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EMBEDDED ETHICS IN PROBLEM DESIGN

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Introduction

The importance of ethics in engineering has emerged in codes of conduct at national and international levels, including codes of the National Society of Professional Engineers (NSPE), the European Federation of National Engineering Associations (FEANI), the Institute for Electrical and Electronic Engineering (IEEE), and the Accreditation Board for Engineering and Technology (ABET). When such codes of conduct and standards are incorporated into engineering education practices, they inevitably differ in emphasis. Thus, there is a need for a collective and global vision of ethics in engineering education and research (Martin et al., 2023). Moreover, the ethical codes used by organizations like the NSPE are often expressed negatively, using terms such as 'not' and 'only' and might be referred to as 'preventive ethics' (Harris, 2008, pp. 153–154).

Osbeck et al. (2018) have highlighted the risk of neglecting the contextual, situational, and knowledge-related aspects of ethical competence. The contextual aspects relate to what Herkert (2001) has termed macro-ethics, which apply "to both the collective social responsibility of the engineering profession and to societal decisions about technology" (Herkert, 2001, p. 404). Conversely, micro-ethics relate to individuals' ethical decisions and the engineering profession's internal relationships (Herkert, 2001). Combining these two definitions provides a comprehensive approach to ethics in engineering education.

Bringing such a comprehensive understanding of ethics into teaching will increase the complexity of integrating ethics into engineering education. Adding to this complexity is the constantly changing nature of the engineering field's ethical concerns. Although there has been an increasing focus on including context in engineering education, this is not a typical consideration in traditional engineering ethics (Barry & Herkert, 2014). According to Elliott and June (2018, p. 32), an open question is whether ethics education meets students' needs considering the ethical dilemmas of a changing world. Meeting these needs requires dynamic educational models that embrace contextual and situational requirements, as well as a flexible curriculum that allows students to reflect on and react to current societal challenges; for example, exploring the use and prospects of emergent technologies like artificial intelligence (AI) or the grand challenge of fostering more sustainable societies.

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There are several dimensions of problem- and project-based learning (PBL). One dimension considers how much influence students have on their own learning processes. In a teacher-driven PBL environment, the problem is designed for students, whereas in a student-driven environment, students identify the problems their work will address within a given framework (Kolmos & de Graaff, 2014; Kolmos et al., 2009). According to Barry and Herkert (2014), PBL can be viewed as an alternative to case-based instruction, the most common pedagogical method in engineering education. Yet, these two approaches can be mutually supportive rather than contradictory. Indeed, case studies can help to provide a nuanced understanding of what a problem is before addressing a problem as a part of PBL (Børsen et al., 2021). Within its various implementations, PBL can include a student- or learning-centered approach, where problems are ill-defined; lectures may support but do not determine student projects (Kolmos & de Graaff, 2014). Together with the intended learning outcomes of the curriculum, the perceived relevance for society also has implications for the types of problems addressed in PBL (Habbal et al., 2024).

Some of the barriers in engineering education include what Newberry (2004) refers to as the ‘technical gravity’ of the curriculum. In contrast to such technical gravity, a curriculum can extend the technical aspects of education by integrating contextual aspects and issues of student responsibility. However, an open question involves how this integration occurs and becomes visible through the formal curriculum.

In this chapter, we seek inspiration from a PBL environment to characterize the intended learning outcomes of formal curricula. We assume that ethics in a PBL approach is not necessarily explicitly stated but indirectly embedded in the problem design and the problem types that students work with. We point at possible enablers of ethics in PBL, and with this outset, the objective is to exemplify ethics embedded in a PBL curriculum.

Positionality

All three authors have a background at Aalborg University, though following different trajectories, from a background in social science to engineering and engineering practice. However, as engineering education researchers we all share a common interest in adapting engineering curricula to meet the challenges of the twenty-first century, including interdisciplinary competences and understanding the variation related to different contextual situations. As researchers at Aalborg University, a university established in 1974 with a problem-oriented and project-organized approach to teaching and learning, the scene for researching forms an excellent base for interdisciplinarity in combination with engineering education. From the beginning in 1974, the university’s pedagogy was based on German critical theory developed in the late 1960s and 1970s. During this period, several reformist universities were established with the idea that universities should develop a socially oriented perspective and integrate societal problems in their curricula. This created entirely new challenges for academia, as it represented a shift from a theoretical academic approach to a more societal approach in terms of market orientation and critical societal discourse. These early developments toward a new university culture would go on to serve as examples for the development of many other universities, in terms of the emphasis on competencies and skills, from the 1990s onward. In the 2010s, the university began working to integrate the United Nations (UN) Sustainable Development Goals (SDGs) in students’ learning. The case of Aalborg University is special, as the critical pedagogy was grounded and practiced before integrating ethics into engineering education became mainstream.

