EXPERIENCES IN INTEGRATING ETHICS FOR ENGINEERS IN MSC PROGRAMMES

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ABSTRACT

Engineering ethics is an important part of education since it helps students to deal with issues they can face in their profession. A project was started at Chalmers University of Technology in 2013 with the aim to improve integration of ethics in the Master's programmes in the educational area: "electrical and computer science engineering, software engineering, and industrial engineering and management". In this paper, experiences are shared from this project. The aim is to support and stimulate to similar activities at other universities. The objectives are to describe:

- the *change process* for integrating ethics into Master's programmes at Chalmers,
- *results* of this work, such as amount and type of ethics integrated into the programmes, and differences in content and intended depth of learning,
- *challenges* to accomplish a successful integration of ethics into the programmes.

There has been a successful integration of ethics in the Masters' programmes, and all of the 13 programs now include some ethics. The most important driver has been that the project has been assigned by the dean of education who can put some pressure on the programme directors. Another important reason for a successful result is that the project has continued over several years as long as there has been a need of improvements. Support has been offered to the programme directors and teachers, and there has been a regular follow up of the progress and encouragement of programmes directors. A main challenge has been that many of the programme directors and teachers are unsure about what ethics is all about and how to include it in education. Thus, it has been a good idea to have short term goals that were not that demanding. It has been important that the actual changes are done by the programme directors and teachers themselves, and that no one else has been telling them how to do.

KEYWORDS

Engineering ethics, research ethics, curriculum development, change process, learning outcomes, faculty competence, CDIO standards: 2, 3, 9

INTRODUCTION

Ethics is an important part of education since it helps students to deal with issues they can face in their profession (in line with Standard 2 in the CDIO Initiative, 2010). An effective way to teach ethics is to use cases, and then not only emergency cases that make the news, but more appropriate cases that an engineer more likely is to encounter (Harris et al., 1997; Lynch

and Kline, 2000). To make these cases effective, they should be formulated to re-sail the complex and open conditions applicable in engineering practice (Lynch and Kline, 2000). Thus, there are strong arguments for integrating ethics into courses on engineering topics instead of giving ethics only as separate courses (in line with Standard 3 in the CDIO Initiative, 2010; Harris et al., 1997; Herkert, 2002). However, this may pose challenges for teachers, who may feel unsure of how this type of learning can be implemented and how values can be handled. Teachers may need support or competence development to become comfortable with integrating ethics in their courses (in line with Standard 9 in the CDIO Initiative, 2010; Herkert, 2002).

The Swedish System of Qualifications for engineers includes learning outcomes for research and engineering ethics (Ministry of Education, 2006). There is a long tradition at Chalmers University of Technology to include sustainable development in the study programmes. However, the focus is on the environmental dimension of sustainable development, and the social dimension and ethics are not included to the same extent. Hence, a project was started in 2013 with the aim to improve the integration of ethics in the Master's programmes in the educational area: "electrical and computer science engineering, software engineering, and industrial engineering and management". The project has been successful and resulted in extensive programme and course development but is still running since there is still need of improvements.

In this paper, experiences are shared from the project mentioned above to improve ethics in Master's programmes at Chalmers. The aim is to support and stimulate to similar activities at other universities. The objectives are to describe:

- the *change process* for integrating ethics into Master's programmes at Chalmers,
- *results* of this work, such as amount and type of ethics integrated into the programmes, and differences in content and intended depth of learning,
- *challenges* to accomplish a successful integration of ethics into the programmes.

Lessons learnt and recommendations for how to support programme directors and teachers to accomplish such a change are included in the discussion. In this paper, the focus in on the change process and intended learning outcomes, and it does not include descriptions of teaching and learning situations and assessment in ethics.

METHOD

Methods for change processes

The change process to integrate ethics in the Master's programmes has been inspired and used element from change processes described in the literature by Kotter (1995) and Holmberg et al. (2012).

