impact. For instance, a planned challenge in a Dynamics module is to redesign a playground in the community; students will have to make choices about materials and design that are rooted in ethical decision-making in order to mitigate concerns about health, safety, and the environment. Additionally, all challenge work is undertaken within teams, so that by the end of the MEng students will have worked in at least 24 teams on 24 different engineering challenges. Teamwork requires a social contract approach to learning in terms of being accountable to others, taking on different team roles, and learning how to thrive in both leadership and followship positions [17]. As students undertake each challenge, they are prompted to regularly reflect on their work as individuals and as a team, promoting the critical analysis required of ethical action and motivation in these professional scenarios [18].

Besides having an embedded ethics component within the MEng curriculum, NMITE's pedagogy is student-centred and designed to promote a more inclusive learning environment [19]. Students have a "home base" in a Studio, where seminars, tutorials, team project work, practical tasks, and mentorship occur for each 25-student class. Studios are designed to be used for the entire 8-hour working day and are flexible and versatile, easily modified according to the needs of various learning activities. They enable the coaching and mentoring function of educators because a higher level of interpersonal engagement occurs when everyone is in the same space for an extended period of time, thus building a trust relationship between educators and students [20]. Comprising elements of active learning, flipped classroom, and studio-based learning, NMITE's pedagogy is one that enables educators to act as guides, responding and adapting to individual learning styles and needs.

Finally, NMITE has adopted an approach of using only authentic assessments; that is, students are assessed on content that requires them to demonstrate the same competencies that engineers demonstrate in professional practice. The MEng uses 16 different assessment types ranging from specifications and project plans to artefacts, media outputs, and presentations. NMITE believes, as Janesick shows, that authentic assessment is a fairer way to evaluate students than traditional exams [21]. Not only are these authentic assessments more inclusive to various learner types and provide opportunities to succeed in a variety of modalities, but they mitigate the culture of policing that surrounds the taking of exams, thus removing punishment from the discourse surrounding assessments [22].

3. Integrating Ethics – Preliminary Activities

A small group of academics worked for over four years to write and develop the MEng programme, beginning with high-level programme learning outcomes and cascading down to the level of learning plans for each module. This interdisciplinary team comprised people from around the world with expertise in both higher education and industry, and included a former university Pro-Vice Chancellor with a background in materials science and engineering education, an atmospheric physicist who worked in the airline industry on mitigating emissions, an educational scholar with a prior career in automotive and agricultural engineering, and a humanities educator specializing in integrating the liberal arts in engineering education.

The programme and curricular development activities included developing an authentic assessment strategy and process, a studio- and problem-based learning pedagogical approach, and methods for delivering mathematics, communication, and ethics instruction alongside technical content. NMITE has adopted engineering ethics education approaches common to the broader field of using applied and professional ethics to "act as a bridge between theory and practice" [23, p.3]. Its pedagogy is rooted in the four-component model of moral psychology developed by neo-Kohlbergian scholars [24]. Research into learning outcomes developed by scholars working in ethics across the curriculum initiatives also informed NMITE's strategy of ethics integration [25]. The result was a proposal for an ethics framework that highlighted specific modes of ethics learning at each curricular level.

3.1 Ethics Learning Framework

Because the MEng curriculum is scaffolded and aligned to learning outcomes that are defined at both the module and programme level, it was essential that the ethics learning framework be structured to complement and enhance it. NMITE's curricular philosophy can be seen depicted in Fig. 1.

The Ethics Learning Framework was also influenced by the Royal Academy of Engineering's Ethics Curriculum Map, the overall requirements of the Accreditation of Higher Education Programmes in engineering [AHEP] and written in line with the UK Standard for Professional Engi-

