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Understanding engineering ethics in countries: Towards an analytical framework

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ABSTRACT

In recent decades, distinct national approaches to engineering ethics have evolved, each tailored to its unique contextual factors. These contextual disparities make it unfeasible to transfer one country's engineering ethics approach directly into another. This calls for a compelling need to enhance our comprehension of engineering ethics within specific national contexts. This paper introduces a novel conceptual framework for national engineering ethics (NEE), inspired by Elinor Ostrom's Institutional Analysis and Development (IAD) framework. The NEE framework categorises engineering ethics activities into three core pillars: research, education, and professional behaviour. This framework facilitates a comprehensive analysis of these activities across three levels—operational, organisational, and governmental. The proposed framework offers a valuable resource for scholars seeking a deeper understanding of engineering ethics within specific national boundaries, enabling structured reporting and analysis. It serves as a critical step towards achieving mutual understanding, allowing for cross-national comparisons and the exchange of best practices. Additionally, it provides a structured platform for policymakers and developers to devise strategies for implementing engineering ethics at the national level.

1. Introduction

About fifty years after the beginning of the engineering ethics boom in the United States and Europe, it has become a relevant notion throughout the world. With the growing interest in different countries, engineering ethics courses are being taught at different universities. Moreover, codes of ethics emanating from these discussions are becoming increasingly relevant in professional engineering organisations and for the practice of engineering, broadly speaking.[1]

While the United States, and at a later stage several European countries, have been pioneers in the field of engineering ethics, it appears that their experiences and approaches cannot be transplanted into other countries. In other words, contextual factors affect the implementation of engineering ethics in countries. Didier [1], for instance, identifies professional and educational institutes as well as intellectual traditions in ethics to be among the factors that are relevant to the local practices of engineering ethics in different countries. The question arises whether and how engineering ethics could be better understood and applied in new contexts. Recommendations and guidelines for the implementation and development of engineering ethics at the national level are needed.

While numerous efforts have been made to elucidate the evolution of engineering ethics in various countries, these studies have predominantly fixated on a limited array of factors, resulting in an absence of comprehensive analysis. For instance, in the case of Davis (1990), who delved into the surge of ethics in the United States, the focus was

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[1] See, e.g., the Netherlands [2], France [15], the United States [19], Germany [20], China [21], Europe [22], Japan [23], Australia [24], Canada [25], Malaysia [26].

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primarily on educational initiatives and the formulation of ethical codes, in which research aspects were overlooked. Similarly, Brumsens' exploration of engineering ethics in the Netherlands in 2005 primarily focused on the contributions of universities and professional organisations, mostly sidelining the role of government entities and the Dutch parliament [2]. Another instance is a study on the history of engineering codes of conduct in China, as demonstrated by Zhang and Davis [3]. They concentrated on the creation and content of codes but omitted the critical aspect of how they were included in education.

There are multiple publications scrutinising distinct aspects of engineering ethics within a single country. Yet, even when collectively considered, they fail to present a comprehensive perspective due to the absence of a unifying framework for a systematic analysis. While it is understandable that individual scholars focus on specific aspects within their research, the pivotal concern is beyond the mere lack of a comprehensive per-country overview: an overarching conceptual framework can further facilitate an all-encompassing analysis of engineering ethics across countries. Such a framework would also provide a suitable basis for strategy design and policymaking and possibly provide general recommendations for the implementation and development of engineering ethics.

The goal of this study is to present such a comprehensive framework designed to enhance the understanding of engineering ethics within the national context. Our aim is to discern the constituent elements of engineering ethics and their intricate interplay at the national level, with a specific emphasis on the contextual variables that influence the *localised interpretation* of engineering ethics in a given nation. A primary focus of this investigation lies in examining the role of various *institutions* in fostering the adoption of national engineering ethics within a country.

Among the contextual factors, institutions play a pivotal and multifaceted role. Their significance lies in their ability to shape, guide, and regulate the ethical conduct and practices of engineers on both an individual and collective level. In this context, institutions (such as laws and norms) are sets of formal or informal rules that structure social behaviour and interaction [4–6]. These institutions are developed by and shape a wide spectrum of entities, including educational and professional organisations, regulatory bodies, and governmental agencies. Let us illustrate this with an example. Education-related institutions provide the foundational ethical training for engineers to shape their future practice. Professional organisations also follow and shape industry-specific ethical standards and codes of conduct in the form of both formal and informal institutions. These institutions provide a shared ethical framework that binds engineers together, ensuring a common understanding of acceptable behaviour and ethical responsibilities within the profession. At a higher-level, regulatory bodies and governmental agencies are instrumental in formally establishing and enforcing legal and ethical standards within the engineering profession. To incorporate the intricate role of institutions in our proposed framework, we draw upon the Institutional Analysis and Development framework, originally introduced by Nobel Laureate Elinor Ostrom (2005), as the foundational basis.

The National Engineering Ethics (NEE) framework, proposed in this paper, offers a valuable tool for identifying key elements and significant contextual factors, as well as comprehending their intricate interplay. This conceptual framework provides a structured and systematic way of understanding the landscape of engineering ethics within a specific nation. It enhances our ability to depict the developmental status of engineering ethics in a country in a more cohesive and comprehensive manner.

Moreover, this framework enables a systematic cross-national comparisons, despite the contextual disparities between different countries, thus facilitating the adaptation and utilisation of earlier national experiences in the formulation of country-specific approaches. On the one hand, this has an added value in the academic studies: i.e. scholars can benefit from an enhanced understanding of engineering ethics activities and improved documenting and reporting methods. On the other hand, the NEE framework can equip policymakers and engineering ethics developers[2] with the necessary tools to leverage the experiences of other countries and to craft effective strategies for the advancement of engineering ethics within their own nation.

The paper is organised as follows. In the first section, the importance and the reason for paying attention to engineering ethics at the national level is explained. In the second section, the IAD framework is briefly described, and the reason why it is considered the method for this study is presented. In the third section, we will present the NEE Framework and describe its elements and their relationships. In this section, the components of this model, the factors affecting it and how they relate are described. Finally, in the fourth section, a working example is presented.