Kotter (1995) suggests that a successful change process goes through a series of eight distinct stages: establishing a sense of urgency; forming a powerful guiding coalition; creating a vision; communicating the vision; empowering others to act on the vision; planning for and creating short-term wins; consolidating improvements and producing still more change; and institutionalizing new approaches.

Holmberg et al. (2012) have experience of three important components for successful change processes at Chalmers: 1) a neutral arena, 2) commitment from the management, and 3) individual engagement and involvement:

1. Organizational bodies that are placed outside the research departments can work as *neutral arenas* and platforms for cooperation and information exchange, and can function as engines for issues that otherwise often become everyone's interest but no-one's responsibility. Neutral arenas can be used to avoid lock-in effects and make teachers from all departments feel welcome to take part in their activities.
2. A clear *commitment from the management* can definitely facilitate a change process and can sometimes be necessary. The role of the management can be to clearly motivate the change process and systematically create incentives and other structures that correlate with the change process.
3. A change process must build on *individual engagement and involvement*. At universities, programme directors and teachers have a high degree of autonomy, which must be respected and dealt with. The *individual interaction method*, developed and used at TU Delft (Peet et al., 2004), is an effective method in a change process at a university. By interviewing individual programme directors or teachers about their programmes and courses and discuss how the topics relate to sustainable development (or in our case *ethics*) and how this can be further improved, they are still in control of their programmes and courses and the experience is that they will open up for change and embedding of sustainable development (or ethics) in a much better way.

Method to identify and analyze integration of ethics in the Master's programmes

The integration of ethics in the Master's programmes have been identified and analyzed based on the *course descriptions in the Chalmers Study Portal* (Chalmers University of Technology, 2016a). The courses that have *intended learning outcomes* in which *ethics* is explicit are considered to be courses in which ethics is integrated.

The *topics for ethics* have been divided first into *engineering* and *research* ethics, and then further into topics mainly based on the formulation of the intended learning outcomes but also on the other parts of the course descriptions.

The *intended depth of learning* in the courses has been analyzed by comparing formulations of the intended learning outcomes with the six levels in *Bloom's taxonomy* for the cognitive domain (Bloom et al., 1956):

- *Knowledge*: Recall previously learned information.
- *Comprehension*: Demonstrate an understanding of the meaning or purpose of previously learned information.
- *Application*: Use previously learned information in novel and concrete situations.
- *Analysis*: Examine the underlying components of learned information and gain an understanding of their organizational structure. This level also includes making inferences and using the information to support broader generalizations.
- *Synthesis*: Integrate previously learned information and its components into new concepts.
- *Evaluation*: Use definite criteria (either provided or self-created) to judge the value of other material and information.

In the next step, the intended depth of learning in the courses has been compared to the *required depth of learning according to the Swedish System of Qualifications for a Master's degree* (Ministry of Education, 2006). The required learning for *engineering ethics* is "ability to *make judgments*, within the field of study, with respect to relevant ethical issues", which corresponds to the level *evaluation* in Bloom's taxonomy. The required learning for *research*

ethics is "ability to *demonstrate an awareness* of ethical aspects of research and development", which corresponds to the level *comprehension* in Bloom's taxonomy.

Finally, the intended depth of learning in the courses has been used to identify potential *progression in learning* in the programmes that include more than one course in which either engineering or research ethics is integrated.

Method to identify challenges

The identification of challenges is based on the results for how well the integration of ethics has succeeded in the Master's programmes in combination with comments from Master's programmes directors and teachers in individual meetings and at seminars.

RESULTS

Change process for integrating ethics into Master's programmes at Chalmers

A project to improve integration of ethics into the Master's programmes in the educational area for "electrical and computer science engineering, software engineering, and industrial engineering and management" (EDIT-I), was started in early 2013. The continuation of the project has been decided on an annual basis, and the project is still running since there is still a need of improvement. The project was initiated by dean of education, and is led by a collegial pedagogical developer at Chalmers (who is the author of this paper). At the time, the Swedish Agency for Higher Education was reviewing all engineering degrees in Sweden, and there was a fear at Chalmers that some of the educational programmes would not pass the requirements in ethics. At the end, Chalmers got a very good result in the evaluation, but two of the Master's programmes did not pass, and lack of ethics was part of the reason for one of them. During the project, the importance of competence in ethics among engineers has got some attention in media, e.g. due to the "emission scandal" involving Volkswagen, which has given additional motivation for the project.