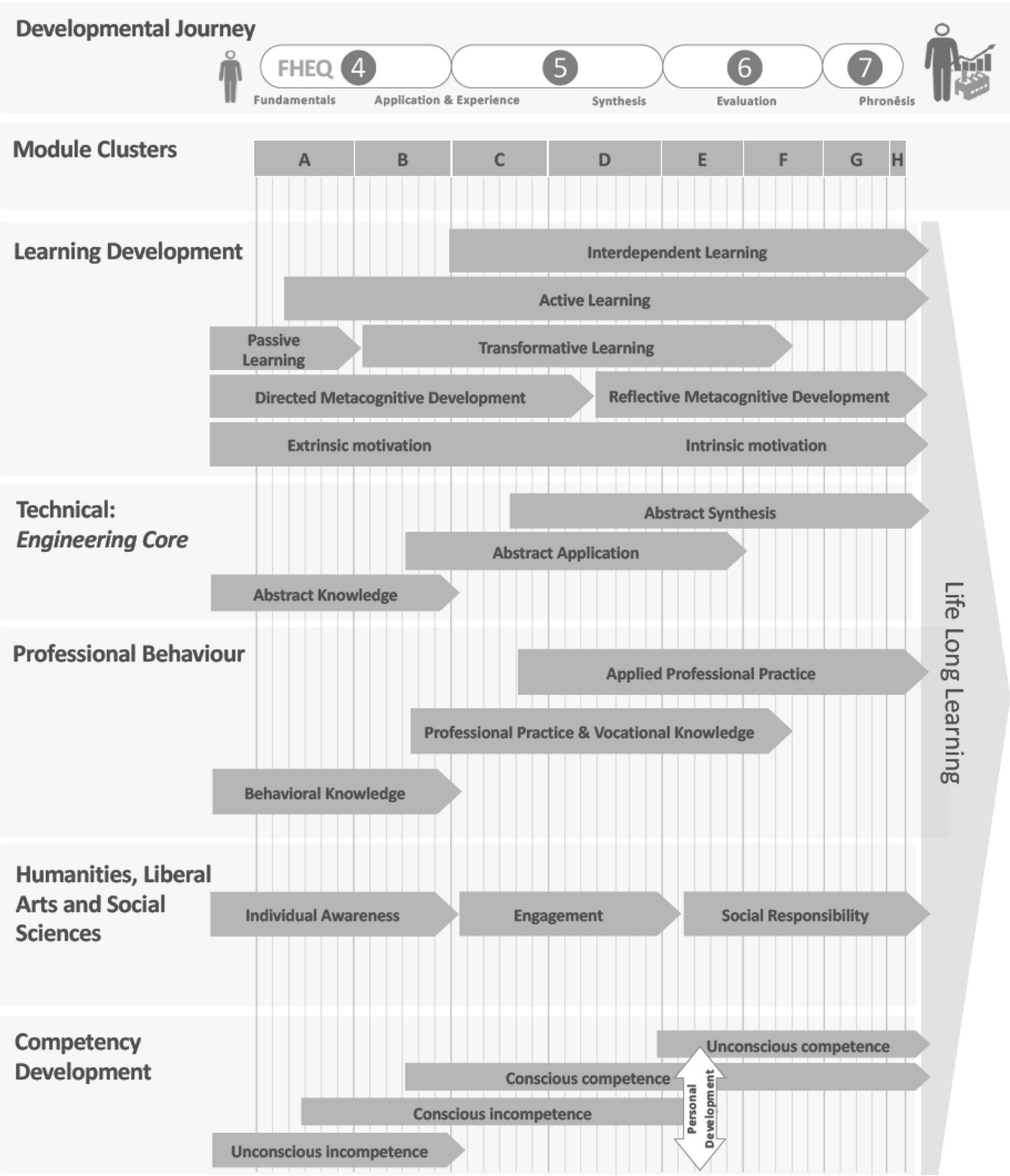

Fig. 1. A visual representation of the interdisciplinary learning components of NMITE's Master's in Integrated Engineering, excerpted from Allan, Hitt, and Rogers [26].

neering Competence [2, 27]. The challenge therefore was to meet all these considerations while also recognising theories on best practices in ethics learning and the recommendations of scholars working within moral education and within engineering ethics specifically.

It has two components: the ethics pedagogy areas and the ethics learning outcomes. These were crafted for the specific context at NMITE which not only includes challenge- and team-based learning, but also the variety of assessment types used at each level. For instance, if students are required to conduct an ethical review of an advanced engineering project in Level 7, they need to have been introduced to strategies for making ethical judgments and given the opportunity to practice ethical analyses at a previous level. These considerations resulted in the framework shown in Table 1.