2. National engineering ethics, what and why?

Engineering ethics in the term *national engineering ethics* implies a set of activities and their outcomes in a country in the field of engineering ethics. This field includes the ethics of the engineering profession and the ethics of technology. This field includes activities related to *research*, *education*, and *professional behaviour* (and virtues). The educational and research activities related to engineering ethics are mainly pursued by educational and research organisations. Moreover, engineering ethics – as it is understood here - is not just a branch of philosophy or a course in a classroom; but also the professional behaviour of engineers – i.e., improving skills such as engineers' moral sensitivity and moral problem-solving skills – is of interest. The latter is the main focus of professional organisations.

This paper specifically puts an emphasis on engineering ethics as a *national* phenomenon which could imply various concepts. Following Geertz [7], the term *nation* often relates to blood, race, and descent. If nation is considered a *Country,* it indicates geographical borders and territorial demarcation, as well as a sense of origin and belonging. Nation as *State* refers to political and civic loyalty to and indivisibilities of law, obedience, force, and government. Nation as *Society* refers to interaction, companionship, and practical association, and finally, nation as *people* implies cultural, historical, linguistic, religious, and psychological affinity. In this paper, national in national engineering ethics refers to a country for several practical and fundamental reasons: in our analysis, we discuss certain actions with respect to teaching, research and professional conduct; all three are best to be studied within the geographic and political confines of a country.

There are two approaches to engineering ethics. Some scholars argue for the need to strive for global engineering ethics arguing that ethics should be more and more internationalised (See, e.g., Jordan and Gray [8]). Others argue instead for localisation, emphasising specific and mono-cultural nationalities arguing that localisation is a necessary step to expand engineering ethics to new countries (See, e.g., Downey et al. [9]).

While the globalisation of engineering ethics could be useful for some purposes, such as in international engineering corporations, globalisation is not always the right approach because engineering ethics sometimes could best be understood against the backdrop of a social and cultural context of a country. For example, in engineering ethics education, Barry and Herkert [10] considered cultural factors to be effective in understanding and resolving moral conflicts and, consequently, in the complexity of education. Downey et al. [9] emphasised that an engineering identity affects engineering ethics. Didier [1] considered two factors of professional and educational organisations and intellectual traditions in ethics to be effective in engineering ethics. Therefore, without rejecting the globalisation of ethics altogether, we

[2] By the term "engineering ethics developer," we refer to individuals, groups, or organisations that strive to develop engineering ethics in their environment. A philosopher or an engineer, a group of engineers, or a professional engineering organisation could be examples of engineering ethics developers.

argue that considering some local characteristics in engineering ethics could be beneficial from an analytic point of view.

Another issue in this regard is that - accepting that localisation is justifiable - the reasons to focus on geographical boundaries of a country (as in the definition of country). To examine the state of engineering ethics in a country, is it not preferable to examine the set of countries affected by similar factors such as regions, cultures, or religions rather than studying each country individually? For example, in some of her works, Didier [1] (2015) explains the features of the European approach to engineering ethics compared to the American one. Similarly, Shuriye et al. [11] explain an Islamic approach to engineering ethics. Therefore, it may be claimed that, for example, to describe the engineering ethics in Iraq, it is justifiable to study engineering ethics in the Middle Eastern countries or Islamic approaches rather than the examination of that specifically in the geographic region of Iraq.

To answer, studying national engineering ethics is actually studying the process or set of actions undertaken in one country to achieve the *goals* of engineering ethics. Examples of these include the development of engineering ethics education at universities and professional organisations, the involvement of more research centres on understanding ethical issues in engineering, and writing or modifying professional ethics codes in engineering.

What develops engineering ethics in a country is the decisions and actions undertaken at different layers of power in that country. These decisions, in turn, depend on other factors that we refer to as contextual variables. It is often a government that, at the most fundamental level of decision-making, provides the do's and don'ts (i.e., institutions) by setting laws, policies, and guidelines for related organisations such as universities and professional organisations. These, in turn, are the local organisations that implement government instructions and issue executive instructions for their administrative subdivisions. Engineering ethics in countries are governed more by their governments and local organisations. Therefore, to assess the current state of engineering ethics in countries and plan its development, these authorities, their performance, and the institutions they develop should be appropriately identified and evaluated.

In order to develop engineering ethics in a country, we must inevitably examine how each of the relevant participants, from the government to a teacher or engineer, interact with each other and what institutions need to change or be created. To answer these questions, we need to look at engineering ethics within their context: the actors involved, their actions and interactions, the physical environment that affects their behaviour and the community in which engineering ethics is situated , leading to outcomes that can then be evaluated from an ethical point of view. All these can be analysed through an institutional perspective, that is introduced next.

3. Institutional analysis and development (IAD) framework

The institutional analysis and development (IAD) framework is composed of a set of actions explaining human behaviour in a complex social situation, especially for studying institutions within their social and physical environment [12]. In this paper, we inspire from this framework to develop the NEE framework as a comprehensive blueprint to organise and analyse the concepts and relations relevant to developing or implementing national engineering ethics.

The Institutional Analysis and Development (IAD) framework, as depicted in Fig. 1, serves as a structured conceptual tool designed to facilitate the understanding of complex scenarios involving diverse human decision-making and interactions. At its core, the framework introduces the concept of an "action arena," a central element where participants and action situations come into play. Within this arena, participants engage in actions and interactions that are influenced by exogenous variables, resulting in a variety of outcomes that, in turn, jointly affect both the participants and the dynamics of the action situation.

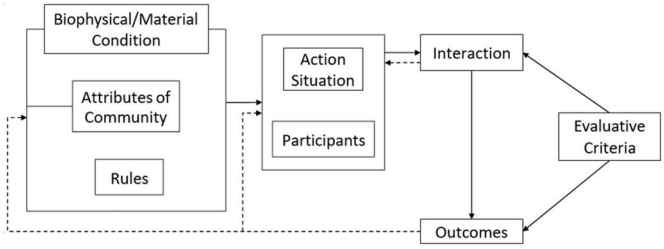

Fig. 1. A framework for institutional analysis, Reference: Ostrom, E [12]. Understanding Institutional Diversity. Princeton University Press.

