Teaching and Learning Ethics in BEng Programmes
Technical University of Denmark

T.E. Nielsen
Educational Consultant
LearningLab DTU
Lyngby, Denmark
E-mail: tien@llab.dtu.dk

B. Lund Christiansen
Head of Center
Learning Lab DTU
Lyngby, Denmark
E-mail: blc@llab.dtu.dk

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INTRODUCTION

Although it has long been recognized that ethical considerations, beliefs and values are a profound part of the engineering profession, some universities still struggle with how to incorporate the ethical field in engineering education curricula. There are nevertheless many good examples of how to work with ethical issues in engineering education [1,2,3] and some even use cross-curricular activities as a way to strengthen the ethical "maturity" of students [4]. In Europe, the European Society for Engineering Education, SEFI, established a working group on Ethics in Engineering Education in 1998, with the aim of integrating the ethical discipline into engineering education, while acknowledging that the challenges posted by ethics are different in nature compared to the field of engineering; ethics being more inexact and relative [5,6].

Another community-based approach originates from the CDIO (Conceive-Design-Implement-Operate) initiative where "professional ethics" is one of the educational outcomes included in the CDIO standards. One of the standards encompasses an extensive "syllabus" that specifies relevant engineering competencies organized in four categories: (1) disciplinary fundamentals, (2) personal and professional, (3) interpersonal and (4) system building skills. As a part of category 2, "professional ethics" are – along with integrity, responsibility and accountability – defined as "personal values and attitudes that are used primarily in a professional context". It is further specified as "one's ethical standards and principles", "the possibility of conflict between professionally ethical imperatives", and "an understanding that it is acceptable to make mistakes, but that one must be accountable for them" [7,8].

Since 2008, all Bachelor of Engineering (BEng) programmes at The Technical University of Denmark (DTU) have been based on the principles for engineering education defined by the international CDIO initiative [9,10]. The BEng is a 3½-year programme – including 5 months mandatory internship at a company - which qualifies the students to take on jobs within the industry, e.g. in production units, project management or control and support functions.

While the general aim for the 18 DTU BEng programmes is a full implementation of all CDIO standards, there still are "blind spots". One issue that has been identified as a generally weak point is the lack of a systematic approach to ethics (ref. CDIO Syllabus section 2.5).

In this paper, we present such an approach to integrating engineering ethics into the curriculum. In a pilot project, programme coordinators and other faculty members have been involved in a process together with a project coordinator and experts from the ethical field to find the best way of working with ethical dilemmas in 4 BEng programmes. The goal of the pilot project is to develop and try out a new model consisting of an introductory module that should provide the basis for implementing ethical thinking later in the education programme. The introductory module should be integrated in a mandatory course, and it should as far as possible be applicable across all DTU BEng programmes while still letting the students work with programme-specific ethical issues.

The development of this model for teaching ethics, the elements of the introductory module, and the preliminary results from teaching the module in 3 of the 4 programmes that are part of the pilot project will be described. Conclusions regarding future adjustments and application of the model in the rest of DTU's BEng programmes are drawn.

1   THE CHALLENGE OF TEACHING ETHICS AT A TECHNICAL UNIVERSITY

By nature, core engineering disciplines imply exact data, well-proven methods and predictable consequences of technical solutions. Teachers of engineering subjects are themselves trained in finding the right – or best possible – solutions to given problems, according to specified standards. This applies even when the problems are open, as there are certain agreed ways of thinking as an engineer within a specific field. On the other hand, when dealing with ethical issues there are no absolute right or wrong answers, and standards for solutions are disputable. Ethics involves considerations about values, convictions, and social or environmental consequences of choices. One can speculate that it is due to the differences in the research fields of engineering and ethics, respectively, that ethics are neglected in the learning objectives of engineering curricula [1,5]. The unfortunate impact is that students have mostly worked with these important aspects of the engineering field on a surface level.

