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Eng+ | Ethics For Sustainable Development In Engineering Programmes A Praxis Report Of Tu Berlin's Think Tank Technology Reflection

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ENG+ | ETHICS FOR SUSTAINABLE DEVELOPMENT IN ENGINEERING PROGRAMMES

A PRAXIS REPORT OF TU BERLIN'S THINK TANK *TECHNOLOGY REFLECTION*

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ABSTRACT

Many technical universities alike, TU Berlin is in a future-oriented process of programme transformation to invite a holistic perspective on technology which includes critical thinking and ethical reflection. To this end, TU Berlin recently issued a general study guideline calling for an orientation of all programmes toward sustainable development. Accordingly, students should know about the historical, social and cultural contexts of science and technology and learn to reflect on the ethical consequences of their actions. Together with training in good scientific practice, this content should comprise 12 ECTS in each respective BA and MA programme. With only minor integration of this content in the current curricula to date, this transformation presents a significant challenge since courses need to be realigned as well as replaced. To find an answer, TU Berlin's engineering faculty initiated a think tank in spring 2022, bringing together students, teachers and administration to search for ways of integrating ethics as well as science reflection and technology reflection to foster sustainable development. In our contribution we present a first outcome, namely the integration framework ENG+ for programme design which allows for the incorporation of ethics and strengthening of core values such as diversity, sustainability, and good scientific practice. In the ENG+ framework, we introduce the strategies of advancing and complementing as well as six corresponding measures for integration – emphasising, empowering, embedding, enabling, enriching, and encountering. We explain how they jointly contribute to the overarching ENG+ concept which brings together ethical reflection and sustainable development.

1 INTRODUCTION

TU Berlin's new General Study and Examination regulation requires that at least 12 credit points (in the following addressed as ECTS) need to be devoted to ethics, science reflection and technology reflection in every degree programme to foster sustainable development. Hence, the key question is: how can these topics be implemented in the TU Berlin engineering programmes? As the structure of the programme design is fixed due to the required 180 ECTS for Bachelor's and 120 ECTS for Master's degrees, a redesign is needed. The TU Berlin has approximately 35,000 students, of whom 5,454 are enrolled at the *Faculty of Mechanical Engineering and Transport Systems*. This requires an enormous transformation at our institution, which will take a lot of time and resources. Furthermore, it requires a fundamental change in the approach to teaching philosophy as well as to engineering. Since the TU Berlin has thus far lacked experience in systematically implementing ethics, sustainability, and gender and diversity perspectives in study programmes, the faculty initiated the *Think Tank Technology Reflection* in spring 2022 where students, teachers and administration come together in monthly meetings. As members of the think tank, we want to present the ENG+ framework for programme transformation as a first result from the think tank process.

Regarding the overarching aim of the transformation, we want to point out three aspects which specify the unique starting point of our engineering faculty, in terms of its opportunities and challenges. Firstly, as engineers, we are already sustainable in terms of cost and material reduction. Hence, there is a basic understanding of sustainability and approaches at hand which can be built upon. Secondly, due to the engineering departments of our institution (e.g. transport, product development, machine design, human factors) we have a good thematic foundation for human-centred design processes which can be extended to include broader societal and ethical reflections. Thirdly, there is a strong emphasis on making and doing, which comes with a lack of discussion culture in engineering education. The latter, however, is essential for implementing ethics, science and technology reflection. Thus the appreciation and training of discussion and reflection represents a major challenge when it comes to curriculum transformation.

Our paper starts with an overview of the main challenges reported in the literature (Sec. 2). How these will be tackled by the strategies and measures of the ENG+ framework is the topic of Section 3. Section 4 shares the challenges of the ongoing process. We conclude with an outlook of the next milestones.