The *action arena* refers to the social space where participants with diverse preferences interact, exchange goods and services, solve problems, dominate one another, or fight. The IAD framework is therefore further unpacked to characterise action situations using seven clusters of variables: (1) *participants* (who may be either single individuals or corporate actors), (2) *positions*, (3) *potential outcomes*, (4) *action-outcome linkages*, (5) the *control* that participants exercise, (6) types of *information* generated, and (7) the *costs and benefits* assigned to actions and outcomes.

Exogenous variables are the factors affecting the structure of an action arena and include three clusters of variables (1) the *rules* (i.e., institutions) that are defined to create a shared understanding among participants about enforced prescriptions concerning what actions (or outcomes) are required, prohibited, or permitted. (2) the *attributes of the biophysical world* that are acted upon in these arenas, and (3) the structure of the more general *community* within which any particular arena is placed. Rules, the biophysical and material world, and the nature of the community all jointly affect the types of actions that individuals can take, the benefits and costs of these actions and the potential outcomes likely achieved [12].

The IAD framework suggests that the national engineering ethics activities undertaken in countries, despite their diversity and differences, have common and repetitive elements. For example, engineering ethics courses are taught in universities, governments accredit these courses, and ethical codes of conduct are published for engineers. Moreover, as mentioned, the development of national engineering ethics depends on contextual factors, especially institutions. Therefore, we need a framework that investigates institutions and other contextual factors.

By comparing IAD concepts with the aspects considered in the reports of national engineering ethics in different countries (Appendix A), it became clear that the IAD framework is able to adequately explain the national engineering context by adding further specifications.

Building on the IAD framework, we consequently categorised the information related to each national engineering action situation into certain categories and related them to each other. For instance, by considering "writing codes of conduct" as an action situation, we classified the information into groups of *exogenous variables*, *participants*, *outcomes*, and so on. In this case, political events, engineering events, or public demands are categorised as exogenous variables of writing codes of conduct, or engineers and philosophers who contribute to writing codes of conduct are classified as participants of this action.

In addition to the IAD framework, we used an additional theory to classify levels of analysis based on the scope of activities as the decision-making levels and activities related to engineering ethics are diverse and layered. Governments often play roles in the development and implementation of engineering ethics by setting rules for engineering ethics education or budgets for engineering ethics research. At a different level, various organisations and companies voluntarily conduct activities that influence the development of engineering ethics. For example, they write codes of conduct or codes of ethics for their employees. Lecturers teaching engineering ethics in courses can also be studied at an operational level of analysis. Each activity at these distinct levels could be

affected by a different set of exogenous factors and lead to different outcomes. Therefore, considering the levels of activities in the analysis besides the IAD concepts helps us better analyse national engineering ethics in a country.

Ostrom defines four different levels of analysis: Operational Choice, Collective Choice, Constitutional Choice, and Constitutional Choice [12]. The operational choice level includes the processes regarding the implementation of operational decisions made by authorised individuals. The collective choice level captures the processes through which institutions are constructed and policy decisions are made by those actors authorised. The constitutional choice level includes the processes through which legitimising and constituting all relevant collective entities that take part in collective or operational choice processes are defined. Finally, the meta-constitutional level of analysis includes long-lasting and often subtle constraints on the forms of constitutional, collective, or operational choice processes that are considered legitimate within an existing culture [13].

In the following section, we introduce the NEE framework, which has emerged as a product of our adaptation process involving the utilisation of the IAD framework and the levels of analysis.

4. The national engineering ethics (NEE) framework

The NEE framework (shown in Fig. 2) is a conceptual map of the national engineering ethics that policymakers and developers can use to systematically understand and explain the developments in the field of engineering ethics in a specific country. This framework is a specification of the IAD framework for a specific class of activities, related to national engineering ethics. It constitutes a set of relevant components that play a role in developing engineering ethics in a country and can serve as a blueprint to better understand the current situation and as a basis to design strategies for the development of engineering ethics. This blueprint captures elements that need to be considered, and how those elements play a role in improving professional ethics among engineers.

This section explains the NEE framework with the help of some examples. For a detailed specification of the application of this framework, the education cluster is further detailed in Appendix B.

4.1. 4-1 The NEE environment

The NEE environment captures all activities performed regarding engineering ethics in a country in a certain period. This environment has nine *action arenas* that arise from classifying activities into three pillars of research, education, and professional conduct; and three levels of governmental, organisational, and operational.

The *education* pillar captures educational activities in universities for students, professional organisations, and other centres providing educational services. The pillar of *research* relates to research activities in universities, professional organisations, research centres, and individuals active in engineering ethics. Finally, the pillar of *professional conduct* refers to all activities relevant to professional conduct that engineering agents (individuals, groups, and organisations) undertake when engaged in engineering practices.

The NEE framework also includes three vertical levels of activities for analytical purposes. These levels are *operational*, *organisational*, and *governmental*. The *operational* level includes individuals (and sometimes organisations) who operate their tasks framed by the institutions instructed by higher-level authorities. A researcher working in engineering ethics independently, a class at a university in which a lecturer and students discuss engineering ethics, and a group of engineers engaged in a professional situation are samples of participants at the operational level. The *organisational level* (cf. collective level in Ostrom's multi-layer analysis) includes the decision-makings and interactions related to the establishment of instructions and strategies and the