This general problem may explain that in spite of a general agreement at DTU that ethical issues could and should be addressed as an integral part of at least some projects during each education programme, it has not resulted in much practical implementation. During discussions and activities involving programme coordinators and teachers, leading to the start of a pilot project, a number of difficulties and barriers were identified. A main barrier seems to be teachers' lack of systematic and profound knowledge about ethics. Furthermore, there is some reluctance to work with the field of ethics which by nature differs so much from the traditional engineering disciplines that the teachers are specialized in.

2

Likewise, the students' motivation for working with ethical issues seems to be influenced by the reluctance to move outside the comfort zone that the more rigid engineering disciplines represent. This is enforced by the fact that most students do not have a perceived need to work with ethics.

Finally, there are difficulties on curriculum level. It is a challenge to add more content and activities to an already overloaded curriculum, and ensuring relevant follow-up activities at different stages during the educational programmes requires a considerable amount of coordination between a large number of faculty members.

The development of a viable model for integration of ethics in the curriculum and the learning objectives of the DTU BEng programmes should address these identified difficulties.

2 ETHICS AS AN INTEGRAL PART OF THE CURRICULUM

2.1 Project start and project organization

Based on these recognized difficulties, a focused effort was initiated at DTU by the Dean of Undergraduate Studies and the coordinators of the BEng programmes early 2013. The aim was to establish a model for integrating engineering ethics into the curriculum of all BEng programmes.

A half day seminar for programme coordinators and other teachers was organized to provide a basis for a more informed discussion on how to address ethics in the BEng programmes. Experts in ethics were invited to introduce ethical concepts, theories and reasoning, and to organize a case-based workshop with a focus on ethical dimensions. The conclusions of the seminar were consistent with the general challenges for teachers with a technical background of teaching ethics, leading to an articulated need of faculty training and support from experts to design and implement teaching activities in ethics. Besides, it was concluded that working with cases seems to be the best way of learning to apply ethical reasoning.

Based on these conclusions, a pilot project was started, involving 4 of DTU's 18 BEng programmes with the aim of establishing a model for teaching ethics that can be tested, refined and applied to the rest of DTU's BEng programmes. The programmes represent a variety of disciplines (Electrical Engineering, Building & Civil Engineering, Traffic & Transportation and Healthcare Technology), and the programme coordinators all volunteered to be part of the pilot program. An external expert was associated to the project, and a project coordinator from DTU's central pedagogical development centre was appointed.

The pilot project that runs in 2014-2105 includes the following activities:

1. Design of an introductory module for students.
2. Teachers' training.
3. Teaching the introductory module for the students at each of the 4 programmes.
4. Evaluation and adjustments.

2.2 Design of an introductory module for students

Early in the project it was decided to design a 1 day introductory module that should be integrated into a mandatory course on each study programme, consisting of half a day of lectures and class-room discussions that introduce core concepts, and half a day's workshop where students work in groups with a programme-specific case.

3

This model meets the intention of developing a module that is applicable across all DTU BEng programmes while still letting the students work with programme-specific ethical issues.

Working with concrete cases closely related to one or more core disciplines of the individual programme is a way to address the need for relevance and meaning for the students. Instead of organizing stand-alone courses where students can be taught a more substantial amount of relevant skills and in-depth knowledge but with the possible drawback that they are perceived as soft subjects with no real importance to their own field of study [5], or general events for students across all study programmes – which had been suggested as a cost-efficient model at DTU - the focus should be on cases developed in a bottom-up process thus ensuring relevance and sense of meaning for both teachers and students involved.

To further create motivation and as a framing for ethics in engineering programmes it was decided that sustainability should be a common theme in all cases. To some extent all programmes already include the possible impacts engineering solutions have on the social, economic or natural environment, and therefore it made sense to build the ethical dimension into the curriculum using the sustainability approach.

With this integration of ethics and sustainability, the following learning objectives were defined for introductory module:

- The students should be able to apply relevant ethical theory on engineering problems so as to identify the underlying values behind decisions.
- The students should be able to identify central sustainability issues in engineering problems.

2.3 Teachers' training

To meet the identified needs for faculty training and support, a 1½ days course was established for study programme coordinators and other teachers involved in the pilot project. The aim was to make the teachers able to

- Develop appropriate programme-specific cases for their students.
- Supervise their students' case work in the workshops.
- Include, supervise and assess ethical reasoning in later parts of the education.

