EMBEDDING SUSTAINABILITY AND ETHICAL COMPETENCES INTO ENGINEERING EDUCATION FOLLOWING CDIO

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ABSTRACT

Integrating sustainable development and ethics into engineering education is essential for every higher education institution. The CDIO syllabus contains both principles, and CDIO 3.0's optional standards promote the integration of CDIO principles into the curriculum of educational institutions. In this context, <Institution> conducted research to determine the level of familiarity engineering students have with ethics and sustainability and to gather their suggestions on how to incorporate these principles into the curriculum. An anonymous web survey was administered to students in three different engineering fields, including ICT (N = 58), Land Surveying (N = 12), and Civil Engineering (N = 32). The survey evaluated their understanding of sustainability and ethics and sought their opinions on how these topics were addressed in their coursework. The content analysis also revealed the perspectives of the students, which suggested practical examples, learning tasks, and the occurrence of themes cross-cuttingly, e.g., in learning projects. The results reflect the thoughts and ideas of stakeholders and give suggestions for practical implementation to incorporate themes into learning. The inclusion of these themes in the practical implementation of the study courses contributes to the integration of ethics and sustainable development into the curricula following the CDIO 3.0 principle and improves the quality of the curricula for its part. The results of a study investigating engineering students' knowledge of sustainability and ethics, as well as their suggestions for incorporating these themes into the curriculum, can be of benefit to the CDIO community. The study found that students generally understand the principles of these themes, but also suggested practical examples and cross-cutting themes for more effective integration into the curriculum. The findings can inform the development of new teaching methods and learning materials, as well as improvements to current CDIO standards, to better integrate sustainability and ethics into engineering education. Ultimately, this can lead to a more relevant and engaging learning experience for students, promoting their commitment to becoming socially responsible engineers.

KEYWORDS

Sustainability, ethics, curriculum, continuous improvement, Optional standards: 3.0 nr 1

INTRODUCTION

As engineers design and develop new products and technologies, they need to consider the impact of their work on society, the economy, and the environment to ensure sustainable

solutions. This requires collaboration with stakeholders and interdisciplinary thinking to balance technical and non-technical factors.

Sustainable development means development that ensures good living conditions for present and future generations. The 2030 Agenda for Sustainable Development Goals (SDG) by UNESCO (2017a, 2017b) aims to eradicate extreme poverty and achieve sustainable development that takes equal account of the environment, the economy, and the people. Its guiding principle is that no one should be left behind in development.

Svanström et al. (2008) have found in the literature about the learning outcomes of sustainable development, common features independent of educational level and target group, such as systemic and comprehensive thinking, integration of different perspectives, emphasized skills, and the appearance of attitudes and values in the learning outcomes. Leiva-Brondo et al. (2022) emphasise the importance of finding connections between daily interests and SDGs in the planning of education strategies. Sustainable development perspectives have been successfully integrated, e.g., into modules (see e.g., Butt et al., 2022) and courses (see e.g., Gunnarsson & Klein, 2021). Indeed, the literature includes an increasing number of studies on sustainability and the integration of sustainable development into engineering curricula (Thürer et al., 2018). There are plenty of studies in the literature on what and how to teach and engage students in the development of sustainable development knowledge and skills through innovative teaching methods and innovations (Desha et al., 2019). According to the literature review by Thürer et al. (2018), SDG was incorporated into curricula for example by adding new courses, adapting existing ones, or introducing the topic through project work.

Along with sustainable development perspectives, ethical issues are also an integral part of engineers' personal and professional lives, connecting micro-ethical problems with macro-ethical consequences (Rottman & Reeve, 2020). In ethics education, in addition to the massive ethical questions, it would be good for engineering students to think about how they relate to daily problems, colleagues, customers, and stakeholders in their community (Pierrakos et al., 2019). Students have been found to experience non-technical perspectives on ethics also uninteresting (Ermer & VanderLeest, 2002), which is why their involvement in designing their learning is important.