Table 1. Master's programmes (two year-long) and associated MSc in engineering programmes (five year-long) in the educational area EDIT-I at Chalmers.

Master's programme	**Code**	**Associated MSc in engineering programme**
Computer science: algorithms, language and logic	MPALG	Computer science and engineering
Computer systems and networks	MPCSN	
Biomedical engineering	MPBME	Electrical engineering
Communication engineering	MPCOM	
Electric power engineering	MPEPO	
Embedded electronic system design	MPEES	
Wireless, photonics and space engineering	MPWPS	
Entrepreneurship and Business Design	MPBDP	Industrial engineering and management
Management and economics of innovation	MPMEI	
Quality and operations management	MPQOM	
Supply chain management	MPSCM	
Interaction design and technologies	MPIDE	Software engineering
Software engineering	MPSOF	

There are 13 two year-long Master's programmes in the educational area of EDIT-I, see Table 1. There are variations in their curricula but a typical programme consists of one fourth of compulsory courses, one fourth of semi-compulsory courses, which means that the students have to choose some courses among a limited set of courses, one fourth of elective courses, and finally one fourth of Master's thesis. All courses in a Master's programme (with just a few exceptions) are on 7.5 higher educational credits (ECTS). Each Master's programme is associated to a five year-long MSs in engineering programme, and belong to one of four educational areas. The heads of programmes and directors of Master's programmes have got their assignments from the educational areas, and order courses to their programmes from the research departments where the teachers are employed who deliver the courses.

The aim of the project is to fulfil the learning outcomes for ethics in the Swedish System of Qualifications for Master's degrees (Ministry of Education, 2006), i.e. "to have the ability to make judgments, within the field of study, with respect to relevant ethical issues, and to demonstrate an awareness of ethical aspects of research and development". Since this aim was a large step for the programmes to take in the beginning of the project, there has been some short term goals during the project. The first goal was to have at least one intended learning outcome in (any) ethics in at least one of the compulsory courses in each programme. Even though not all of the programmes had fulfilled this goal, there was a second goal introduced to have intended learning outcomes for both engineering and research ethics in compulsory courses in each programme. The next goal is to formulate intended learning outcomes that fulfil the depth of learning that is required in the System of Qualifications.

The strategy that is used for integrating ethics in the programmes is to include ethics as part of courses in which it can be integrated in a relevant way with the engineering field (in line with standard 3 in the CDIO Initiative, 2010). It would not be a good strategy to have a whole course in ethics in the Master's programmes, since all courses are on 7.5 credits, which is a lot, and there is just a few compulsory courses in a programme. Another important reason is that it can be easier to connect ethics to the engineering field when it is integrated in courses rather than in a separate course.

A requirement in the project is that ethics should be *explicit in the intended learning outcomes* (in line with standard 2 in the CDIO Initiative, 2010), and that teaching and assessment in courses should be *constructively aligned* with these intended learning outcomes (Biggs & Tang, 2007). Another requirement is that ethics should be integrated in *compulsory courses* to make sure that all students in a programme take this course.

The change process in the project started by informing Master's programme directors and vice head of departments responsible for education about the project, including motivation and long and short term goals. The Master's programme directors were asked to identify courses in their programmes in which ethics were already included but could be enhanced with explicit intended learning outcomes, and courses in which ethics could be relevant to include. The Master's programme directors were then encouraged to talk to the teachers in the identified courses about possibilities to make appropriate changes. During the project, there has been an annual follow up of the progress in the programmes and continued encouragement of programmes directors and teachers to make improvements.