The course was taught by the external expert in ethics. During the course, the teachers were given the opportunity to learn about central ideas in ethics, find an appropriate and relevant ethical dimension of their own field and construct a professional case for their students' case work with the guidance of the expert. Between the first and the second day of the course, the teachers identified and made a draft description of the case. During the last half day of the course, the case was further discussed in teachers' groups, and they got advice and feedback from the expert.

The concrete result of the course – a case description with discussion points for each programme – has been a direct preparation for the introductory module for the students. During the last part of this module, the teachers have introduced the case, facilitated the students' case work, and been responsible for the summary – with the support of the external expert.

4

2.4 Teaching the introductory module

2.4.1 Content of the non-programme specific part

The content of the first half day - which is common to all programmes - is:

1. Ethics in everyday living
2. Who are ethical agents, subjects and objects [11]
3. Ethical theories, e.g. Contractarianism, Utilitarianism and Ethics of responsibility
4. Sustainability: social, economic and natural aspects

2.4.2 Content of programme-specific part

This example of a programme-specific case was used in the spring of 2015 at the BEng of Traffic & Transportation.

"One casualty is one too many"

Background: The Danish Commission for Road Safety in 2013 published a report with proposals on how to reduce the (mortal) traffic casualties from 2013 to 2020. The report includes considerations about how much a casualty costs the Danish society and the effects of different interventions to reduce the number.

Students' preparation: students were asked to read the report by the Commission.

Classroom activity: students were asked to work with the following questions on ethics and sustainability:

1. The title on the Commission´s report is "One accident is one too many – one common responsibility". How do you think Utilitarian ethics and Deontological ethics, respectively, would relate to this title, considering both the number of accidents and the notion of a common responsibility?
2. In traffic safety the estimated cost for a human injury is (in 2013) 5.209.408 DKK. How will Contractarianistic ethics relate to this way of estimating? And Utilitarian ethics? Why?
3. Politicians and experts in the field may have different opinions about the proposals from the Commission. What kind of factual disagreements could they have, and what kind of differences in underlying values might they have? Find three examples of each.
4. List at least 10 different forms of transportation
5. Prioritise the 10 forms of transportation such that the most environmentally sustainable form comes first. Explain why you prioritise like you do.
6. Then prioritise so that the most economically sustainable form comes first.
7. And finally prioritise so that the most socially sustainable form comes first.
8. Compare the prioritised lists and identify differences and similarities.

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3. EVALUATION

So far, introductory modules have been run for 3 different study programmes. The number of students has varied from 8 to 30. After each module, evaluation has taken place based on written evaluation forms for students and teachers with closed and open questions, an oral feedback from students, semi-structured observations by the project coordinator, and discussions of the process between teachers and the external expert immediately after the end of module.

A summary of the most important findings among students, teachers and regarding the organizational settings is given below.

The student evaluations showed that:
- All students are satisfied with their learning outcome of the non-programme specific part, i.e. the introduction given by the external expert in the morning session.
- More than 80% finds the introduction by the expert useful for the case work.

- More than 50% think that it is motivating to work with the case.
- More than 50% have developed a more nuanced perception about what ethics is and why it is important for engineers. Examples of comments that support this are: "*I have a better understanding of) different angles of a given problem and their meaning*" and "*You can see things from different perspectives*", "*It gets very complex when you see it from different angles*".
- A number of students express that they have developed a more critical perception of the concept of sustainability, demonstrated by comments like "*You can weigh the concept of sustainability in a* more nuanced way" and "(I am better at evaluating) the buzz word sustainability!"
- More than 50% of the students answer that they will probably not think of ethical issues related to their own field of engineering in the future.