In Finnish Universities of Applied Sciences, the competences of qualifications are defined as education-specific and common competences by the rectors' conference of Finnish Universities of Applied Sciences (Arene, 2022). Competences are defined as broad sets of competences, combinations of an individual's knowledge, skills, and attitudes. The programme-specific competences form the basis of a student's professional competence. Competencies shared by various qualifications and diplomas form the foundation for professional endeavours, collaboration, and expertise advancement. The recommendation on the application of common competences in higher education degrees is to promote an understanding of how to apply the competences described in the National Qualifications Framework (NQF) to curriculum development, competence profiling, and assessment. The Finnish qualifications framework is based on the recommendation of the European Parliament and of the Council on the establishment of the European Qualifications Framework (EQF) for lifelong learning. The Finnish qualifications framework is also in line with the European Higher Education Area (EHEA) qualifications framework.

The aim of this development project is to assess the current knowledge of sustainability and ethics among students at our university and use the results to develop new teaching and curriculum that better incorporate these topics. Additionally, this study aims to share the

findings with the CDIO community to inform sustainability and ethics education in other universities. Further, to ensure continuous improvement of the engineering education curriculum, it was asked, what are students' expectations for developing sustainability and ethical considerations in engineering education curriculum and pedagogy? The survey and the results are presented in the following chapters

DATA COLLECTION AND ANALYSIS METHODS

To provide background information on the embedding of ethical and SDG competencies into learning, collecting thoughts from engineering students as an anonymous web survey is considered the most appropriate in this study. The survey was sent to all engineering students (ICT engineering N= 315., Civil Engineering (CE) N = 426, Land Surveying engineering (LS) N = 279) at the Rovaniemi campus of the Lapland University of Applied Sciences at the beginning of October 2022, and two weeks were given to answer.

The web survey was conducted with the Webropol v. 3.0 system in Finnish. At the beginning of the web survey, the students were told e.g., the purpose, voluntary nature, the policies for publishing the results, and the principles of data storage. After the demographic information, the students were asked to assess whether they know the meaning of the term's sustainability and ethics and ethical principles. There were two questions regarding sustainable development. They were preceded by the CDIO (2022) consortium's rationale for sustainable development and the goal of integrating them into engineering education. In the first question about sustainable development, students were asked to evaluate the current stage in education in terms of incorporating sustainable development perspectives into teaching and learning. The question was identical to the optional standard 1 for sustainable development (Malmqvist et al., 2020) in CDIO's (2022) optional standards 3.0 and provided statements to determine the level following the rubric for self-assessment. The optional standard is useful, not only for assessing the integration of sustainable development but also for promoting and guiding it (Rosén et al., 2021). The second question was open-ended, asking for suggestions and expectations regarding the organization of sustainable development learning tasks. Furthermore, there were three questions regarding ethics. As an initial introduction, the Archimedean oath was presented to the students, and research ethics and professional ethics of engineers were defined according to Heikkerö (2009). The first question regarding ethics inquired if the student was aware of what is meant by the term responsibility. Examples such as reference management, copyright, rights of participants in research, GDPR, and critical media literacy) were given. The second question investigated students' awareness of the meaning of respect. Again, some examples were given to guide thinking, such as respect for colleagues, research partners, and fellow students. Finally, the open question asked for suggestions and expectations for introducing ethical perspectives in education.

The answers to the survey were as follows: engineering students of ICT (N = 58), Land Surveying (N = 12), and Civil Engineering (N = 32). Overall, 102 responses were received, giving a modest response rate of 10 % (ICT 18%, CE 8 %, LS 4 %). Of the students who responded, 40 studied in the daytime group and 58 in multi-format or online studies, and two students studied in some other. Most of the respondents represented early-stage students. Of the respondents, 33 (32.4 %) were first-year students, 34 (33.3 %) were second-year, 16 (15.7%) were third-year, and 19 (18.6%) were fourth-year students or more.

In the content analysis (Bengtsson, 2016; Elo et al., 2014) of the open answers, the answers were first read through and divided into analysis units, which were labelled as codes. Answers

that were not related to the topic were excluded. The codes were classified into categories/themes using inductive reasoning (Bengtsson, 2016). The authors went through the thematic categories together to form a consensus.

RESULTS

Most of the students, 95 (93 %), claimed to have knowledge of the meaning of sustainable development. There were 6 (6 %) who did not know and 1 (1 %) were blank answers. There was a minor difference between the degree programmes. Regarding the concept of ethics, 83 (81 %) of the respondents knew the meaning of the concept, 18 (18 %) did not know and 1 (1 %) was blank. Among ICT students were the highest proportion of NO answers 11 (19 %). Compared to Land Surveying (LS), the corresponding value was 2 (17 %), and Civil Engineering (CE) 5 (16%).