2 CHALLENGES OF INTEGRATING ETHICS, SCIENCE AND TECHNOLOGY REFLECTION INTO ENGINEERING PROGRAMMES

Since the 1980s the necessity of ethics education and the importance of strengthening reflection competencies has been consistently highlighted in the literature of engineering education (Grunwald 1999; Mitcham and Englehardt 2019; Sætra and Danaher 2022; Fiesler, Garrett, and Beard 2020). Nevertheless, advancement has been slow, and "the question of the integration of the ideal of

engineering education for ethics has been largely ignored" by academic research (Martin, Conlon, and Bowe 2021, 24). Although there are good examples of the integration of ethical reflection into engineering programs, such as programmes at TU Twente and TU Delft (van de Poel and Smuga-Fries 2015; Doorn 2021), there are still challenges to overcome.

In the literature of engineering ethics education, two main challenges have been reported. Firstly, teachers often struggle to understand and ensure alignment among the variety of theoretical frameworks, learning objectives, instructional activities, and assessment methods. There are numerous interrelated learning objectives, but no consensus in the literature as to which strategies are most effective in achieving them or which objectives should be prioritized (Martin, Conlon, and Bowe 2021). This means that teachers find it particularly difficult to formulate ethical learning objectives for their courses or modules (ibid.) – especially because of a lack of familiarity with ethical issues and methods. This raises the problem of deriving appropriate didactic as well as pedagogical content and methods to connect ethical issues to technical ones. To address this issue, co-teaching activities can be implemented, in which engineers work together with philosophers and social scientists to integrate socially relevant aspects into technical contexts and to show that ethics and technical thinking go hand in hand. The approach can be improved by integrating ethical mini-modules into existing modules, so that students become habituated to reflecting ethically. In this way, students can learn about a variety of concrete ethical issues and problems in their field.[1] Co-teaching also provides another additional advantage, as "interdisciplinary ethics learning provides a better basis than disciplinary ethics learning" (Mitcham and Englehardt 2019, 1756).

Secondly, institutional framework conditions and a lack of support from the administration represent another major obstacle. The challenges listed above are further compounded by institutional constraints: the prominence given to ethics in the curriculum is critical to conveying the message to students that ethics is not a peripheral issue in engineering, but an essential aspect of their profession (Mitcham and Englehardt 2019; Fiesler, Garrett, and Beard 2020; Martin, Conlon, and Bowe 2021). This is why the "top-down support to secure appropriate embedding in the university" cannot be stressed enough (Mitcham and Englehardt 2019, 1756). To ensure appropriate embedding in the university, support is needed from the administration. As it is clearly an important, and certainly open, question how to make room for new content in full curricula, thus a coherent and focused overall strategy for a unified curriculum is needed. In order to make societally relevant aspects central to education, having a coordinated institutional response is a central requirement (cf. Martin, Conlon, and Bowe 2021). Support from the institution is also needed to implement support services such as professional training, joint

[1] A good example of an integrative, overarching approach can be seen at the TU Twente and TU Delft ("RESTS REflection on Science Technology and Society (RESTS)" n.d.; van de Poel and Smuga-Fries 2015; Doorn 2021).

development of course content or teaching (for example, in the sense of co-teaching), or mentoring and networking opportunities (cf. Mitcham and Englehardt 2019). Prioritization of an implementation strategy is the only way to ensure systematic implementation of a unified curriculum.

A key learning from these reports is that a coherent and targeted strategy at the institutional level is needed to implement ethics systematically in engineering programmes. As a first step, this requires an overarching concept at the programme level which breaks down to the second step of a curriculum redesign at the course level with appropriate learning goals. To set such goals, working together with philosophers and social scientists as well as program committees is essential for connecting ethical reflection to the discipline-specific content of the programs. Additionally, further support from the institution is necessary regarding training courses to help teachers learn about ethically relevant issues in their discipline, support them in formulating ethical learning goals, and develop teaching material for their courses.