The findings from the teachers' evaluations were that

- Half of the teachers feel sufficiently trained to facilitate their students' case work. However, all should prefer to have more training.
- It is important to have the support from an expert, both when designing the case and during the introductory day, including the students' case work.
- The case work functions as a lever to get the students into ethical thinking in engineering problems. A comment was that the case work "*seems good and relevant for the programme*".
- The structured group work provides a good framework for making students talk to each other about ethical considerations.
- The process of designing and using the case at the introductory day is working, but it would be better to integrate ethical considerations during the entire study programme: "*one could perhaps use the case in a spiral type of learning*".
- The cases need some adjustments, e.g. reduction of amount of background material and clarification of the questions.

Regarding the organizational setting, the evaluation showed that

- A few students were frustrated because the module was placed in a very busy period.
- The introductory module is placed on 4 different semesters at the 4 four pilot programmes. This makes a difference regarding the maturity of students and their openness towards ethical thinking, and this probably has an impact on how well the modules have been evaluated. On the other hand, observations showed that the 2nd semester students in one of the programmes were able to discuss their case on a relatively high level, so the openness and ability to work with ethical considerations may also depend on other factors such as specific experiences from project work in other courses.

4. CONCLUSIONS AND PERSPECTIVES

So far, the pilot project has demonstrated that the chosen approach works well. The development of programme-specific cases were intended to meet the challenge of low motivation for working with ethics among students, and also to improve the learning process and outcome for students as well as teachers. Furthermore, the fact that the module is integrated in a mandatory course, and that the case is developed and presented by the usual teacher(s) has probably contributed to the students' perception of the relevance and importance of dealing with ethical aspects of engineering solutions.

The reactions from the students who have participated in the introductory module until now confirms that the approach has worked as intended. The students in general find the lectures and case work motivating for their learning, and in general they seem to relate to the cases in a constructive way. Their case work demonstrates that it is possible for them to meet the first learning objective, i.e. being able to apply relevant ethical theory on engineering problems. However, there are some reservations regarding mainly relevance and importance for their future work with engineering applications. This outcome shows the significance of planning follow-up actions later in the curriculum, for each study programme.

Another outcome is related to the second learning objective, i.e. being able to identify central sustainability issues in engineering problems. The general positive perception of "sustainability" has been subject to more critical judgement by the students. This should make them able to critically question the use of the concept e.g. when it is used as a public policy statement by companies with the primary underlying aim of selling more products.

The teachers involved in the pilot project in general express a positive experience with both learning about ethics and producing the cases with expert help during the teachers' training course. Being trained through lectures and by constructing a relevant case for their own students makes the somehow intangible new knowledge more concrete and meaningful to the teachers. An important aspect of feeling confident when teaching their students ethics is the joint teaching with the expert that has been offered. In this way, the pilot project seems to have addressed the barriers and difficulties for integrating ethics into engineering curricula by giving the teachers the support they need. The fact that the teachers mention a need for more training is quite foreseeable given that they are facilitating in a rather new area for the first time on this level. It points to a need for considering follow-up training for the teachers.

Based on the experiences from the first part of the pilot project, the following enhancements of the introductory module should be considered:
- Add a requirement for the students to hand in an assignment, based on the case work.
- Include questions about ethical issues and ethical approaches in the final exam for the course where the introductory module is imbedded.

Both suggestions will urge the students to take the work with ethics more seriously, and probably ease the application when they work with engineering problems in the future.

Other points of development that should be considered are
- Identification of appropriate follow-up actions later in the study programme, e.g. in specific courses or projects, the internship, and the bachelor project
- Follow-up training for teachers after they have completed the first cycle of introductory modules for their students.

Finally, some needs for further development are related to the roll-out of the model developed in the pilot project to the rest of the 18 BEng programs at DTU. When all programmes have implemented the introductory module, the module will run 25-30 times per year. The implications are that the external expert can neither teach the introductory lectures nor support the DTU teachers facilitating the case work at every modules. Therefore, the development of a blended learning model is planned. The first half day of the introductory module that is common for all programmes will be transformed into an online course with video lectures and exercises like questions for individual reflection and for group discussions. This module can be placed in the

normal schedule of the course where the ethics module is imbedded. To support the teachers the first time they facilitate the students' case work, internal resources are being identified at the DTU department that is responsible for courses on philosophy of sciences.

5. ACKNOWLEDGMENTS

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