Table 1. Components of the Ethics Learning Framework in NMITE's Master's in Integrated Engineering

Ethics Pedagogy Areas			
Level 4	**Level 5**	**Level 6**	**Level 7**
Introduce ethical awareness and ethical sensitivity.	Introduce ethical theories and ethical analysis and reasoning.	Introduce ethical judgment and ethical motivation.	Introduce ethics in integrated engineering contexts: policy / environment / business / cultures.
Introduce codes of conduct and professional obligations.	Reinforce ethical awareness and ethical sensitivity.	Apply ethical analysis and reasoning in ambiguous and uncertain contexts.	Reinforce and apply ethical judgment and ethical motivation.
	Reinforce codes of conduct and professional obligations.	Reinforce application of ethical awareness and ethical sensitivity.	Reinforce application of ethical analysis in ambiguous and uncertain contexts.
		Reinforce codes of conduct and professional obligations.	Reinforce application of ethical awareness and ethical sensitivity.
			Reinforce codes of conduct and professional obligations.
Outcomes			
Ethical Sensitivity	**Ethical Knowledge**	**Ethical Judgment**	**Ethical Motivation**
Students will identify ethical issues from the perspectives of a variety of stakeholders (client, manager, etc.).	Students will describe professional norms, principles, and ideals related to their chosen field.	Students will justify an ethical stance.	Students will evaluate viable courses of actions or solutions in response to an ethical dilemma.
Students will recognise ethical dilemmas in engineering.	Students will describe the ethical issues that are inherent in the roles of professional engineers.	Students will analyse ethical dimensions and complexities of a dilemma.	Students will apply ethical principles to the evaluation of strategies for resolving ethical issues.
Students will identify the dilemma when presented with an ethical situation.	Students will identify options for resolving an ethical dilemma.	Students will describe the consequences of a variety of possible solutions to an ethical dilemma.	Students will propose policy relating to ethical questions in engineering.
	Students will apply a Code of Ethics to situations that involve engineers, their clients, and the public.		Students will describe how their value systems inform and influence their professional practice.

3.2 Planning Ethics Integration in Trial Modules

With the pedagogy areas and outcomes in place, ethics integration was tested in two trial modules. These modules were delivered in fall 2019 as a part of a larger effort to trial various aspects of the learning programme as it had been designed over the previous year. The trial modules described here are Introduction to Electrical and Electronic Engineering (EEE1) and Observant Engineering, two separate but linked module types within the MEng. EEE1 is classified as an "Engineering Sprint", a 3.5-week block of learning at Level 4 that students will take within the first 6 months of entry to the MEng. It was tested with a group of six Trial Learners that continued the work of the Design Cohort, 31 young people who were participants in NMITE's co-design year and worked on activities relating to community engagement, learning spaces, and curricular approaches. The Trial Learners had already tested elements of five other planned NMITE modules throughout the prior year, though none of these had explicit ethics content embedded, and were delivered prior to the establishment of ethics pedagogy areas and outcomes.

Observant Engineering is classified as a "Toolkit," a 1-week block of learning that is designed to introduce specific skills that students will use throughout the remainder of the programme, and deliberately integrates technical and liberal elements. When NMITE deploys this toolkit after the trial stages it will form part of a 3-week Level 4 "Toolbox" module called "Making it Happen" which combines learning outcomes in CAD and Engineering Design as well. Observant Engineering was tested with a group of visiting students from the Colorado School of Mines, who had never engaged with the NMITE learning approach but were all familiar with the ethos of learning engineering in context, and all had some previous introduction to ethics concepts.

Referencing NMITE's ethics learning framework, there are two aims of ethics learning in Level 4: to introduce ethical awareness and ethical sensitivity, and to introduce codes of conduct and professional obligations. Following from those aims are these outcomes:

- Students will identify ethical issues from the perspectives of a variety of stakeholders (client, manager, etc.)
- Students will recognise ethical dilemmas in engineering.

- Students will identify the dilemma(s) when presented with an ethical situation.

As the ethics content was planned for the trial modules, it quickly became clear that not all of these aims and outcomes could (or should) be addressed in every Level 4 module (there are nine modules at Level 4), so it was necessary to choose specific elements of ethics learning to introduce within these trial modules. It was therefore decided that the main focus would be on developing the ability of students to recognise ethical issues, and for them to be able to see these issues from multiple perspectives.

3.3 Trial Engineering Sprint: Introduction to Electrical and Electronic Engineering (EEE1)

The challenge set for EEE1 was to build a water-level sensor for a local restaurant that would alert the owner when floodwaters from the nearby river could potentially damage food stores located on the lower level of the building. As is common in such introductory electronics modules, the technical learning comprised elements like circuits, transistors, operational amplifiers, electronic sensors, and actuators. Due to the pressure of testing this large amount of technical content on the accelerated 3.5-week scale, the Module Lead set aside only one hour for a "liberal seminar" in which relevant ethics material could be covered.