Students evaluate the inclusion of sustainable development perspectives in their education program in their learning according to Figure 1. The statements by the CDIO standard were cited from the CDIO (2022) rubric for self-assessment in the first Optional standard 3.0.

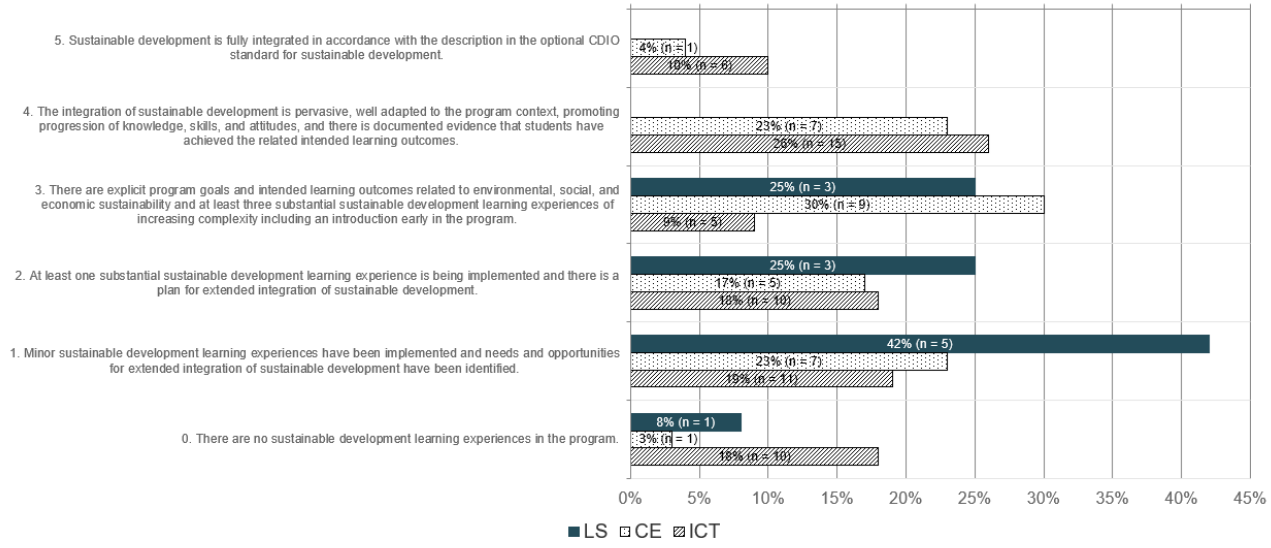

Figure 1. Students' assessments for the sustainable development statements by degree programmes.

Most of the engineering students answered that their education is either at level 1 (N = 23, 23%) or level 4 (N = 22, 22%) in the rubric. Level 5 received the fewest responses (N = 7, or 7%). Between the degree programmes (see Table 1) it appeared that all answers of LS were at levels 3, 2, 1, and 0, at levels 4 and 5 there were no answers. Regarding CE and ICT, all levels received answers. The fewest answers (N = 7.7%) were graded 5, i.e., sustainability is comprehensively integrated into the degree programme according to the description of sustainable development in CDIO optional standard. The pairwice Mann-Whitney U-test show no evidence against the null across degree programmes (LS vs. CE: U = 221, p = 0.0566; CE vs. ICT: U = 736.5, p = 0.4785, LS Vs. ICT: U = 360, p = 0.3743).

Table 1. Students' assessments for the level according to the rubric of sustainable development statements in CDIO optional standard by degree programmes.

	ICT		LS		CE		
Level	N	%	N	%	N	%	Total
5	6	10,5 %		0,0 %	1	3,4 %	7
4	15	26,3 %		0,0 %	7	23,3 %	22
3	5	8,8 %	3	25,0 %	9	30,0 %	17
2	10	17,6 %	3	25,0 %	5	16,7 %	18
1	11	19,3 %	5	41,7 %	7	23,3 %	23
0	10	17,5 %	1	8,3 %	1	3,3 %	12
Total	57		12		30		99

The LS degree programme had relatively the most level 2 responses (N = 5, 42 %), i.e., small-scale implementations of sustainable development. Corresponding values were for CE (N = 7, 23%) and ICT (N=11, 19 %). Almost one-third of ICT engineering students estimate that the degree programme is at level 4 (N = 15, 26 %) or 5 (N = 6, 10 %). CE has the most answers at level 3 (N = 9, 30 %). Levels 4 and 1 had the same number of answers (N = 7, 23 %).