As researchers we work from a pragmatic view following a problem-based approach integrating the theories and methods needed to address the specific problem at hand and to point to appropriate solutions. In other words, we carry out problem-based research. In this chapter, we have set out to address the problem of ethics being implicit in a PBL curriculum.

Ethics from a PBL perspective

Beyond the explicit mention of ethics in engineering education curricula, the theoretical framework presented in this section attempts to conceptualize potential enablers of ethics. The specificity of PBL is that the problem is the *point of departure*, whereas the *problem design* and the *problem type* are the primary focus of the following. This is not to say that ethical considerations do not happen in the problem-solving phase, but problem-solving is seen as a continuous interaction and contribution to the problem design, which is iteratively altered through the PBL process.

Problem design in a PBL environment

De Graaf and Kolmos (2003, 2007) have presented three approaches embedded in a PBL framework: the learning, the content, and the social. The learning approach emphasizes that learning *starts from* and is *organized around* problems, which are exemplary for societal practices and change. The content approach concerns the disciplinary, interdisciplinary, and exemplary content, meaning that the problem can call for the combination of different knowledge combinations and is exemplary for the intended learning outcomes. The social approach embraces team-based, participant-directed aspects and considers learning a social act. Concerning participant-directed learning, it is important to note, though, that a PBL curriculum design must allow some space and freedom for the students to have the possibility to identify and analyze problems (Habbal et al., 2024). Thus, the problem is grounded in a careful problem design process, which ensures that the problem and the way that the students address the problem matches the conditions of the abovementioned PBL approaches.

In this regard, Hung (2006) has developed the ‘3C3R model,’ a comprehensive model of problem design components for faculty to use. The three core components of this model include content, context, and connection (the ‘three Cs’). Connections “interweave (1) the concepts and information within the conceptual framework, and (2) content into context” (Hung, 2006, p. 61). The processing components include researching, reasoning, and reflecting (the ‘three Rs’), which concern the learners’ processes and problem-solving skills. Based on this framework, Hung (2009) presents a nine-step PBL problem design model intended to “help instructional designers and educators use the 3C3R PBL problem design model” (Hung, 2009, p. 123). The nine steps are as follows (Hung, 2009, p. 123):

1. Set goals and objectives
2. Conduct content/task analysis
3. Analyze context specification
4. Select/generate PBL problem
5. Conduct PBL affordance analysis
6. Conduct correspondence analysis
7. Conduct calibration processes
8. Construct reflection component
9. Examine intersupporting relationships of 3C3R components

In his later work, Hung (2019) highlighted the affective aspects of problem design and further developed the second generation of the 3C3R PBL problem design model. This added a third class of components related to the affective and social aspects of learning (Hung, 2019); namely, problem difficulty, teamwork, and affect. Hung's comprehensive work – based on the interaction of core, processual, affective, and social components – seeks to inspire educational designers to design problems.

Holgaard et al. (2017) have also presented a framework to support students in designing their own problems as part of the PBL process. Based on Hung (2006) and others, five steps of problem design were defined (Holgaard et al., 2017, p. 1077):

1. Relating to a theme to clarify boundaries (e.g., provided by the intended learning outcomes)
2. Mapping the problem field to screen for opportunities, challenges, and unknowns
3. Narrowing down the problems to select one problem for further analysis
4. Analyzing the problem and contextualizing to pinpoint specific motivations for action
5. Formulating the problem to create the bridge between the problem analysis and problem-solving process

It should be noted that the analysis of the problem context is emphasized in both process models described above for the design of problems. In this regard, Holgaard et al. (2017) further relate problem analysis to other types of analyses, including analysis within the fields of sustainability and ethics, stakeholder analysis, actor analysis, and constructive technology assessment. Furthermore, Holgaard et al. (2017) conclude, based on an empirical study of students' experiences as problem designers, that a conceptual model for students' problem design activities should draw attention to "the process of moving from a broad theme to an initiating problem and starting up a problem analysis" (p. 1083).