A visit from a guest speaker is a common approach to "ticking the ethics box" in some engineering education contexts, and while students may perceive it as a helpful learning experience, some educators question the value of guest speakers in terms of their ability to link professional scenarios with learning outcomes [28, 29]. These events can however be more or less impactful depending on how the talk is pitched, for instance: whether the speaker makes general or specific connections to the technical work of the module, whether they have any knowledge at all of the engineering learning happening concurrently to their talk, and whether students are expected to reflect on or make use of the content delivered in the guest seminar. Thus, the ethics intervention that was tested in the context of an engineering sprint was whether or not a short, one-hour seminar about ethics issues relevant to the challenge would have any bearing on their solution or affect the way that they approached the module challenge, even though the EEE1 module assessments (Specification, Artefact, Tutorial Questions) did not require students to apply any ethics knowledge.

The one-hour seminar occurred when students were well into the technical aspects of designing their sensor, about 2/3 of the way through the module. It was designed as a Socratic discussion framed around the concept of responsibility in three stakeholder areas: to the client, to the other businesses and people located in the same complex that was affected by flooding, and to the environment; that is, whether and how to consider Nature as a moral patient in this or similar cases. Again, because this is a Level 4 module and therefore one of the first times students engaged with ethical considerations as related to their engineering and technology work, they had not yet been introduced to any specific ethical terms, theories, or approaches. Indeed, as indicated earlier, the seminar wasn't even framed as "ethics" but as "liberal studies." So, the goal of the seminar was simply to open up the discussion from the intimate technical details of electrical and electronic engineering required in their challenge to the broader contexts of the solution, through which issues of ethics are embedded. No particular conclusions were drawn at the end of the discussion as to a "right" or "wrong" or "better" or "worse" approach, it was simply an exploration of ideas and concerns that had either not before been considered or had not been thoroughly investigated.

Because of this somewhat non-explicit approach to ethics learning it was unclear whether or not the seminar material would have any impact whatsoever on their work or their solution. However, when the students presented their Artefacts, they commented on the stakeholders, their responsibilities, and had even done, without being required to or trained to, a sort of layperson's ethical analysis of broader environmental issues related to their work. One of the students commented that through the challenge, they could see that they were not just making switches and circuits, but their technical design choices related to the notification system had the potential to protect businesses from financial ruin as well as maintain the livelihood of its owners and workers. This is evidence that even short conversations can have ethics learning impacts, at least at the levels of awareness and sensitivity. However, unlike many cases where guest speakers visit but never return to the classroom, in this case they had knowledge of the technical challenge, understood the learning context, could work with Module Lead on ongoing or follow-up topics, and could even engage in informal discussion with the students later in the module as they progressed through the challenge.

Neil Rogers, the EEE1 trial Module Lead, reflected on the session as follows: "When delivering technical content, [instructors] can sometimes slip into a very narrow field of view and purely address the technical challenges without considering wider impacts – this can end up being technically very satisfying but ultimately could be a waste of time and energy and not satisfying at all! I found these [ethics-focused] sessions critical to ensure that students question what they are doing and why. [They served] to ensure that students are made to stand back and reassess these issues before they are too far into their final design. This then not only brought added context to what they were doing but also improved motivation" [30].

3.4 Trial Toolkit: Observant Engineering

Unlike Engineering Sprints, Toolkit modules do not have a specified challenge. Instead, students engage in seminars, tutorials, tasks, and activities designed to develop specific skills, approaches, and mindsets crucial to engineering work. The aim of the Observant Engineering toolkit is to develop the student's ability and motivation to gather and evaluate information that enables better judgments. In order to achieve this aim, students must understand their own perspectives, values, behaviours, and biases, as well as learn how to use observational strategies and techniques to determine the relevance and importance of historical, economic, social, political, and material factors on decision-making and judgments. One outcome is focused inward, on turning a critical and reflective eye on oneself, and the other outcome is focused outward, on questions of empathy, justice, access, shared public spaces and human experiences. Both of these outcomes relate to the development of ethical awareness and sensitivity [31, 32].