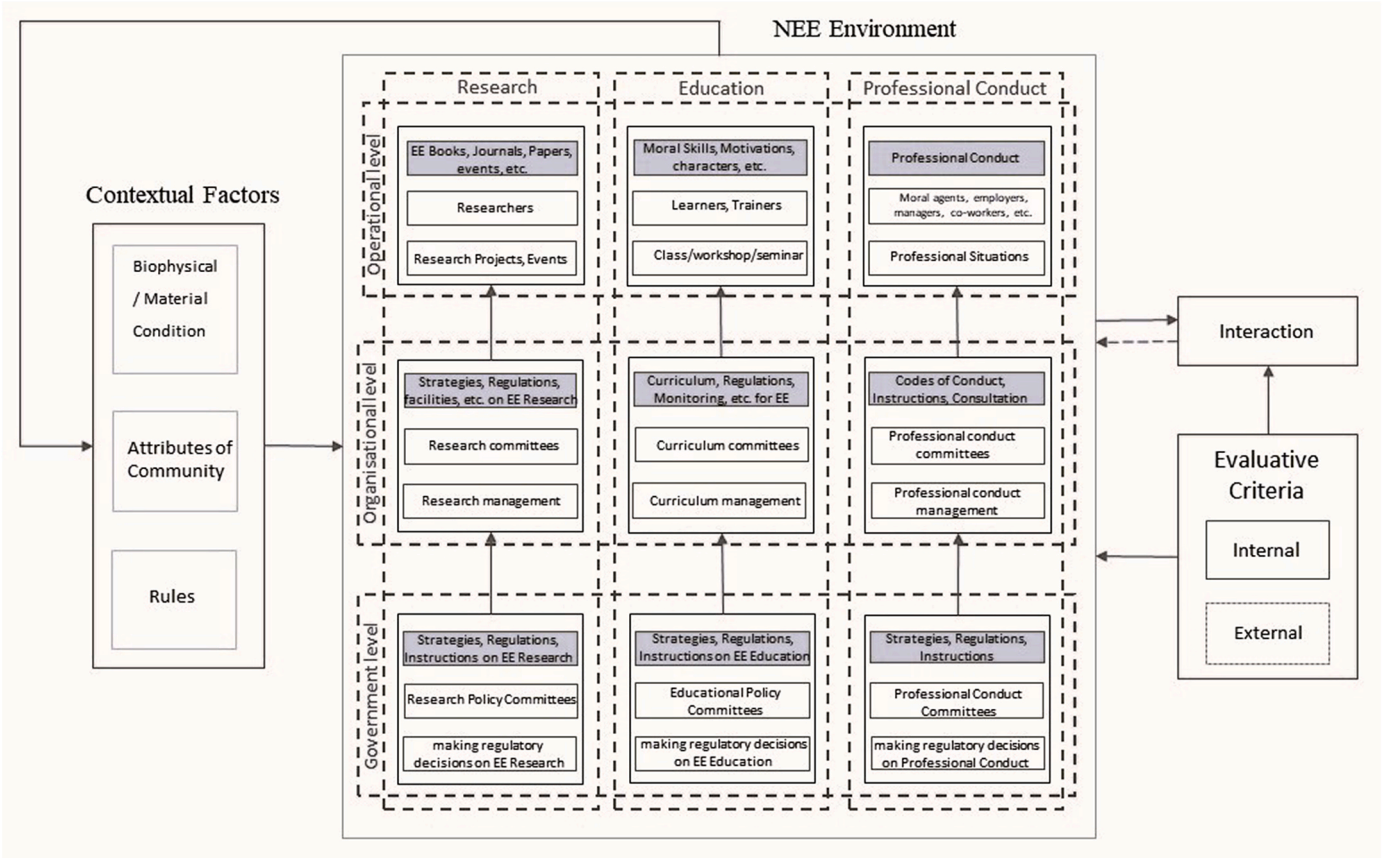

Fig. 2. National engineering ethics (NEE) framework.

implementation of laws and regulations at the operational level. As such, the outcomes of this level affect the action situations at the operational level. Designing strategies for the studies of engineering ethics in research centres, curricula plans for engineering ethics courses in universities, and codes of conduct provided by professional organisations are some samples of the constituents related to this level. The third level of the NEE framework is dedicated to the activities carried out by governments (cf. constitutional level in Ostrom's multi-layer analysis). The government develops national laws, regulations, policies, and strategies to develop national engineering ethics in the country at a national level. The results are then passed on to affiliated organisations – the second level of the framework- as the rules to implement. Allocating funds for the development of engineering ethics in the industry, accrediting engineering ethics courses in higher education, and granting professional autonomy to professional organisations to develop their codes of conduct are examples of activities at this level (Fig. 2).

With the three pillars (education, research, professional conduct) and three levels (operational, organisational, governmental), the environment of NEE is subdivided into nine action arenas. Action arenas, in turn, are analysed under four constituents: *action situation*, *participants*, *interaction*, and *outcome*. In each action arena, participants interact with each other in action situations to achieve the desired outcomes. For instance, at the operational level of *Education*, action situations are classes in universities in which lecturers and students in the process of teaching-learning interact with each other to learn how they solve moral problems in their engineering practices. As an example, the Education pillar is further detailed in Appendix B.

4.2. Evaluation criteria (internal and external)

The evaluation criteria consist of two different types of criteria: internal and external. Internal criteria are used by participants (e.g., university as an overarching organisation) to evaluate the interactions and outcomes of the action arenas. In contrast, external criteria are defined by the system analyst to evaluate them normatively.

To examine national engineering ethics in a country in a descriptive approach, the internal evaluation criteria are sufficient. However, if we want to evaluate those activities normatively, we need to set and articulate the normative external criteria. For instance, the analyst may ask whether appropriate teaching-learning methods are used in a class. Are qualified teachers employed at that university? Do learners learn problem-solving skills in the classroom? In this case, the analysts' criteria may differ from those used by the participants.

4.3. Contextual factors

As mentioned, the context of countries influences their engineering ethics activities. According to the IAD framework, contextual factors include biophysical/material conditions, attributes of a community, and rules.

- Biophysical/material condition: Events in the external world sometimes affect the action arenas of the NEE environment. Natural disasters such as earthquakes and floods or unnatural events such as wars and disasters, which create special or critical conditions for a country, can, for instance, make a difference in the implementation and development of engineering ethics. The boom of engineering ethics in the United States began when numerous airline and car accidents happened [14]. China's engineering codes of conduct were written in the 1940s with war conditions [3]. US sanctions on Iran made Iranian engineers interested in the reverse engineering process. Global warming, Ozone depletion, and biodiversity loss have led countries to pay more attention to environmental protection and renewable energy sources. These examples show that in the analysis of engineering ethics of countries, these variables sometimes play a decisive role.
- Attributes of community: Action areas of NEE are related to the social attributes of that country, such as public culture, people's beliefs, cultural preferences, historical experiences, and economic conditions. Didier [15], in her study of engineering ethics in France, reports that due to cultural and historical reasons, the question of whether engineering is a profession or not has not been an issue. Therefore, until recently, there have been no engineering ethics courses, no research programs on the topic, nor a specific code of ethics for engineers in France. As a result, professional ethics in engineering in France has not developed as it has in English-speaking countries. Barry and Herkert [10] consider cultural factors to be influential in understanding and resolving moral conflicts and, consequently, in the complexity of education. Downey et al. [9] emphasised that engineering identity affects engineering ethics. In her study of the differences between engineering ethics in the United States and Europe and among European countries, Didier [1] considered two factors of professional and educational organisations and intellectual traditions in ethics to be influential in engineering ethics. Asking the question, "Is professional autonomy a necessary component of engineering ethics?", Luegenbiehl [16] contrasted the conceptions of autonomy in Japan and the United States. He believes that the assumption of autonomy so dominant in western cultural discussions of professional ethics is, however, not a significant feature of actions by professionals in all cultures.