Regardless of the steps taken in the problem design process, and whether the students 'own and direct' the problem design process, the type of problem that emerges through the design has implications for the complexity of the problem design process.

Problem types and their implications for problem design

Holgaard et al. (2017) describe problem design as an exploratory process that considers the existing situation as well as arguments and possibilities for change. From this perspective, a problem can be understood as a discrepancy between what is and what could be. Jonassen (2011) characterizes problems based on the extent to which they are structured, complex, contextual, dynamic, and domain-specific. In the following section, we elaborate on these problem types as dimensions, whereas ill-structuredness and dynamicity are merged under the term 'integrated aspects of complexity.'

The first dimension represents the simple versus the complex. Complex problems are ill-structured. Ill-structured problems provide multiple potential solutions and solution paths and unknown problem elements. An example of an ill-structured problem is the problem of self-medication, in which considerable effort must be given to the problem analysis to outline user needs. The problem design process is rather simple for structured problems, whereas it is multi-directional and time-consuming for ill-structured problems. As a result, numerous assumptions and limitations are typically involved in the problem design process of ill-structured problems to reach the problem-solving stage.

Complexity also relates to the level of emergence and number of relationships embedded in a problem. As noted by Kurtz and Snowden (2003) in their view of complex problems:

> This is the domain of complexity theory, which studies how patterns emerge through the interaction of many agents. There are cause and effect relationships between the agents, but both the number of agents and the number of relationships defy categorization or analytic techniques. Emergent patterns can be perceived but not predicted.
>
> *(p. 469)*

From this, it follows that a complex problem must be addressed dynamically through emergent practices if students are to perceive emergent patterns. It is not sufficient, or even possible, to analyze existing practices from a distance. Indeed, practices must include lived experiences interacting with the field, and engaging with knowledge providers and stakeholders. In other words, complex problems require students to be *in* the problem context, which adds an enactment dimension to the problem analysis as part of the problem design process. Complex problems are 'wicked,' where 'wicked' refers to a state where it is simply not clear what the problem is, and likewise even less clear how to effectively intervene (Rittel & Webber, 1973). For example, a complex design problem for potential assistive technology for elder care might require students to experience daily practices (of, e.g., being at a nursing home) to enable them to understand how the technology can be of assistance. Another example of a complex problem is an emergent and unexpected biodiversity loss, where it is not clear why this is happening or how to intervene most effectively.

On the other hand, simple problems are structured. They have prescriptive and known elements and a fixed or expected solution. A typical textbook math problem is an example, as the problem is clearly stated and includes all necessary information that must be employed in clear problem-solving procedures to arrive at a fixed solution. Whereas structuredness describes problems in terms of the predictability of the problem space, complexity highlights interrelatedness in the problem space (Hung, 2016). Simple problems do not exhibit interrelationships between many elements, and "the objectivity is such that any reasonable person would accept the constraints of best practice" (Kurtz & Snowden, 2003, p. 468).

The second dimension, 'from text to context,' relates to the situation in which the problem is embedded. This dimension relates to the relative nature between *text* and *context*. In an educational curriculum, the 'text' relates to the delimited problem of what the specific engineering discipline can contribute to. In contrast, the context relates to what must be addressed in order to qualify the use of disciplinary knowledge. In other words, what is used as the *text* for a student in architecture and design might instead be the *context* for a student in civil engineering – and vice versa.

In engineering and science, the concept of context is also a way of acknowledging that technological artifacts are socially constructed and, therefore, closely interrelated with societal problems and social groups, as noted by Bijker et al. (1989). Societal problems also relate to the analysis of known and potential consequences, for example, through a constructive technology assessment (CTA), as elaborated by Rip et al. (1995). The problem analysis can be further expanded based on theories in Science and Technology Studies (STS), but this also increases the complexity and methodological span of a problem analysis.