In-class activities focused on recognizing cognitive bias, practicing the use of multiple senses, and seeing common objects from alien perspectives, all of which were designed to heighten self-awareness. These were paired with the City as Text™ methodology, which emphasizes exploration, analysis, interpretation, and evaluation of the built and natural environment [33]. Place as Text is a pedagogy developed and disseminated by the National Collegiate Honors Council in the USA and uses key components of mapping, observing, listening, and reflecting through writing. This has previously been used successfully in an integrated first-year engineering design and ethics course as a way to emphasize engineering-in-context and community impact of design decisions [34]. In Observant Engineering, students did two Place as Text walkabouts in Hereford; one was on the first day and acted as an initial introduction to the city and one was near the end of the Toolkit in order to extend their observational learning to another part of town. In both, students were prompted to consider questions that have an ethical underpinning, such as what might be missing and thus excluded from a space, or what it might be like to experience the place from another person's perspective. Observing the people and their interactions within the space heightens an appreciation of everyday ethics such as curb cuts that enable pushchair access or street crossing lights that increase the safety of less mobile citizens as they navigate the city [32].

These explorations fed into the students' final assessment for the module, which was to deliver a presentation in which they described the design flaws that they found within the city centre. Instead of leaping to proposed solutions, keeping the focus on problem definition requires an emphasis on awareness and sensitivity to issues that often, if not always, have roots in culture, identity, and aspects of daily life [35]. In the presentations, students were assessed on two components: how they used and applied observational skills to diagnose a gap in products, processes, or services within the city, and their analysis and reflection on their observational learning journeys. On the whole, students demonstrated the ability to turn a critical eye on themselves as observers, having become aware of their own biases, values, and perspectives. All students scored above the pass mark for the rubric criterion measuring this area on the final assessment. They scored even higher on the rubric criterion measuring their ability to use observation to define a problem, and in doing so focused intensely on an ethic of accessibility and safety, and even employed elements of ethical reasoning as they made the case for the gap they had diagnosed. Students still struggled to look beyond their own particular age group, background, and needs, making it clear that at some point within Level 4 ethics learning, a deliberate shift needs to be made from a focus on the self as moral patient to an awareness and sensitivity to ethical considerations of others not like them. However, since half of the activities within the module were explicitly designed to spur self-analysis and self-reflection, this focus was expected. And indeed, the experience of group observation, discussion, and interpretation that followed the City as Text™ explorations indicated that students were taking first steps in imagining other ways of being in the world and other experiences, which is key to achieving the outcome of identifying ethical issues from the perspectives of other stakeholders.

4. Findings, Reflection, and Action

These ethics activities were useful in achieving the aims of Level 4 ethics learning relevant to two trial modules. However, without an instructor framing the issues with an ethical lens, the ability of students to recognise and identify situations as having ethical components may diminish [29]. As Génova and

González show, guided discussion during and after these sorts of activities is one way to make these components visible and explicit to students [36]. These Socratic discussions can illuminate the ethical underpinning of the issues that students have identified in the course of their class activities and explain the things they have observed and considered from an ethical perspective. In other words, ethics learning will not happen automatically: students must be guided toward identification and recognition of ethical issues. But this is made easier if they have personally experienced something that can then be identified and recognised as "ethics" rather than learning about ethical concepts abstractly or at second-hand [37]. Additionally, it is clear that repeated interventions like these kinds of activities and discussions are key to effective ethics learning because each student develops insights at different stages and in different ways from others [38]. It cannot be assumed that one dose of ethical awareness activity in one module will carry forward in the same way for everyone.

Because of the insights gained after running the trial modules, it became clear that the ethics curriculum in the MEng would have to be made much more deliberate and explicit, at least to instructors. In a fully integrated programme where there is not a specific module devoted to ethics, this is the only way to ensure that key components of ethics education are not lost as students advance through the degree. As Keefer and Davis explain, "an ethics curriculum needs to be carefully crafted, appropriately aligned, and adequately assessed in order to provide opportunity for an iterative process for reflection and adjustment" [39, p. 88]. Two crucial components are required for success: (1) someone to plan, deliver, and monitor that ethics instruction and (2) cooperation of all other Module Leads in allowing that material to be integrated into their technical modules. While this may be difficult in many programmes due to devolved responsibilities or oversight, NMITE had the opportunity to integrate this in the MEng as we started from scratch and worked as a small team to lay the groundwork.