3 ENG+ FRAMEWORK: INTEGRATING ETHICS, SCIENCE REFLECTION AND TECHNOLOGY REFLECTION INTO ENGINEERING PROGRAMMES

3.1 Background

A starting point for the transformation process at TU Berlin was a long-range, university-wide vision for teaching which was adopted in 2018. It includes educational goals and combines academic education with personal development:

> *The mission statement for teaching […] forms the basis for all regulations, rules and strategies that determine teaching at the TU Berlin. It must be reflected in all study and examination regulations, in the curricula and in quality management for studies and teaching. […] Our teaching enables students to face technological change and its social impact with creative ability, a sense of responsibility and high professional qualifications. (Technische Universität Berlin 2018, 5-6)*

This mission statement has been transformed into a binding requirement for all Bachelor's and Master's programmes by the new General Study and Examination regulation (AllgStuPO):

> *[1]In the study programmes, the rules of good scientific practice are taught at the earliest possible stage and continuously trained. [2]Students learn to place knowledge and action in an overarching historical, social and cultural context and to consider ethical consequences of action in order to be able to contribute to sustainable development. [3]It is to be ensured that all students have completed relevant study content amounting to at least 12 ECTS by the time they graduate. (Technische Universität Berlin 2021, §44, 3)*

To respond to the new AllgStuPO, members of the *Faculty of Transport and Mechanical Engineering* launched the think tank at an internal faculty meeting in spring 2022. Its aim is to develop an overarching strategy for integrating ethics, science reflection and technology reflection. It should serve as a vision for curriculum redesign and, as a follow-up step, the (re)design of courses. The think tank's

monthly hybrid meetings brought together students, teaching and administrative staff, as well as two women's representatives. Since the think tank raised interest also from other faculties as well as the university's central administration, we were able to draw on perspectives across the university.

3.2 ENG+ Framework: Strategies and Measures

As a first result of the think tank, we want to present an overarching heuristic for integrating ethics as well as science reflection and technology reflection to foster sustainable development. Methodologically, the think tank started with a literature review of the key learnings and challenges when trying to integrate ethics into engineering education (see section 2). A coherent and targeted strategy at the institutional level was then identified as the central goal. Subsequently, a conceptual analysis of possible ways to connect ethical reflection to the discipline-specific content of the programs was conducted. As a result, the integration framework ENG+ offers different ways of implementing these topics in programme design. Contextualizing engineering problems allows students to see their broader societal and environmental impact, to understand the interrelation between technology and society, and to grasp potential ethical risks in emerging technologies. From a traditional (disciplinary) point of view, this endeavor is of a deeply interdisciplinary nature, as it brings to the engineering curriculum knowledge and competencies rooted in philosophy, humanities, and social sciences. However, ENG+ is less about including additional disciplinary viewpoints, but rather introducing students to holistic thinking and enabling them to experience the intrinsic complexity of technology.

To arrive at an integrated programme design, ENG+ draws on two major strategies, advancing and complementing, which need to go hand in hand (see fig. 1).