Rules in use: rules are shared understandings among those involved that refer to enforced prescriptions about what actions (or states of the world) are required, prohibited, or permitted. Working rules are the set of rules that participants use, referring to them if asked to explain and justify their actions to fellow participants [12]. Religious and moral values affecting the content of engineering ethics in different countries and social norms affecting professional behaviour of engineers are examples of rules-in-use. In the NEE framework, shared rules across levels of analysis are captured as contextual factors, while those specific to certain levels of analysis are framed in separate action arenas.

In the following section, we explain how the NEE framework can be used to study the development of engineering ethics in a country and how it can also be used as a comparative tool.

5. Practical applications of the NEE framework

The NEE framework, as outlined in this study, presents an invaluable tool for enhancing the analysis and implementation of national engineering ethics at various levels.

5.1. Comprehensive and systematic analysis of engineering ethics activities

One of the core strengths of the NEE framework is its inclusive nature. It comprehensively covers diverse activities associated with engineering ethics, categorising them into nine discrete areas of activities. This breadth allows for a holistic assessment, ensuring that no aspect of engineering ethics goes unexamined.

5.2. Systematic cross-national comparisons

The NEE framework excels in promoting systematic analysis. It encourages the structured examination of engineering ethics activities, facilitating comparisons of data collected from engineering ethics studies conducted in different countries. This systematic approach enables the identification of trends, best practices, and variations, enhancing our understanding of engineering ethics practices worldwide.

5.3. Emphasis on contextual factors and institutional dynamics

A distinctive feature of the NEE framework is its focus on contextual

factors and their interconnectedness with institutional dynamics. By systematically identifying, classifying, and linking these contextual factors to engineering ethics activities and the existing institutional environment, the framework underscores the pivotal role played by contextual influences in shaping ethical practices within a specific nation.

This contextual consideration provides a nuanced understanding of how local factors, including cultural norms, legal frameworks, and socio-economic conditions, intersect with and impact the institutional rules governing engineering ethics. Recognising the interplay between contextual factors and institutional rules is crucial to comprehending how they collectively influence and, in some cases, even dictate the ethical behaviour and decision-making processes of engineers within a given nation.

5.4. Holistic understanding of development

The NEE framework goes beyond the traditional understanding of engineering ethics development, acknowledging that it extends far beyond the provision of educational resources and ethical codes of conduct. Instead, it delves into the crucial role of actors and their organisational structure within the field of engineering ethics. Moreover, it highlights that the success or failure of engineering ethics development hinges on the interactions among these actors in various action situations. This dynamic perspective underscores the importance of correctly answering questions about the actors involved, their organisation, interactions, decision-making processes, and outcome assessments. These answers may ultimately determine whether the development of engineering ethics succeeds or falters.

5.5. Target audiences and versatile application

The primary beneficiaries of the NEE framework include academics seeking in-depth insights into a country's engineering ethics landscape or comprehensively comparing engineering ethics across countries and aiming to report on it more effectively. Additionally, national policymakers and developers interested in comprehending the current status of engineering ethics within a country to formulate strategies can gain from using this framework. Furthermore, it is important to note that the NEE framework is not limited to national applications. Its concepts and elements can be tailored to lower levels of analysis, enabling the examination of engineering ethics activities within organisations.

Appendix C provides a practical example of how the framework can be employed to analyse national activities in engineering ethics education in China. Given this adaptability, the NEE framework can serve as a versatile tool for diverse analytical purposes, empowering individuals and organisations to strengthen engineering ethics on multiple fronts.

6. Conclusion

The NEE framework, presented and explored in this study, is a comprehensive tool with far-reaching implications for the analysis and implementation of national engineering ethics. By considering diverse activities linked to engineering ethics and categorising them into nine distinct areas, the framework provides a blueprint to facilitate holistic and systematic analyses.

The NEE framework provides a structured approach to the study of engineering ethics. It enables systematic data collection on engineering ethics, as well as structuring secondary data from engineering ethics studies. Such structured data enables broad analysis of engineering ethics at the national level and allows for holistic cross-country comparisons. This systematic approach not only broadens our understanding of engineering ethics practices but also promotes the identification of best practices and areas for improvement on a global scale.

The NEE framework places a strong emphasis on contextual factors and their connection to institutional dynamics, offering a nuanced perspective on the interplay between the broader socio-cultural and regulatory landscape and the established rules and norms governing engineering ethics. This recognition of the interdependence between contextual factors and institutions is essential for comprehending how they collectively influence ethical behaviours and decision-making within a specific nation.

Furthermore, the NEE framework challenges conventional wisdom by demonstrating that the development of engineering ethics in a country extends beyond the mere provision of educational resources or ethical codes of conduct. It acknowledges the central role of actors, their organisational structures, and their interactions within various action situations. These factors, along with their decision-making processes and assessments of outcomes, are critical in determining the ultimate success or failure of engineering ethics development.

This paper proposed a framework that uses well-established social science theories as its foundation. By applying the concepts of these theories to engineering ethics, we provided further details and extensions to make these theories applicable to the context of national engineering ethics. Yet, to validate the NEE framework further, case studies are needed to study its true applicability and impact in this domain.