The third and final dimension concerns domain specificity, which concerns problem-solving strategies specific to particular domains (Jonassen, 2011). To underscore the increasing interdisciplinary aspects of problem-solving, we position problem-solving strategies that span multiple domains (interdomains) aligned with complex and contextual problems. For example, architecture and design students and civil engineering students may work together to solve a problem by combining problem-solving strategies within their respective domains. The interdomain approach, reflecting an academic context of interdisciplinarity, aims to interrelate different types of epistemologies in the problem-solving process. Thus the problem design is open to much broader problem formulations. Wenger (1998) has used the notion of 'communities of practice' (CoP) as a central aspect of social learning theory, presenting boundary-crossing as an essential element to explain the interactions between different CoPs.

To work in the inter-domain sphere, students – and educators – must remain open-minded and do considerable boundary work. It is not enough to 'borrow' from other knowledge fields to design a problem and then narrow it down to accommodate problem-solving processes within disciplinary bounds. Instead, the problem-solving process itself must become interdisciplinary. In an educational context, an interdisciplinary problem expands to encompass a combination of disciplines before the problem can be solved meaningfully. For example, in the case of self-medication above, the context of study might end up with limited insight into the psychological aspects of self-medication. In a disciplinary project, students will view this as a project delimitation. In contrast, from an interdisciplinary problem perspective, they will view it as an opportunity to collaborate in a meaningful interaction with students from other disciplines.

Ethics in problem design and potential enablers of ethics

In the previous sections, we outlined that problems that are ill-structured, complex, and highly contextually dependent require assumptions, limitations, enactment, interventions, and, most likely, a move across established domains. We have also argued that this complicates problem design, as it becomes a multi-directional process governed by an overarching question: *Who determines the problem, when and where, in what direction, and with which arguments?* Overall, problem designers must consider the 'right' way to proceed, with the right arguments, and making certain assumptions.

The range of ethical concerns we see as related to problem design includes:

- Some problems are initially addressed; others are not.
- Some stakeholder interests are considered; others are not.
- Some success criteria are selected; others are not.
- Some solutions are addressed; some are not.
- Some impacts are assessed; others are not.
- Some trade-offs are accepted; others are not.
- Some project types are seen as appropriate responses to the problem; others are not.
- Some team members might agree on the chosen decisions; others might not.

These concerns not only activate moral values but also reflect the moral itself; thus, they become ethical questions. Furthermore, more explicit ethical questions might also be put forward, such as consideration of the ethical consequences of a specific emerging technology by carrying out an ethical constructive technology assessment (eCTA) as elaborated by Kiran et al. (2015).

Van de Poel and Royakkers (2011) have presented six categories of morals in the domain of engineering ethics, which are aligned with different goals for engineering ethics education: sensibility, analysis, creativity, judgment, decision-making, and argumentation. Based on an extensive literature review, Martin et al. (2021) further elaborate on this list, adding categories related to knowledge, design, agency and action, character and virtuous development, emotional development, and situatedness. Each category implies specific kinds of responsibility for students in a self-directed PBL environment, as exemplified in Table 21.1, while the responsibility of curriculum designers and teaching staff is to support students in taking on such responsibilities.

Table 21.1 Examples of student responsibility in a PBL environment, based on the categorization made in van de Poel and Royakkers (2011)* and Martin et al. (2021)**

Moral categories	*Examples of student responsibility in a PBL environment*
Sensibility*	Recognize and acknowledge ethical issues in problem design and problem-solving.
Analysis*	Incorporate an analysis of the underlying moral problems embedded in the problems addressed in relation to technology.
Creativity*	Be open to alternative solutions and taking time to explore them from an ethical point of view.
Judgement*	Work to understand all viewpoints and make an informed judgement based on transparent criteria.
Decision-making*	Participate in team discussions, negotiate, and compromise toward a shared decision, taking into consideration different views of team members.
Argumentation*	Justify one's own actions regarding the project outcome, learning objectives, and professional identity.
Knowledge**	Obtain knowledge of ethical theories, codes, and language and use these to inform moral arguments, judgments, and decisions.
Design**	See moral considerations as an integrated part of the design and use of technological artifacts.
Agency and action**	Engage with and contribute to the reshaping of the society for common good.
Character and virtuous development**	Be able to articulate one's own virtues and use them to define the virtues of a team.
Emotional development**	Endeavour to understand one's own and others' emotions, and how they can impact the project outcome and process.
Situatedness**	Connect both technology and engineering practice to relevant contextual settings.