In many ways this style of ethics learning could be similar to the communication and mathematics learning that was already embedded throughout the programme via the assessments. Based on work done in Writing Across the Curriculum efforts, and learning from the burgeoning movement for Ethics Across the Curriculum, NMITE's Ethics Across the MEng Map was created so that we could see what ethics outcomes and associated knowledge and learning activities mapped onto the individual MEng modules. Specific ethics content is integrated within engineering modules and is designed to support the real-world challenge forming the basis of the module's learning activities. This content is also mapped to the Ethics Learning Framework. An example from FHEQ Level 5 (equivalent to undergraduate second year) can be seen in Table 2.

Additionally, ethics content was further broken down into three categories of relevant ethics learning: (1) professional situations (conflicts of interest, bribery, reputation, etc.), (2) ethical issues (privacy, sustainability, EDI, etc.), and (3) moral knowledge (justice, care, duty, utility, virtue, etc.). These content categories will be used to achieve the moral pedagogy scaffolded across the different curriculum levels described above. While it would be impossible to address every piece of content, a broad cross-section of each category could be covered, and in some cases the opportunity would be there to repeatedly reinforce certain areas as a student progresses through the programme. Indeed, this

Table 2. Examples of Ethics content integrated into NMITE's MEng modules at FHEQ Level 5

Module Title	Module Challenge	Ethics Pedagogy Area	Ethics Outcome	Ethics Integration Content
Electromagnetics in Engineering.	Flooding Communications System.	Introduce ethical theories and ethical analysis and reasoning.	Students will describe the ethical issues that are inherent in the roles of professional engineers.	Introduction to Environmental Ethics: Stakeholder Mapping.
Structural Materials and their Innovation.	Equipment Malfunction.	Introduce ethical theories and ethical analysis and reasoning.	Students will identify options for resolving an ethical dilemma.	Introduction to Ethical Analysis with consideration of a Leaking Underground Storage Tank.
Control Systems.	Linear Control System.	Reinforce codes of conduct and professional obligations.	Students will apply a Code of Ethics to situations that involve engineers, their clients, and the public.	Codes of Ethics relevant to Robotics and AI.
Manufacturing Systems Optimization.	Improving a Workstation.	Reinforce ethical awareness and ethical sensitivity.	Students will describe professional norms, principles, and ideals related to their chosen field.	Ethical Duties and Corporate Social Responsibility.

material is similar to what would be found in the content of a standalone engineering ethics module but spread across and integrated within the entire MEng [40].

Consultations were then held with each of the Module Leads. The timing of these consultations was critical because the discussions occurred at the same time as or prior to when they were developing the learning plans for the modules, ensuring that the level and aim of the activity was appropriate to both the technical challenge and the ethics curriculum map. These discussions not only helped us know and understand what students would be learning in prior modules so that the ethics learning could be coherently built upon and further developed, but they also helped the Module Leads understand the importance of the timing of ethics interventions and the ways that those activities could feed into their own learning outcomes and assessment aims. Types of teaching methods will include those commonly found in engineering ethics lessons including codes, heuristics, case studies, debate and discussion, and games [41]. Crucially, the authentic assessment types discussed above also easily enable ethics learning to be integrated.

Also key to the success of this ethics curricular integration is the content of the Advanced Engineering Sprints and Bachelor's and Master's capstone Projects in Levels 6 and 7, which are the site where all prior learning comes together, technical or otherwise. For ethics it will be no different. The assessments and outcomes of these modules are written in a highly interdisciplinary way that emphasizes social, economic, and environmental impacts of engineering and that teases out and highlights the ethical underpinnings of these impacts. Too, in these advanced modules we will be able to bring in increasing levels of ambiguity, uncertainty, and complexity that are inherent in real-world problems and provide the opportunity to reveal not only a student's ethical decision-making skills, but also to enhance their motivation to act and engineer ethically [42, 43]. In this way, ethics becomes explicit at graduate-level engineering work.

