SUSTAINABLE DEVELOPMENT IN ENGINEERING EDUCATION

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ABSTRACT

At present, education has challenges to adequately react to the sustainability crisis taking place all around us. Education should provide students with competences, which help them to act in a changing world, bringing it towards a sustainable future. The impacts of the sustainability crisis, climate change or loss of biodiversity are usually not very common topics in the discussion on the development of education: how education should react and ensure competences and motivation to mitigate them. However, higher education institutions (HEIs) are now increasingly responding to the challenge and taking action to promote sustainability. In Finland, HEIs have published their programmes to advance sustainable development (SD) and responsibility in education. These programmes cover the practical steps for embedding sustainability issues in education. In addition, the CDIO framework for engineering education has added the optional standard for engineering education to contribute to sustainable development as a key competence. In this paper, we first discuss the key concepts and challenges in embedding sustainable development in education and the learning objectives. We explore how higher education (HE) in Finland introduces the practical steps in embedding SD in education and describe this implementation process at Turku University of Applied Sciences (Turku UAS) in Finland. The special focus of our description is on the work in progress in the engineering programmes at Turku UAS. Because the CDIO optional standard in SD was launched quite recently, the work is in progress and there are still several open questions and challenges. The purpose of this paper is to discuss these challenges and share best practices to be able to genuinely incorporate SD into engineering education.

KEYWORDS

Sustainable development, engineering education, higher education, sustainable development education, Optional standard 1

INTRODUCTION

The 2030 Agenda for Sustainable Development (Agenda 2030), agreed by the UN Member States, aims at sustainable development, taking equal account of the environment, the economy and the human being (United Nations, 2015). The goal of Agenda 2030 is to ensure by 2030 that all learners receive the knowledge and skills necessary to promote sustainable development. At present, education has challenges to adequately react to the sustainability crisis taking place all around us. Studies show that sustainable development is mainly

mentioned in the general objectives of education, but in practical activities and teaching it is not very noticeable in most European HEIs (Konst & Scheinin, 2020). Education should provide the students with knowledge, skills and competences as well as develop attitudes and values, which help them to act in the changing work environment and society bringing them towards a sustainable future. The impacts of the sustainability crisis and climate change are often ignored in the discussion on the development of education: how education should react and ensure competences and motivation to mitigate them. Recent research publications set demands on the development of education. For example, the loss of biodiversity requires economics and engineering to develop more sustainable use of natural resources (Dasgupta, 2021).

In this paper, we first discuss what sustainable education means in the context of higher education and what a sustainable higher education institution is like. The are several challenges in embedding sustainable development in education and the learning objectives, and the problem definition of this paper focuses especially on that how these challenges are approached in our case example. In more detail, this means that we first explore how higher education in Finland introduces the practical steps in embedding SD in education and describe this implementation process at Turku University of Applied Sciences (Turku UAS) in Finland. The special focus of our description is on the work in progress in engineering programmes at Turku UAS aiming to fulfil the requirements set by the CDIO Optional standard 1, Sustainable development. Because the CDIO optional standard in SD was launched quite recently, the work is in progress and there are still several open questions and challenges. The purpose of this paper is to discuss these challenges and share best practices to be able to genuinely incorporate SD into engineering education.

SUSTAINABLE DEVELOPMENT IN HIGHER EDUCATION

The characteristics of sustainability in higher education has been described by several researchers during the last decades. Beynaghi et al. (2016) suggest that the advancement of sustainability through societal collaboration and functions such as education and research will increasingly constitute a core mission for universities. They frame possible future orientations through three different scenarios called a socially, environmentally and economically oriented university. Pursuit of sustainable development through each of these would involve unique and fundamental changes. These would have an impact on all university actions, e.g., on the university mission, focus areas, disciplines and faculties, education in sustainable development, external partners, projects and research activities, outputs with societal stakeholders, and geographical focus (Beynaghi et al., 2016).

Lozano et al. (2013) suggest that to become leaders and change drivers in sustainable development, universities must ensure that the needs of present and future generations are better understood and considered in all university actions: education, research, campus activities and stakeholder relationships. This requires university staff having a deep understanding of SD so that they can effectively educate and motivate students to help make the transition to sustainable societies and societal patterns. To do so, the university management and staff must be empowered to redesign their thinking patterns and implement new paradigms and ensure that SD is like a ‘Golden Thread’ throughout the entire university system (Lozano et al., 2013).