One way that educational designers can support students is to introduce a systematic method of integrating moral problems into the problem design. Van de Poel and Royakkers (2011) have presented such a method which they term the 'ethical cycle,' which takes its point of departure in a case. In many ways, the ethical cycle recapitulates the problem design process described above, with its steps of problem identification, analysis, statement, and solution. However, the ethical cycle more explicitly requires ethical problem statements, evaluations as well as action. On the other hand, the PBL approach can initiate a series of built-in cases for ethical consideration, contemplating these moral requirements.

Another way for educational designers to support and motivate students to engage with ethical considerations is to clarify that ethical responsibility and moral problems are among the intended learning outcomes in the curriculum. Ethics can be an explicit part of the curriculum delivered through explicit statements, or they can be explored indirectly via the establishment of an obligation for students to take ethical responsibility upon themselves (as exemplified in Table 21.1). In keeping with the desire to support and motivate students to engage with ethics, the authors of Chapter 26 present a framework for assessing the 'ethical competencies and affective dispositions' of students based upon the same 'moral categories' listed in Table 21.1.

Furthermore, we argue that PBL makes ethical considerations a team concern related to care ethics instead of a purely individual matter. In this way, the team structure becomes another factor enabling students to address ethical considerations; indeed, students might have the same duties

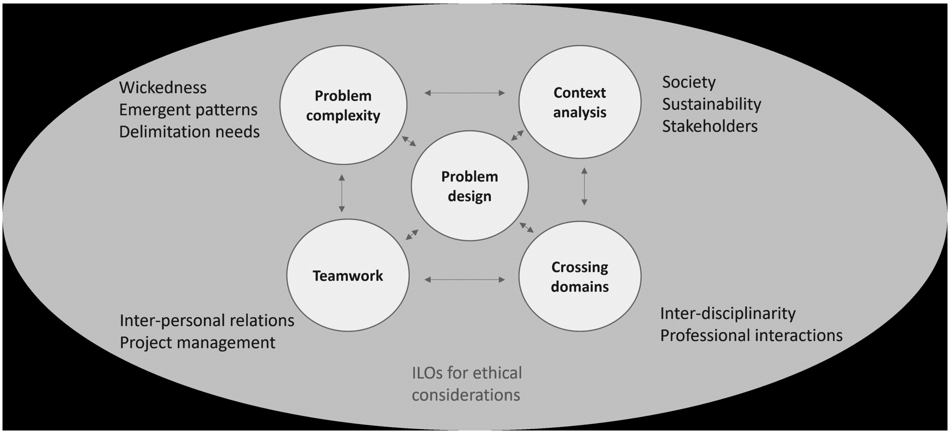

Figure 21.1 Ethical enablers in a PBL curriculum.

in the context of a curriculum, but the negotiated virtues and values of the team are of high importance for coordinated action in the design and solving of a problem. To provide a complete picture of the factors enabling students' ethical engagement, Figure 21.1 presents a theoretical framework for the empirical study to be discussed in this section. Four factors influence the problem design: problem complexity, context analysis, crossing domains, and teamwork. Moreover, curricula considerations to the problem design itself will be considered.

In the following sections, we relate the factors enabling engagement with ethical concerns to examples of explicit and implicit ways to integrate moral and ethical considerations into the curriculum. Our point of departure is the case of a university implementing PBL systemically at the institutional level, namely, Aalborg University in Denmark. The examples have been extracted from a comprehensive analysis of Aalborg University's engineering and science education curricula.

PBL at Aalborg University

Engineering education programs at Aalborg University have included a course on Technology and Society, usually in the first year of study. Students learn to analyze problems from a societal perspective and, if possible, apply sociological or more action-driven methodologies. Over the last 12 years, the integration of Sustainable Development Goals (SDGs) has been emphasized by focusing on problems in the area of sustainability. Students learn to analyze problems from a sustainability point of view and to identify related dilemmas in society. They are encouraged to recognize that there are moral issues related to each problem in society, including how we understand and analyze the problem, who the stakeholders are, and the values and worldviews underlying the chosen solutions.