Besides using the framework in various case studies, further research could focus more on identifying contextual factors affecting action arenas of national engineering ethics development in different countries. Another possible continuation of this research lies in the design domain, where common recommendations and guidelines can be structured on a country-specific basis.

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CRediT authorship contribution statement

Ali Dizani: Conceptualization, Investigation, Methodology, Writing – original draft. **Amineh Ghorbani:** Methodology, Supervision, Writing – review & editing. **Behnam Taebi:** Supervision, Writing – review & editing. **Ibo van de Poel:** Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

Appendix A. Examples of action situations, participants, and outcomes in NEE

Research			
	Action Situations	Participants	outcomes
1	Researching ethical aspects of engineering practice and technology, writing papers and books	Researchers, Engineers, research centres, professional organisations, government, students	books, journals, dissertations,
2	Holding conferences, seminars, etc.	Researchers, Engineers, research centres, professional organisations, government, students	Scientific events (conferences, etc.)
3	Researching ethical issues in engineering and technology	Researchers	Scientific development

Education			
	Action Situations	Participants[3,4]	outcomes
1	Accreditation of education	Government, Educational policymakers, professional engineering organisations, engineers, people, the media	Educational Laws and permission
2	Teaching	Instructors, students	Skills, knowledge, virtues, etc.
3	Educational planning	Government, planning experts, instructors, students, engineers, engineering organisations,	Educational plans such as course titles (in general), instructor training systems, and everything related to education)out of class(
4	Curricula planning	Instructors, students, engineers, engineering organisations. Philosophers, …	Textbooks, training methods, cases, courses (in detail), and everything related to education)in class(
5	Writing textbooks	Engineering and philosophy experts	textbooks
6	Holding seminars, workshops, etc.	Higher educational centres, professional organisations, instructors, researchers, engineers, students	Skills, knowledge, virtues, etc.

Engineering practice			
	Action Situations	Participants	outcomes
1	Writing and accrediting ethical resources (codes, etc.)	Professional organisations, engineers, government	Ethical resources: codes of conduct, oaths, obligations, etc.
2	Legislation	Legislators, government	Laws and regulations
3	Ethical Consulate	Consolers, engineers	Knowledge, skills, better decision making and problem-solving
4	Moral development planning	Ethical Committees, engineering organisational managers, engineers, government, people	Organisational plans
5	Behaviour control and evaluation	Ethical committees, engineering organisations managers, engineers	More moral, professional conduct (moral development)
6	Facing practical moral issues	Engineers, engineering organisations managers, government	Better decisions, Less engineering accidents, higher social safety, security, etc.

Appendix B. Further explanation of Education as a pillar of the NEE framework

Education is one of the main activities that countries undertake to develop engineering ethics. In fact, it is Education that provides the basis for the development of ethical behaviour in professions. Studies on the state of engineering ethics in different countries indicate that the strategies for teaching engineering ethics among countries are different. For example, in some countries, this course is not among the most common courses offered to engineering students, and it is only lecturers who suggest teaching engineering ethics in some semesters, while in some other countries, teaching this course has become a national regulation. In the paragraphs, we explain, according to the framework, these differences by applying the *levels* to engineering ethics education.

1) Operational level

By *operational level* of *Education*, we mean educational situations such as classrooms where learners engage with educators in a learning-teaching process on a topic related to engineering ethics. This action arena, like other action arenas, includes the following constituents.

- Action Situation: such as courses, educational seminars, and workshops executed in a university, educational institute, and professional organisation.
- Participants: Includes learners such as engineering students (undergraduate, graduate, PhD), engineers interested in entering the profession of engineering, professional engineers, and trainers such as philosophers or engineers.
- Interaction: Includes the methods of teaching-learning such as micro-insertion, case-based and lecture methods and educational resources, such as textbooks, articles, and case studies.
- Output: The result of such an education could be learners taking this course with moral problem-solving skills, moral sensitivities, moral motivation, and moral character [17].
- Evaluation criteria: Measures by which educational systems evaluate the success of Education, such as exams and research assignments.

2) Organisational level

By organisational level, we mean the level of activity that manages operational activities (courses). These activities, which are generally performed in sections, departments, and universities (educational institutions), or professional organisations, include planning, monitoring, controlling, and evaluating Education and related matters such as human resource management. This activity may have several layers of decision-making.

- Action situation: educational management

- Participants: members of educational committees (groups, councils) in a section or department of an educational organisation/professional organisation
- Interaction: In this constituent, how to analyse educational issues and make decisions in educational committees is examined. For example, how do committee members interact with engineering professionals or philosophers in the process of curriculum development? Do they interact with other participants at other levels and pillars?
- Outcome: Engineering ethics curriculum, including course design, educational resources, lecturer qualifications, admitted lecturer, etc.

3) Governmental level

We mean the governmental level of education, activities related to policymaking, strategy design, legislation, regulation setting and educational guidelines, and educational planning for the whole country. At this level, questions are asked to determine the role of government and how much this intervention has affected the activities of higher education levels.

- Action situation: This concept pays attention to the decision-making positions of the government at the national level for the realisation and development of ethics. At this level, questions such as the following are asked: Has the government validated engineering ethics training in higher education or training in professional organisations? What is the extent of government intervention in engineering ethics education? Regarding engineering ethics education, what are the decision-making positions in the government?
- Participants: What committees (council, group) have participated in the relevant decisions? What are the competencies of the members of these committees, and what is their role?
- Interaction: How do the participants interact with each other? What issues have they considered? What kind of interaction do they have with the participants of higher levels of decision-making and operations, other pillars, as well as other groups in the society?
- Outcome: What decisions have been made by the government regarding engineering ethics education, such as laws, guidelines, regulations, and curriculum?

Appendix C. A study of engineering ethics education in Chinese universities (Working example)

In this section, we will show how the presented framework in my paper will contribute to a better and richer understanding of engineering ethics in a specific country. To that end, we will apply my framework to an earlier published paper about Chinese universities. So, building on what they have done, we will show how the information they collected can be put into the NEE framework and, in this way, can be connected to other information from other publications by others, giving more comprehensive insight.