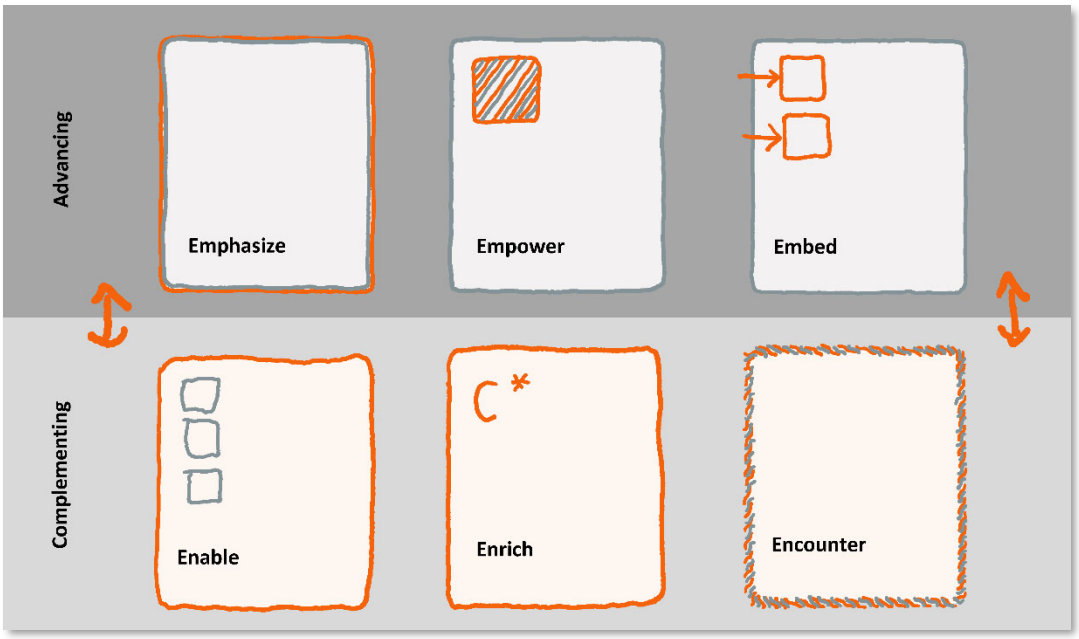

Fig. 1. ENG+ framework to integrate ethics, science reflection and technology reflection into engineering programmes. Graphics: S. Ammon 2023

Advancing aims at the further development of existing STEM courses to show the relevance of ethics and reflection for engineers, as well as the connection to STEM topics. Advice, training and targeted support for STEM teachers will play a key role here. Advancing comprises the following measures:

- **Emphasize**: further development of existing STEM courses that have already integrated ethics, science reflection and/ or technology reflection and establish the contribution of these areas to sustainable development within the framework of the subject of the course. Targeted emphasis will make this orientation more visible and strengthen it.
- **Empower**: further development of existing STEM courses that have not yet integrated ethics, science and/ or technology reflection. Through targeted guidance and training, teachers are empowered to integrate ethics, science and/or technology reflection and to establish the contribution of these areas to sustainable development within the context of the course topic.
- **Embed**: further development of existing STEM courses that draw on the expertise of ethics, humanities and/ or social science experts to embed ethics, science reflection and/or technology reflection. For this purpose, mini-modules (e.g., 2-6 h per week) are integrated into the existing course in order to incorporate questions of ethics, science reflection and/or technology reflection directly into the overarching topic of the course.

Complementing furthers the development of new courses in the area of ethics, science reflection and technology reflection. They should comprise topics such as research ethics, professional ethics, technology ethics, environmental ethics, technology assessment, history of science and technology, or science and technology studies. It will be essential to tailor the content of these courses to topics of the respective STEM disciplines. We recommend that interdisciplinary co-teaching be given a high priority. Complementing comprises the following measures:

- **Enable**: A foundational course that introduces basic ethical concepts and trains ethical reflection practice. The added value of ethical knowledge and ethical competencies for sustainable development is to be made tangible by directly linking ethical issues to topics in the STEM fields. The contextualization of technology and science and their critical reflection play an important role.
- **Enrich**: In-depth courses in the field of (applied) ethics, science reflection and technology reflection. Students can earn certificates, which certify a focus of study. The Faculty of Mechanical Engineering and Transport Systems offers in-house certificates such as the Berlin Ethics Certificate (see Ammon et al. 2022) and the Sustainability Certificate.
- **Encounter**: Interdisciplinarity can be experienced through collaborative teaching and learning in diverse settings by teachers from STEM areas and humanities or social sciences. Differing disciplinary cultures and perspectives can be experienced, along with the relevance of interdisciplinary cooperation. The collaborating teacher acts as a role model.