The concept of responsibility was familiar to the students. There was a total of 93 positive answers (92%). The corresponding response numbers between degree programmes were LS (N=11, 91.7%), ICT (N = 51, 89.5 %), and CE (N = 28, 96.6 %). There was one missing answer. The concept of respect was also generally well-known. Most of the students (N = 100, 98.0 %) knew the importance of respect in operations. There were not many differences between the degree programmes. There were two negative answers from ICT engineering students.

Table 2. lists students' suggestions for including sustainable development in learning by theme. A total of 47 responses were received: 5 from LS, 13 from CE, and 29 from ICT. Learning projects were most wanted in six comments, but they only appeared in ICT students' answers. I don't know –answers were 1 in LS students' answers, and 2 in CE and ICT students' answers.

Table 2. Students' suggestions for including sustainability in learning.

LS	CE	ICT
Practical examples	Recycling and reuse of building materials (3 answers)	Learning projects (6 answers)
Opportunities for utilization in the future	Construction-related learning projects (2 answers)	Reflection and learning assignments (4 answers)
Basics of sustainable development	Review of general goals and problems	Energy conservation and renewable energy (3 answers)
Learning assignments	Comparison of different building materials and their durability	Practical guidance through the curriculum (3 answers)
	Possible ways to improve the materials	Info/event/presentation (2 answers)
	Economic factors	Technology's support for nature (2 answers)
	Should be in everything	Home energy efficiency (2 answers)
	Wood construction on a large scale	Optimization of algorithms from the point of view of energy consumption
	Opportunities offered by own electricity production	Perspectives related to citizens' well-being and health care
	Quality of Construction	Calculation of life cycle costs and investments
		Life cycle thinking of applications and systems
		Practical examples
		Electrical and home automation

There were concrete answers related to the theme of sustainable development, for example, the following response from the CE student:

> *In connection with construction, a project where, for example, sustainable development is supported e.g., with own electricity production (wind power).* (Translated from Finnish)

Table 3 describes the students' suggestions by themes for including ethical perspectives in learning. A total of 44 responses were received, of which 5 were from LS, 9 from CE, and the remaining 30 from ICT. The students suggested that the theme should be cross-cutting, which at Lapland UAS means including the theme holistically in the curriculum during the entire study path from the point of view of each subject. There was a total of 6 responses related to this theme.

Table 3. Students' suggestions for including the ethical themes in learning.

LS	**CE**	**ICT**
Principles of research and professional ethics (2 answers)	Conflict resolution (2 answers)	Cross-cutting (5 answers)
Learning projects	Separate ethics course (2 answers)	Principles of research and professional ethics (4 answers)
Copyrights	Reflection assignments (2 answers)	Copyright, GDPR (2 answers)
Review in connection with Thesis	Privacy (2 answers)	Separate ethics course (2 answers)
In connection with orientation studies (organized for the first-year students)	Interaction and communication management	Practical examples (2 answers)
	Information security	Learning projects (2 answers)
	Value discussion	Ethics of application and system development
	Instructor's examples	Equality issues
	Ethical use of natural resources	Source criticality
	Cross-cutting	Information packages
	Emphasizing quality	

Furthermore, research and professional ethics were mentioned in 6 responses and separate ethics courses were suggested in 4 responses. There were 7 total responses suggesting research and professional ethics be included in learning, but they were not further specified. For example, the student from the ICT degree programme suggested a deeper discussion of source criticality:

> *At least I haven't come across GDPR in my studies, but I've delved into it in my work. We could always talk more about source criticism.* (Translated from Finnish)

Data protection and copyright came up in the answers of students from each degree programme. Two CE and one ICT student answered that they do not know.

DISCUSSION

According to the survey results, it can be concluded that the students believe they have a good understanding of both sustainable development and ethics. They were able to assess the extent to which these principles are incorporated and emphasized in their educational programs, based on their perception.

The level of sustainable development education was evaluated on a 6-point scale from 0 to 5, where 0 and 5 represent the extremes. Based on the distribution of the answers, the students' opinions were spread over the entire scale. For example, levels four and one had almost the same number of answers in both. 46 answers were rated better than level three and 53 answers were given a level two or lower. In the comparison between sectors, LS gave the most negative evaluations and ICT the most positive.