The paper by Qian Wang and Ping Yan [18] deals with engineering ethics education in Chinese universities. To this end, they consider five universities to be representative of Chinese universities. This paper includes sections on course curricula, teaching content, teaching methodologies, and evaluation of teaching. In each section, in addition to describing the current situation, assessments and recommendations are made.

Categorising the information of the paper based on the framework, we will examine the categories and concepts of the framework covering the information of the paper and how it describes and categorises the information.

Using the NEE framework, the information presented by Qian Wang and Ping Yan fits into two action arenas, including the situations of education in the class (operational level) and the situations of educational management in universities (organisational level). As explained in the previous section, in the operation level of education, the interactions of lecturers and students during the teaching-learning process in the course are examined. Also, at the organisational level of education, the interactions of experts and administrators in university committees for the educational management of engineering ethics are analysed (Fig. 3).

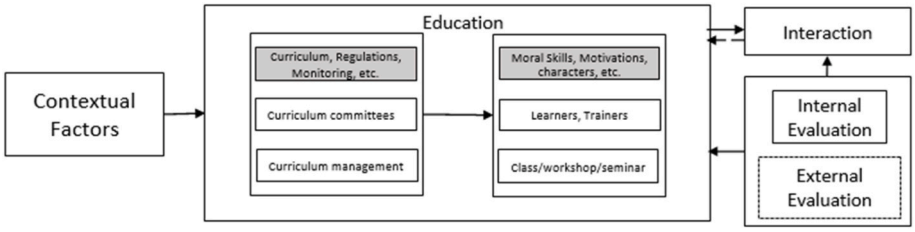


Fig. 3. The part of the NEE framework contributes to the case

Analysis of Chinese engineering ethics courses (operational level)

As explained earlier in this paper, to analyse the courses of engineering ethics according to the NEE framework, we should explore the concepts of action situations, including course profiles, learners and teachers, educational objectives, teaching methods, resources and content, and finally, the methods of evaluation.[3] Therefore, my suggestions for this level of education are:

First, the framework emphasises that action situations should be explored in detail. Therefore, the concepts related to these courses, such as the educational objectives, resources, teaching and evaluation methods, could be added to the information and analysed separately.

Second, although the paper briefly presents data regarding the degree to which students participate in these courses, the framework emphasises that participants need to be identified. What kind of students are eligible to take part in the classes? For example, are first-year students able to register

[3] According to Ostrom, in a more in-depth analysis, the main concepts of an action situation are *participants*, *positions*, *actions*, *information*, *control*, *net costs and profits*, and *potential outcomes*. These concepts are used to provide a more accurate analysis of the operational level (Appendix D).

for these courses? Also, regarding lecturers, what competencies should they have to teach engineering ethics in Chinese universities? For instance, Are they philosophers, engineers, or both of them?

Third, regarding the teaching evaluation section in the paper, distinguishing internal and external evaluation criteria, the framework suggests that researchers in their report not only identify the problems in course evaluation methods but also describe how engineering ethics lecturers evaluate their students.

Finally, the NEE framework emphasises the role of contextual factors in action situations. By identifying these exogenous variables and their roles in engineering ethics, analysers will be able to do institutional analysis and provide recommendations to develop engineering ethics in the country. In this case, the paper refers to the content of China in different places and its impact on engineering ethics courses. For instance, it emphasises that the traditional Chinese ethics and the traditional methods of ethics teaching have influenced these engineering ethics courses, and along with the content of western ethical thought and methods, should be applied more. It also states that the rapid development of technology in China and the growth rate of the engineering graduate population have led to more attention to engineering ethics in the country. Also, "because of the Chinese education system from the 1950s through the 1970s, cultivation of moral consciousness and the ethics of engineering students and technical staff have been integrated with ideological and political education. There has not been a relatively independent, professional education in science and technology ethics. Some people unconsciously behaved unethically in their scientific research and production activities" (p 1727). In this regard, the framework suggests that researchers should focus more on which rules participants should apply and how environmental conditions (such as the states of the country's development) and attributes of the community (such as traditions and religions) affect the conceptual components of the action situation such as educational objectives, content and teaching methods. These are valuable additions that could help draw a richer picture of the national engineering ethics in China. These are additions that the NEE Framework proposes to the NEE analysts. If the information collected from other studies on China is placed in the framework, it can provide a more comprehensive picture of the state of national engineering ethics in the country.

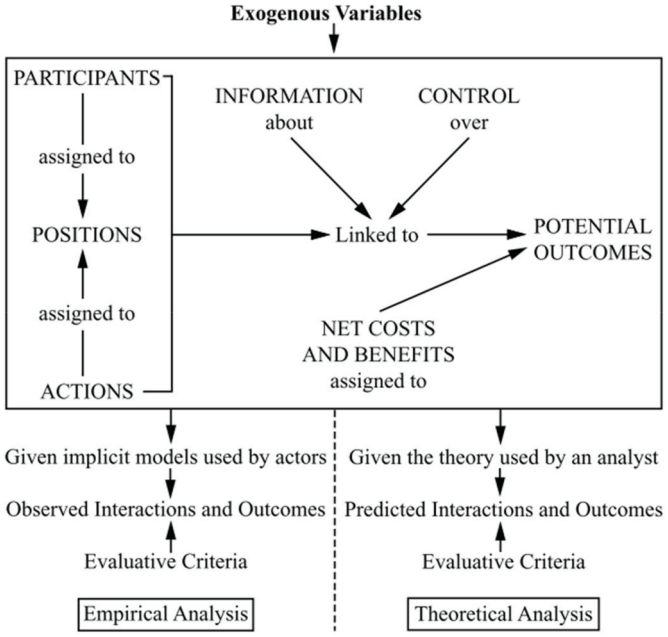
Analysis of Chinese curriculum management of engineering ethics (organisational level)

The organisational level, instead of focusing on the interactions of lecturers and students in courses, focuses on the interactions of participants in university curriculum committees who are developing and monitoring the curriculum. In the paper, the authors provide useful information about this level of activities that helps us understand some decisions in engineering ethics education. For instance, we learn from the paper that these five Chinese universities, in addition to introducing western ethics and the case studies introduced in the international resources, pay attention to the Chinese ethical traditions and the traditional teaching of Chinese ethics and Chinese cases. They exchange educational resources and content. Also, they aim to play a leading role for other universities.