For a successful programme transformation, the strategies of advancing and complementing need to resonate with each other. That means a complementary curriculum design, mutual references of the courses, as well as an overall vision which draws on sustainable development need to come together. This also implies a *cultural change* which strengthens a culture of togetherness and encourages cooperative forms of teaching and learning. An appreciation of diversity, a non-discriminatory environment, the ability to change perspectives and a constructive approach to divergent opinions as well as to inter- and transdisciplinary are all important elements of this strategy. Teachers serve as key role models in this cultural change.

ENG+ as an overarching vision for programme design ensures that the different measures interrelate with each other. It also shows that it is not required that all courses address the topics of ethics, technology reflection and science reflection to the same extent. The integration of ethics, science reflection and technology reflection is more than the sum of different measures; thus it is the overall effect that counts.

4 HURDLES IN IMPLEMENTING THE ENG+ FRAMEWORK

Since the new General Study and Examination regulation leaves open how the 12 ECTS are covered in the degree programmes, it is up to the programme directors to decide. For the implementation of the ENG+ framework, we suggest a pragmatic approach in which 6 ECTS are anchored in the engineering programme by advancing and another 6 ECTS by complementing measures.

For **complementing**, a best practice example can be found in the physical engineering programme which has introduced an elective area for students to choose among courses on ethics, sustainability, as well as gender and diversity. However, choosing e.g. a course on sustainability would not necessarily imply that students are taught ethics. This leaves open the question of how it can be ensured that every student learns about basic concepts and approaches of applied ethics.

Another obstacle is that traditional, conservative ways of thinking that can cause difficulties in creating space for new topics in the curriculum. Teachers who see the training of technical competences as the sole goal of engineering education may be resistant and underestimate the relevance of critical reflection and the ability to act sustainably and responsibly.

When it comes to **advancing**, a high level of topics surrounding ethics, science reflection and technology reflection is desirable. However, not every course will be suitable to cover these issues in a meaningful way. For courses like linear algebra or other basic mathematical subjects, an integration might seem rather forced and far-fetched. The advancing strategy also comes with measuring challenges for examination administration. Once the topics are dealt with in an integrative way, how can the 6 ECTS be detected? For example, in a 6 ECTS course which deals to some extent with issues of gender and diversity, how many transformation points does it cover? Should a course which deals with the design of wind turbines be counted in

full towards covering sustainability, simply because wind turbines are counted as renewable energy? There are currently no sensible answer to such questions.

In addition, the strategy of advancing requires that teachers be empowered to integrate ethical issues into their technical courses. This requires expert advice and support or training for teachers. Probably the biggest obstacle to the implementation of this strategy is funding, as well as the creation of free time in everyday university teaching. The use of initiatives to promote innovation in teaching, as well as centralized university training, can provide at least some support. Also, teachers must be encouraged to further develop themselves and their courses in this direction. This requires suitable incentive systems.

At the same time, however, this can also contribute to the cultural change needed to support the overall transformation process. Raising awareness among faculty members through structural measures and promoting formats for exchange and networking between teachers can contribute to a culture of togetherness. Collaborative forms of teaching, which could contribute to this cultural change, currently face administrative obstacles. For example, the crediting of co-teaching courses cannot be taken into account in teaching performance according to effort. Existing calculation models should be reviewed to ensure that teachers have the freedom they need to develop themselves and their courses. It is clear that the transformation process needs to be supported by overarching measures, which still need to be identified.

5 OUTLOOK

After having developed the ENG+ framework, the next step will be its implementation and testing within a prototypical engineering programme. To this end, a process of quality assurance needs to be developed, which includes reporting to and feedback from the executive board. The process of redesigning programmes as described above takes time, a lot of resources and commitment. Thus it is important to raise awareness and empower teachers to integrate ethical issues into their courses. It is also necessary to have administrative and professional support for the change process. To this end, we want to use the ongoing think tank to encourage exchange and networking among faculty members, as well as to facilitate formats such as workshops, peer-to-peer consultations, mutual shadowing, expert support and learning from other institutions.

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