The Master's programmes directors and teachers have been offered different types of *support* during the project. The collegial pedagogical developer, who is leading the project, has offered *individual support* to programme directors and teachers and has given support to the ones who

have asked for it, e.g. to identify relevant courses in dialogue with programme directors and to give feed-back on suggestions from teachers of intended learning outcomes, teaching and learning situations, and assessment. The teachers have also been offered some *financial support* for course development from the educational area.

The challenges that were faced and the need of different types of support became clearer as the project went on. As a consequence, Chalmers Learning Centre organized two *seminars* on ethics to which programme directors and teachers were invited (in line with standard 9 in the CDIO Initiative, 2010). Both seminars included a presentation by an invited guest followed by allocated time for discussion. The first seminar in spring 2015 was about engineering ethics, and Sven Ove Hansson who is professor in philosophy at the Royal Institute of Technology in Stockholm was invited to have a presentation. The second seminar in autumn 2015 was about integrating ethics in education, and Ibo van de Poel, who is professor in philosophy at Delft University of Technology, was invited to have a presentation. In contrast to Chalmers, both these universities have departments with philosophers who do research and teaching in ethics. Both these professors have written books on ethics and engineering (Hansson, 2009; van de Poel & Royakkers, 2011).

Requests of support from teachers and programme directors during individual meetings and at the seminars resulted in a *webpage* (Chalmers University of Technology, 2016b) that includes different types of recourses for ethics, either directly or indirectly through links to other webpages, with the purposes:

- *for teachers and programme directors to learn about ethics:* such as a short description of ethics theory and references to books that include more thorough descriptions.
- *to learn about how to integrate ethics in education*: such as an example of strategy for how to integrate ethics in programmes, examples of intended learning outcomes, and examples of rubrics;
- *to be a source of materials that could be used in education*: examples of real cases in engineering, codes of conducts, examples of course literature, and methods to analyse ethical problems.

Ethics integrated into the programmes

There has been a large improvement since the academic year 2012/13, and the *number of courses* that include ethics has increased from only two courses in 2012/13 to in total 29 courses in 2016/17 (four of the courses include both engineering and research ethics), see Table 2. It is seven of the 13 programmes that include courses in both engineering and research ethics that the students take independent on which courses they choose. A comparison between the number of compulsory courses that include ethics and the share of Master's programmes that include ethics between the EDIT-I educational area and the three other educational areas shows a large difference, see Table 3.

There is a variation between the *engineering fields* in how many courses that include ethics. The field of *industrial engineering and management* has the largest number of courses both in absolute terms as well as in relation to the number of Master's programmes (eleven courses in four programmes). The field of *electrical engineering* has the lowest number in relation to the number of Master's programmes (nine courses in five Master's programmes). Table 4 includes the topics for engineering and research ethics that are covered in the programmes.

Table 2. Number of courses that include ethics that the students take in a programme. The reason for the range in some programmes is that the number of courses depends on which courses that the students choose to take. Source: (Chalmers University of Technology, 2016a)

Associated MSc in engineering programme	**Master's programme**	**Number of courses that include ethics**			
		Engineering ethics		**Research ethics**	
		2012/13	**2016/17**	**2012/13**	**2016/17**
Computer science and engineering (5 courses)	MPALG	0	1	0	1
	MPCSN	0	1-3	0	1
Electrical engineering (9 courses)	MPBME	0	1	0	1
	MPCOM	0	1	0	1
	MPEPO	0	3	0	1
	MPEES	0	1	0	1
	MPWPS	0	1	0	0
Industrial engineering and management (11 courses)	MPBDP	0	3-5	0	0
	MPMEI	0	0	1	1
	MPQOM	0	0-1	0	2-3
	MPSCM	1	1	0	0
Software engineering (4 courses)	MPIDE	0	2-3	0	1
	MPSOF	0	0	0	1

Table 3. The number of compulsory courses that include ethics and the share of Master's programmes that include ethics in the educational areas at Chalmers.