Beyond PBL, Aalborg University is distinguished by its close collaboration with industry and its efforts to balance business and academic needs. Since 2023, the university has aimed to become a mission-driven institution, developing interdisciplinary competences through initiatives such as the formation of interdisciplinary teams consisting of groups or individual students from both STEM (science technology, engineering, and mathematics) and SSH (social sciences and humanities) fields. In turn, this impacts the problems that students are given to work on. In addition, it has a vital role as an essential element in the cultivation of technical and non-technical excellence, as discussed by Harris (2008, p. 163).

The following section starts by exploring the study regulations and the curricular contexts of the Faculty of Engineering and Science and the Technical Faculty for IT [Information Technology] and Design at Aalborg University. Using the model illustrated in Figure 21.1, the curricula are analyzed and discussed accordingly.

Ethics discourses and enablers in the PBL curricula

The explicit use of the word 'ethics' is infrequent in the studied curricula; however, the activities mentioned implicitly indicate a comprehensive exploration of ethics. The curricula include ethical perspectives concerning energy, AI, chemistry, and techno-anthropology.

One example is that students exploring authentic technological case studies formulate technological dilemmas and use ethical methods to propose solutions, for example, ethical, technological assessment, and ethical scenario-building. This approach is consistent with the advice given by Jonassen et al. (2009, p. 235), suggesting that rather than explicitly teaching students about ethics, providing students with experiences of solving authentic 'everyday' engineering ethics problems may be more impactful.

Another approach is to include the notion of ethics together with other contextual components, for example, mentioning ethics alongside a societal and theory-of-science perspective. Other elements directly related to the notion of ethics include engineering science, technological development and use, responsibility, value-sensibility, future scenarios, privacy, trust, fairness, research implications, and change agency. Students are asked to understand, analyze, apply, evaluate, argue, discuss, construct visions and interventions, and further reflect on and contextualize ethical considerations, problems, and representations. Other requests are more descriptive, for example, asking students to describe the traditions of engineering, the engineer's role in society, or ethical issues in engineering science. The descriptive nature of such requests implies that a given set of norms is followed.

Notably, there is a lack of attention to character, virtues, and emotional development regarding moral categories, as Martin et al. (2021) emphasized (which Chapters 26–31 of this handbook seek to address). The term 'ethics' describes a responsibility or orientation toward something or someone – not necessarily in the sense of positioning oneself in terms of morals and virtues. Furthermore, the domain of ethics is typically treated as comprehensive, as seen in the framing of courses such as 'Technology and Ethics,' 'Ethics and Technological Intervention Processes,' and 'Privacy and Ethics in Computer Systems' – in contrast, ethical considerations are not explicitly connected to project modules. At the project level, ethics is more implicitly integrated by including opportunities to engage with ethical considerations.

Van de Poel and Royakkers (2011) noted that engineering is an inherently morally motivated activity. In contrast, ethics involves systematically reflecting upon morality and dialogically expressing what is perceived as 'right' and 'wrong.' In the previous sections, we have explored how moral opinions, decisions, and actions of students in a participant-directed learning environment can open up discussion of ethical considerations (for more on reflective and dialogical approaches in engineering ethics education, see Chapter 25). The objective of the following section is to provide a richer description of the factors enabling such integration of ethical thinking without the explicit mention of ethics – and discuss implications of these factors.

Problem design processes and problem complexity as ethical enablers

Some of Aalborg University's curricula explicitly call for students to design the problems they will work with, for example, by setting as a learning goal the ability to provide a problem analysis, a problem statement, and perspectives relating to the context in which the problem is defined. Furthermore, some indications are made in the curricula of the types of actions expected from students in the problem design process – including the ability to justify, critically evaluate, and argue. The evaluation aspect implies that students should be able to assess the possible solutions they have identified to decide which is optimal. This decision-making competence is just as crucial as any problem-solving competence and is highly complex due to the influence of numerous technical, environmental, social, economic, and ethical constraints (El-Zein et al., 2008, p. 170).

Other curricula emphasize the importance of students being able to argue for the chosen solutions, explain how they have narrowed an open problem space to something possible to complete within the given timeframe, and describe the potential of disciplinary contributions. It is explicitly stated that students must open the solution space themselves; this is an integrated part of the problem design process, as noted by Holgaard et al. (2017). In one example, the curriculum explicitly calls for a minimization of the proposed solution, which, inadvertently, might lead to a reductionist approach. Others direct students to argue for their choice of problem bounds – the chosen delimitations. Byrne and Mullally (2014) highlight the necessity of challenging reductionist thinking and suggest that a broader and more contingent view of the engineer's professional role is required. In either case, however, it remains somewhat unclear how the 'narrowing down' process is happening, and whether students are reflecting on the value propositions they make in this process.