5. Challenges and Limitations

NMITE recognizes that despite the promise of enacting and sustaining such a programme of ethics learning, there are several ongoing challenges to overcome in order to ensure its success. First, this comprehensive approach is self-imposed, so the reality is that it could be self-destroyed as institutional or instructional priorities shift. Fortunately, new accreditation standards via the 4th edition of AHEP provide support as well as a benchmark for the expectations of including this content across the curriculum. AHEP 4 revisions should also help work against the challenge that is usual in every engineering programme: technical knowledge and skills are sometimes prioritized at the expense of other learning when it is perceived that there isn't enough time to thoroughly address those [27]. However, the adoption of a combination of approaches discussed above which include micro-insertion and authentic assessments should help avoid that barrier [44]. Additionally, there is much to consider in terms of the methods by which we would evaluate the success of this structure of ethics learning: for instance, should this be done via student assessments that are set within the programme, via a separate survey instrument, or some other way? There are still many unanswered questions about best methods of evaluating ethics learning and what we can learn from those assessments [45]. One thing that is possible at NMITE without excessive burden to the students is to identify areas within assessments where explicit ethics outcomes can be measured. Again, this will require the collaboration of Module Leads and an ethics education coordinator over a long-term period.

Besides the curricular challenges are those rooted in the different perceptions of the purpose, value, and expectations of ethics instruction among various stakeholders [46]. Additionally, the value of integrating ethics in technical courses is often preached more than it is practiced [47]. And even within NMITE's culture where educators are hired because of their desire to be a part of an integrated programme of learning, there are various levels of enthusiasm among academics to adopt these regular ethics interventions. Naturally, every Module Lead believes (especially on a block- and accelerated-delivery timetable) that all the hours are needed to focus on their specific learning outcomes. Fortunately, the vast majority of NMITE educators also see that ethics and communication are embedded within their technical learning outcomes, so that it is impossible to succeed at one without the other.

A final challenge is that this type of ethics curriculum requires specific expertise and motivation to establish. Besides the engineers being willing to bring in the ethics content, the ethics instructors have to be willing to work within the framework of engineering education, which is not necessarily easy or natural for each group. It's a lot "easier" to have a siloed, standalone engineering ethics course where the professor has total ownership of and is only accountable to their own outcomes and departmental expectations, rather than integrating their work across dozens of modules and having to work within the context of another instructor's disciplinary content. For this reason, NMITE's ethics curricular plan is an exercise in diplomacy as much as anything else. Ultimately, we hope to adopt a "train the trainer" approach for some of this content so that the engineering educators develop the competence and confidence to deliver the ethics learning appropriate to their modules. Indeed, this is a lifelong learning exercise for the professors as well. Haws testifies to his own experience in this area: "Given that I have a responsibility to ground the ethical understanding of my students, I first need to absorb that understanding myself. This takes time and study, requires a divergent mind, and will call for some rather painful adjustments in the way we train, select, and evaluate our engineering instructors" [5, p. 228]. Thus, the institution as a whole also bears some responsibility to ensure this model is effective, by providing professional development support for faculty, which can be out of the control of individual educators.

In some respects, planning the ethics integration across the entire MEng has probably been easier than it would be to retroactively integrate ethics into an existing curriculum. NMITE's founding faculty were all aligned in their belief that ethics is essential to engineering learning and practice, and were willing to work with liberal studies educators to ensure that curricular plans provided a best-case scenario for effective ethics instruction. That said, these activities would be replicable in other institutions given the time, encouragement, and will to enact them at a strategic as well as practical level.

Crucially, NMITE's objective is not to simply achieve the MEng programme learning outcomes, but rather to nurture a culture of ethical engineers and of ethical engineering practice. After all, in terms of ethical motivation and character, we want to instil social responsibility and civic engagement as graduates move on to their careers [48]. This is why ethics education must not stop with Level 7 Master's students, and it must not be limited to a professional development workshop here and there across decades of engineering practice. As Haws wrote in 2001, "Learning, and then passing along technical skills and knowledge is relatively easy. Becoming morally grounded takes much more time. To enable a sense of moral grounding in someone else requires devotion. These are not the kind of learning objectives achieved in a few seminars, and most educators in this area recognize that ethics, as a subject, requires a lifetime to truly master" [44, p. 228].

6. Conclusion

This paper has described the development of a holistic, scaffolded approach to embedding ethics across a Master's in Integrated Engineering at a new higher education provider. This was accomplished through a process of identifying learning outcomes within ethics education, creating an ethics learning framework that aligns with institutional curricular design, and mapping ethics pedagogy to align with aims and outcomes of technical engineering modules. The ethics integration approach was then tested via two trial modules, and revised based on insights gained during the testing process. Beginning in September 2021, it will be enacted with a Pioneer Cohort of students.

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