The NEE framework suggests answering the following questions to better understand and evaluate the interactions and outcomes: Who participates in these committees, and what are their qualifications? What rules and restrictions announced by the government affect their decisions? What decisions (such as policies and strategies) have these committees made? What is the evaluation of these committees regarding the current state of engineering ethics in their universities? What is the researchers' evaluation of the activities and outcomes of these committees?

To conclude, applying the NEE framework in this study could make the information better organised and identify necessary information that leads to better system analysis. The better we analyse the NEE system, the better we can develop it.

Appendix D. The internal structure of an action situation



References

[1] Christelle Didier, Engineering ethics at the Catholic University of Lille (France): research and teaching in a European context, Eur. J. Eng. Educ. 25 (February) (2000) 325–335, https://doi.org/10.1080/03043790050200368.

[2] Michiel Brumsen, Ethics in engineering in The Netherlands: the role of professional associations, universities, and law, Int. J. Eng. Educ. 21 (3) (2005) 391–401.

[3] Hengli Zhang, Michael Davis, Engineering ethics in China, Bus. Prof. Ethics J. 37 (1) (2018) 105–135, https://doi.org/10.5840/bpej201821967.

[4] Geoffrey M. Hodgson, What are institutions? J. Econ. Issues 40 (1) (2006) 1–25, https://doi.org/10.1080/00213624.2006.11506879.

[5] Douglass C. North, Institutions, institutional change and economic performance. Political Economy of Institutions and Decisions, Cambridge University Press, Cambridge, 1990. https://books.google.com/books?id=oFnWbTqgNPYC.

[6] E. Ostrom, R. Gardner, A. Agrawal, J. Walker, J.M. Walker, J. Walker, *Rules, Games, and Common-Pool Resources*. ACLS Humanities E-Book, University of Michigan Press, 1994. https://books.google.com/books?id=DgmLa8gPo4gC.

[7] Clifford Geertz, What is a country if it is not a nation? Brown J. World Aff. 4 (2) (1997) 235–247.

[8] Sara R. Jordan, Phillip W. Gray, Responsible conduct of research training for engineers: adopting research ethics training for engineering graduate students, in: Engineering Ethics for a Globalized World, Springer, 2015, pp. 213–228.

[9] Gary Lee Downey, Juan C. Lucena, Carl Mitcham, Engineering ethics and identity: emerging initiatives in comparative perspective, Sci. Eng. Ethics 13 (4) (2007) 463–487, https://doi.org/10.1007/s11948-007-9040-7.

[10] Brock E. Barry, Joseph R. Herkert, Overcoming the challenges of teaching engineering ethics in an international context: a us perspective, in: Engineering Ethics for a Globalized World, Springer, 2015, pp. 167–187.

[11] Abdi O. Shuriye, Mohammad H. Hassan, Waleed F. Faris, Islamic engineering ethics: foundation, integration and practice, Future Text Publication (2006) 67–73.

[12] E. Ostrom, Understanding Institutional Diversity, Princeton University Press, Princeton, 2005.

[13] Michael D. McGinnis, An introduction to IAD and the language of the Ostrom workshop: a simple guide to a complex framework, Pol. Stud. J. 39 (1) (2011) 169–183, https://doi.org/10.1111/j.1541-0072.2010.00401.x.

[14] C.E. Harris, M.S. Pritchard, M.J. Rabins, Practicing engineering ethics. IEEE Engineer's Guide to Business, IEEE, 1997. https://books.google.co.uk/books?id=iYdRAAAAMAAJ.

[15] Christelle Didier, Engineering ethics in France: a historical perspective, Technol. Soc. 21 (4) (1999) 471–486, https://doi.org/10.1016/S0160-791X(99)00029-9.

[16] Heinz C. Luegenbiehl, Ethical autonomy and engineering in a cross-cultural context, Techné 8 (1) (2004) 57–78.

[17] D. Narvaez, J. Rest, The four components of acting morally, Moral behavior and moral development: An introduction 1 (1) (1995) 385–400.

[18] Qian Wang, Ping Yan, Development of ethics education in science and technology in technical universities in China: commentary on ethics upfront: generating an organisational framework for a new university of technology, Sci. Eng. Ethics 25 (6) (2019) 1721–1733, https://doi.org/10.1007/s11948-019-00156-6.

[19] Vivian Weil, The rise of engineering ethics, Technol. Soc. 6 (4) (1984) 341–345. http://www.sciencedirect.com/science/article/B6V80-4665H3F-16/2/b7655ebd0b345128cd41cf41587c7c9f.

[20] Alois Huning, Carl Mitcham, The historical and philosophical development of engineering ethics in Germany, Technol. Soc. 15 (4) (1993) 427–439, https://doi.org/10.1016/0160-791X(93)90014-F.

[21] Fei Guo, Xu-gang Wang, Introducing engineering ethics in China: background, aim and solutions, J. Huazhong Univ. Sci. Technol. (Nat. Sci. Ed.) 4 (2009) 23.

[22] Christelle Didier, Engineering ethics: European perspectives, in: Ethics, Science, Technology, and Engineering: A Global Resource, 2015, pp. 87–90. http://hal.univ-lille3.fr/hal-01668152.

[23] Natsume Kenichi, Japan's Engineering Ethics and Western Culture: Social Status, Democracy, and Economic Globalization, Lexington Books, Lanham, 2021.

[24] Stephen Johnston, Helen McGregor, Elizabeth Taylor, Practice-focused ethics in Australian engineering education, Eur. J. Eng. Educ. 25 (4) (2000) 315–324, https://doi.org/10.1080/03043790050200359.

[25] Andrew Roncin, Thoughts on engineering ethics education in Canada. Proceedings of the Canadian Engineering Education Association (CEEA), 2013, pp. 13–17, https://doi.org/10.24908/pceea.v0i0.4909.

[26] Balamuralithara Balakrishnan, Fumihiko Tochinai, Hidekazu Kanemitsu, Engineering ethics education: a comparative study of Japan and Malaysia, Sci. Eng. Ethics 25 (4) (2019) 1069–1083, https://doi.org/10.1007/s11948-018-0051-3.