Problem complexity is reflected in how students combine the various of aspects of a problem during the problem design process, particularly in relation to actors, organizational conditions, and institutional framings. Such a combination of aspects implies the 'wickedness' of the problem. Complexity can also be understood from a system perspective, in which the challenge is to narrow down a technological system. The system perspective includes a call for students to understand the relationships and interdependencies in a system. Complexity is also seen in the emergent patterns considered in relation to future systems, within a comprehensive approach to emergent technologies. Some curricula explicitly state that students should be able to solve complex problems, although some make it clear that this is within disciplinary borders. Other curricula address the need to 'futureproof' solutions using methodologies such as scenario-building, life-cycle assessment, and cost–benefit analyses based on a set of pre-defined criteria. The ethical question – which may, in fact, be a part of practice – is for the students to consider the ways in which these criteria are defined, and by whom. As stated by Bucciarelli (2008), however, learning about the social, organizational, and even political complexities of practice may be a more fundamental prerequisite for students but without neglecting ethics in engineering education.

Ethics enabled by teamwork and boundary-crossing activities

Interpersonal reflections provide a way to nurture students' awareness of personal virtues. One example is a request for students to participate actively, collaboratively, constructively, and critically in order to develop communicative solutions with a specific focus on culture and values. Some curricular requirements highlight students' ability to reflect on their own role in a team, consider group dynamics, identify their own and others' competencies, and reflect on their individual and collaborative learning processes. The process of developing this awareness is a component of developing team norms within a group work context, which the curricula explicitly name as an objective of group projects. In some cases, the study regulation (i.e., syllabus or project brief) calls for students to demonstrate specific virtues in the context of teamwork (e.g., to be tolerant and resilient). Concerning project management, students are encouraged to be analytical and forward-looking. For example, students may be instructed to analyze how their team organizes its work in order to identify strengths and weaknesses in their approach and, based on this analysis, provide recommendations for enhancing teamwork in the future. This implicitly calls for the team to set specific analytical parameters and evaluation criteria. These are examples of what Conlon (2008) refers to as generic competencies, which are non-technical competencies (like communication, project management, leadership, and teamwork) that help make engineers more effective and engineering students more prepared for future management tasks.

The importance of a boundary-crossing perspective is highlighted to students via activities that involve collaboration across teams. The recognition of different disciplinary languages is also emphasized, most often by requesting students use the language of a particular discipline. Other activities ask students to recognize specific academic norms within their field of study, which implies that someone (e.g., a facilitator) is actively defining those specific norms. From a broader perspective, there is an explicit discussion of interdisciplinary work in the curricula, but the level of interdisciplinarity called for is often left open to interpretation. This overall situation reflects Nair and Bulleit's (2020, p. 71) argument that engineering ethics should be taught in a way that embraces interdisciplinary thinking, including the recognition and use of disciplinary knowledge from beyond engineering within the practice of engineering ethics.

In addition, connections to the professional sphere are made in the curricula by emphasizing the importance of concepts, models, methods, and techniques that are relevant to professional teamwork. There are examples of discussions of organizational cultures, structures, and decision-making, and in some cases, the interdisciplinary and cross-departmental perspective is put on the same footing. A question that emerges here involves how the difference between the two types of boundary-crossings, in terms of disciplines and professions alike, can ease the transition from engineering education to the workplace. Another open question involves what students expect of their future workplaces and whether integrating such reflections and awareness into the curriculum will benefit students professionally. Discussing engineering virtues and what characterizes a 'good engineer' (Harris, 2008) could be a point of departure to connect the educational domain with the professional domain.

Contextual analysis as ethical enablers

A contextual analysis moves technological considerations to the societal level and emphasizes grand challenges such as sustainable development. As Aalborg University has embedded contextual learning and exemplarity in its PBL model, the curricula are especially rich in this aspect related to the problem design and problem-solving processes. Overall, however, there are two broad types of curricula: one is focused on integrating specific technologies into contexts, while the other (examples of which include curricula related to design) takes an inherited and integrated approach to contextual factors. In other words, they are part of the 'text.' Although historical, political, cultural, and philosophical contexts are mentioned, along with considerations to the theory of science, the most frequent reference to context is societal – and, more implicitly, a business context. As a part of the societal context, the consideration of various actors and sustainability are recurring themes.