Educational area	**Number of courses**	**Share of Master's programmes**
EDIT-I	21	13/13 = 100%
The three other educational areas	8	5/27 = 19%

The results for the analysis of the *intended depth of learning* in the courses in the Master's programmes in relation to the six levels in Bloom's taxonomy are presented in Table 5. According to the intended learning outcomes, seven (ALG, BDP, COM, CSN, EPO, IDE, WPS) of the 13 programmes fulfil the requirement for intended depth of learning for *engineering ethics* according to the Swedish System of Qualifications for Master's degrees, which is *evaluation,* independent on which courses that the students choose. Some examples of intended learning outcomes that fulfil this requirement are:

- *Discuss and **value** the social and ethical aspects of distributed systems and their applications.*
- ***Make** ethically responsible **choices** when packaging or visualizing intellectual assets into physical, virtual, or intellectual properties or services.*
- ***Make an informed evaluation** of the ethical and societal impact of a design.*

According to the intended learning outcomes in courses that all students take, ten of the 13 programmes fulfil the requirement for intended depth of learning for *research ethics* according to the Swedish System of Qualifications for Master's degrees, which is *comprehension*. Some examples of intended learning outcomes that fulfil the requirement are:

- ***Make and defend** ethical judgement within the area of scientific writing, e.g. related to plagiarism and authorship.*
- ***Take into account** different ethical aspects when **doing** interviews.*

- ***Apply*** *ethical principles to data collection, analysis and presentation of research and investigations.*
- ***Explain*** *the importance of research ethics.*

Table 4. Topics for engineering and research ethics that are covered in the Master's programmes. The topics are sorted to the MSc in engineering programmes that the Master's programmes are associated to. Source: (Chalmers University of Technology, 2016a)

Associated MSc in engineering programme	**Topics in the Master's programmes**	
	Engineering ethics	**Research ethics**
Computer science and engineering	- Computer science; - Research in computer systems and networks; - Distributed systems and their applications; - Computer security; - Data integrity	- Academic/ scientific writing, e.g. plagiarism, authorship, proper citation and use of statistics
Electrical engineering	- eHealth and medical technology; - Embedded electronic system design; - Electric power systems and engineering; - Electric drive systems - Photonics - Design in communication engineering	- Biomedical instrumentation systems; - Scientific writing, e.g., plagiarism and authorship; - Data collection, analysis and presentation of results - Dual use
Industrial engineering and management	- Intellectual assets and property in relation to innovation and business strategy; - Entrepreneurship; - Supply chain management: purchasing and social responsibility; - Change management in industry - Role of patents in strategic business development; - Idea evaluations, including how to relate professionally to different stakeholders in the idea evaluation process, such as idea providers, in the role of consultant/analyst; - Packaging or visualizing intellectual assets into physical, virtual, or intellectual properties or services	- Business research; - Academic writing, including referencing and quoting; - Interviews; - Data collection, analysis and presentation of research, investigations

Software engineering	- Design process and final design;
	- Gameplay design;
	- Interaction design and technologies:
	  - Involvement of users in design;
	  - Impact and consequences of design on different levels (man – society), e.g. "critical design"
		- Conducting research in software engineering;
		- Interaction design research

Table 5. Intended depth of learning based on the intended learning outcomes in the courses in the Master's programmes in relation to the six levels in Bloom's taxonomy for the cognitive domain. E and R stands for courses that include engineering or research ethics, respectively. The numbers stand for the study period in which the course is given: 1-4 in year one and 5-6 in the autumn semester in year two. Courses in parentheses are not compulsory.

Master's programme	Know-ledge	Compre-hension	Appli-cation	Analysis	Synthesis	Evaluating
MPALG			R6			E6
MPCSN		(E3)				R5, (E3), (E2/6)
MPBME	E4	R1-2				
MPCOM		R3				E1
MPEPO		E1, E1	R5/6			E5/6
MPEES			E2, R2			
MPWPS						E3
MPBDP			E1	E1-2		(E3), (E3), (E5)
MPMEI		R4				
MPQOM		(E5)	R2, R4, (R3-4)			
MPSCM				E1		
MPIDE		R1				E1, (E4), E5
MPSOF						R2

Five of the programmes include more than one course in either engineering or research ethics (CSN, EPO, BDP, QOM, IDE), see Table 5. There is a potential *progression* of learning in three of them (CSN, EPO, BDP) since they have courses in their curricula with lower intended depth of learning (*comprehension* or *application*) that come before courses with higher intended depth of learning (*evaluation*).