As shown in earlier studies, the project-based learning curriculum has shown its effectiveness. ICT-Department projects are real-life projects either from local companies or R&D projects with other stakeholders. The suitable courses are integrated into the project and learning is done according to the same rules as in working life in real companies and projects (see e.g., Angelva et al., 2017). Learning projects emerged in the results of this study as well, when students suggested incorporating SDG perspectives and ethical issues into them. According to Guerra (2017), education for sustainable development is one of the challenges engineering education currently faces. In engineering education at Aalborg University, problem-based learning is an answer to integrating sustainability in engineering curricula by sharing core learning principles and by enhancing competencies for sustainable development and professional expertise. The study made by Guerra (2017) shows that it is necessary to look further into curriculum elements: knowledge and learning objectives, types of problems, resources, staff and students' roles, and assessment. Alaswad & Junaid (2022) provided successful examples of integrating discussions into sustainable development themes in engineering education. In the case of ethical issues, the students in this current study also suggested cross-cutting. Indeed, this could also be implemented through problem-based or project-based learning in authentic industry-based project assignments. From the students' answers to open questions, some suggestions can be included in practical teaching and learning. For example, civil engineering projects may contain requirements for emission-free energy production and energy consumption in buildings. Furthermore, life cycle costs and investment calculation as well as traditional aspects of recycling, e.g., on construction sites, can be included in the learning contents of the projects.

The engineering students at Lapland UAS possess a thorough understanding of the goals of sustainable development, according to their perception. This contrasts with the results of a study conducted by Leiva-Brondo et al. (2022) among Spanish university students, where only 15.9% considered themselves to have a strong knowledge of these goals. This difference may be attributed to a variety of factors, such as prior academic background or age distribution. It should be noted that Finnish university students, including a substantial number of adult learners, tend to start their studies at a later age compared to many European countries. However, no information was gathered in the present study on the sources of the student's knowledge or their ages.

To integrate ethics into learning, responses from students in this study included several suggestions for separate ethics courses in engineering and research ethics as well as practical

examples. Rottman and Reeve (2020) encourage practitioners to create open-ended case studies depicting the ethical dilemmas experienced by various engineering groups, and prompt students to identify the macroethical consequences of microethical dilemmas in these cases. Case studies are one of the most popular ways to integrate ethics (Hess & Fore, 2018) and found to be successful in several studies (see e.g., Loendorf, 2009; Martin et al., 2021).

There are some concerns with this study that the reader should consider. First, the response rate was modest, and the small sample size can cause distortion of the results and does not represent the opinions of the entire population. Secondly, students cannot know if the degree programs have plans to include the SDGs in the curriculum (see level 2 rubric). Thirdly, the descriptions of the rubric's levels have been translated from English to Finnish, so the tone and nuances of the descriptions may have changed or been distorted. Furthermore, it is unclear whether the students' answers would have changed if they had studied and understood the themes more deeply. Despite these limitations, the authors believe that the research results achieved a sufficiently reliable answer to the research question for further measures.

The survey data can be used when developing the contents of teaching and study plans in such a way that ethical questions and the principles of sustainable development are considered in teaching. The results of the survey can also be used when comparing the results of other higher education institutions with each other, provided that the survey is carried out using a sufficiently similar method. The answers to the open questions can be used directly in the implementation of teaching and the development of curricula. Naturally, the layout of the questions and the survey method can be further developed and improved in the future.

CONCLUSIONS

The study found that students have a basic understanding of both themes, but also suggested practical examples, cross-cutting themes, and learning tasks to effectively integrate ethics and sustainable development into the curriculum. The findings can inform the development of new teaching methods, learning materials, and improvements to current CDIO standards to better integrate ethics and sustainable development into engineering education.

The study shows the importance of benchmarking the results of different higher education institutions and developing new teaching methods and learning materials to better integrate ethics and sustainable development into engineering education. Ultimately, the inclusion of these themes in the practical implementation of study courses can lead to a more relevant and engaging learning experience for students, promoting their commitment to becoming socially responsible engineers.

Further research is needed e.g., to find out the effectiveness of any measures taken and student satisfaction. It could also be interesting to map how students reflect on their own competence after studying SDG and ethics themes.

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