Discussions of sustainability and ethics are often connected to and embedded within each other (Chance et al., 2021, p. 94). Sustainability is also an integrated part of most of the engineering curricula at Aalborg University, using a variety of approaches. Some intended learning outcomes focus on the calculation of environmental impacts; others focus on sustainability standards; still others focus on designing and re-designing for sustainability. Reference to the United Nations' SDGs is also present, either with explicit reference to specific goals or as a broad guideline for alignment with the goals as a whole. Keywords are 'work environment,' 'ecology,' 'eco-systems,' 'safety,' 'circular economy,' 'life-cycle assessment,' 'principles for sustainability,' and, more broadly, the 'interplay between humans and nature.' Students are expected to analyze, assess, discuss, design for, and reflect on various aspects of sustainability. For example, students are asked to evaluate trade-offs between environmental, social, and economic sustainability. Further, globalization is often discussed as an essential societal consideration in decision-making regarding options for development, with attention to both local and global consequences. This approach reflects the importance of global awareness for engineers, as discussed by Nair and Bulleit (2020), who recommend a focus on how human well-being in the local context may be affected, not only from a market perspective.

Market-driven discourse, as described by Jamison et al. (2014) is also present, and issues such as competitiveness and socio-economics on the micro-, meso- and macro-levels are mentioned. Another discourse related to the business context involves entrepreneurship and students' ability to work in a commercial value-oriented approach and to address business cases and models, which include value propositions. For example, students should be able to understand and create a business case for a given technological system and must evaluate the effectiveness and applicability of certain technologies. In this case, the importance of establishing criteria is implicit.

Students are also asked in some curricula to identify and engage relevant actors in the assessment of technological consequences, which gives the students the responsibility of evaluating what and who is relevant in the given context. Students' ability to assess conflicts of interest is also mentioned in the curricula. In some cases, students are expected to make actor analyses using specific approaches like actor network theory (ANT). Engagement with users is specifically highlighted through principles of design, for example, co-design or participatory design. Other actors are mentioned in relation to societal responsibility, including researchers, experts, professionals, and companies. The goal of these requirements is to help students recognize that the problem-solving process is a community activity that must involve input from all involved parties (Nair & Bulleit, 2020, p. 71). Research indicates that engagement with users and stakeholders can enhance students' ethical sensitivity and reflexivity while also stimulating ethical decision-making in the design process (Corple et al., 2020).

The contextual factors related to sustainability, market orientation, and the cast of actors involved are numerous, as are the interdependencies between them; a significant amount of decision-making is thus necessary in the problem-solving process. This might present a challenge to students' critical and holistic thinking and stimulate their engagement with the ethical considerations embedded in the sustainability and market discourse. Furthermore, disciplinary framings, which are continuously referenced throughout many of the curricula, might also challenge students' motivation to work in an interdisciplinary context.

Curricula frequently refer to society as a context, as a framework condition, and/or as an object of technological implications. At the same time, however, it remains open for students to define the societal aspects of a problem and proposed solution, and the 'relevance' of the problem is often used as a criterion. This suggests that students are left with the challenge of deciding what is relevant, and although implicit, this carries considerable learning potential for ethics in engineering education.

Final remarks

Even if there is no explicit learning outcome regarding ethics in a given engineering curriculum, students can implicitly learn to analyze, understand, and resolve a range of ethical issues inherited from the involvement of stakeholders, collaborative behavior, and the impact of developed technologies. However, although the curriculum may open doors for such ethical considerations, the implicitness of ethics might impede students' transition from the problem design cycle in a technological context to the ethical cycle. This transition would enhance students' specific attention to moral considerations and actions. The question is how much emphasis on ethical theory, methods, and mindset is needed for educators and students to integrate ethics throughout engineering education. This chapter intends to argue for exploring the depths of possible ethical considerations implicitly present in a PBL environment. The currently implicit opportunities for ethical thinking must be studied further to fully examine their associated learning potential, and it might not be sufficient to expect students to enter these openings independently. Rather, ethics in engineering education must be scaffolded and deliberately nurtured.

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