Challenges

It has been a huge challenge to integrate ethics in some programmes for different reasons. Many of the programme directors and teachers do not have deep knowledge in ethics and feel unsure about how to design teaching and learning situations and how to perform assessment. The first improvements were made in programmes that had programme directors and teacher with good knowledge in ethics, which was mainly the case for programmes in the field of *industrial engineering and management*. However, there have been hardly no improvements in some programmes until just recently, and unsure programme directors and teachers could be one reason. Another reason may be that it is more or less easy to integrate ethics in different engineering fields.

Another main challenge has been to find philosophers who have good knowledge in engineering and who could have the possibility to work as guest lecturers at Chalmers. Programme directors for programmes that do not have teachers with good knowledge in ethics have expressed a need of such guest lecturers. However, due to the lack of such philosophers, there has been an increasing awareness among programme directors that improvements have to be made by our own teachers in engineering.

Other challenges are about *teaching and assessment* of ethics. Teachers who have not been teaching in ethics before can be unsure in how to design appropriate teaching and learning situations as well as assessments, including rubrics for assessment, which are constructively aligned to the intended learning outcomes.

Another challenge that has been expressed by some programme directors is that ethics takes place from other content in the programme. It has also been difficult to get programme directors and teachers to prioritize this work. Money has not been a problem since there are some funding available for course development but it has rather been time and lack of priority.

DISCUSSION AND CONCLUSIONS

It has taken time to integrate ethics in the Master's programmes in the educational area EDIT-I at Chalmers, and there is still a need of improvements. However, a comparison of the integration of ethics in the Master's programmes to the other educational areas at Chalmers shows that the project has been successful. One reason for a successful result could be that the project has continued over several years as long as there has been a need of improvements. There has been a regular follow up of the progress and encouragement of programmes directors. Additionally, the project has tried to be sensitive to the need of support and has given the support that has been possible to give.

The evaluation of all engineering degrees in Sweden performed by the Swedish Agency for Higher Education has worked as an important driver for the change process, as well as media attention about the need of competences in ethics among engineers. However, the most important driver has been that the project has been assigned by the dean of education who can put some pressure on the programme directors.

It has been a good idea to have short term goals that were not that demanding compared to the requirements in the Swedish System of Qualification. It has made it possible for programme directors and teachers to develop their own competence in ethics during the project in a pace that has still made it possible for them to make some improvements in their programmes. However, some programmes directors and teachers already had good knowledge in ethics and for those programmes there could have been higher demands and the improvements could have been done faster.

It has been important that the actual changes are done by the programme directors and teachers themselves, and that no one else has been telling them how to do. They have to own the change process for their own programmes and courses to create commitment and long lasting changes, and they are also the ones who have best knowledge to make good connections between ethics and their engineering fields.

It is not obvious whether it is best to have teachers in engineering who has learnt about ethics who do the teaching in ethics or to have philosophers who have learnt about engineering who work as guest lecturers in ethics. Different solutions are probably best for different programmes and courses. It can be a strength if teachers in engineering can improve their competence in ethics to make it possible for themselves to do the teaching in ethics, but it can take time and be a large effort. Alternatively, it can be a strength to have philosophers who have good knowledge in engineering who could work as guest lecturers at Chalmers. However, this can also require large effort for teachers at Chalmers who would have to work in close collaboration

with the philosophers to make sure that the ethics content is well integrated in the courses and relevant for engineers. An advantage to have such philosophers at Chalmers could be that they potentially could give advice to teachers and to secure good quality of ethics integrated in other courses.

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