Transition towards real sustainability needs real actions; the strategy and the mission together with different SD programmes are not enough. For example, practices according to which the

HE sector globally carries out their daily activities is an important demonstration of how to reinforce the desired sustainable values and achieve environmentally responsible living standards, and finally moderate and renew the operation of the whole society (Lukman & Glavič, 2007; Friman et al., 2018). The coverage of SD activities seems to be a remarkable measurement of the maturation level of the university. In addition, the university's own, shared SD profile supports the in-house development process of different actors, also informing the external partners and stakeholders about the priorities in SD.

Higher education cannot be renewed by developing learning contents only. Making real change also requires redesigning structures, processes and ways of action in higher education institutions (Ávila et al., 2017). Strategic decision-making, management commitment and practical actions are needed in everyday life to promote a sustainable future and solutions. HEI staff plays a significant role when redesigning education towards sustainability. If especially teachers and lecturers do not commit to the reforms, or resist them, the reforms tend to fail. The teaching staff needs support, motivation and further training when education aims at the desired direction (Blanco-Portela et al., 2017; Kairisto-Mertanen & Konst, 2020). As always with change processes, the reform needs to be implemented so that participants themselves perceive the need for change, and thus a will to do things differently, in a new way. The systemic nature of sustainability issues requires deep and extensive understanding of the hierarchy of SD topics and their interdependencies. This usually requires time and plenty of discussion, as well as inclusion (e.g., Holm et al., 2015).

In addition, integration of SD in higher education is challenging because of the extensive, hierarchical and systemic nature of the concept. The Sustainable Development Goals (SDGs) adopted by the United Nations (2015) are often used as a framework for the topics covered. They form an ambitious set of 17 overarching global goals to combat poverty and achieve sustainable development by 2030, covering topics from gender equality to climate change, and education to clean drinking water. There is also a hierarchy between the SDGs; the SDG 'wedding cake' (Figure 1) shows the biosphere as the foundation of economies and societies and as the basis of all SDGs. Such a conceptualization adopts an integrated view of social, economic, and ecological development. Third, the SDGs form a system having interlinkages and interdependencies in between and affecting one will affect also the others more or less.

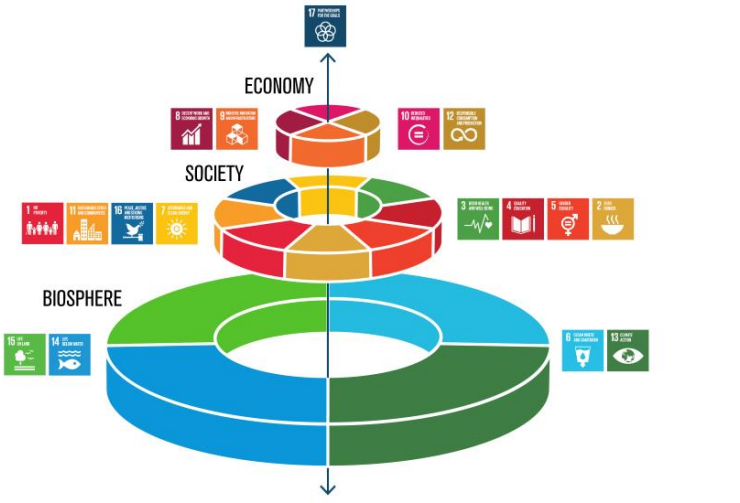

Figure 1. A new way of viewing the sustainable development goals (Azote for Stockholm Resilience Centre, Stockholm University, 2016)

APPROACHING SD EDUCATION IN FINNISH HIGHER EDUCATION

As stated earlier, studies show that sustainable development is often mentioned in the general objectives of higher education, but in practical activities it has not been visible. However, the situation is gradually changing. Real integration of sustainable development is crucial for the development of future education. According to the "Competences 2035" report published by the Finnish National Agency for Education, sustainability competence will be the most important skill in future working life, even surpassing digital skills (Finnish National Agency for Education, 2019). In Finland, higher education institutions have published their joint sustainable development and responsibility programmes in late 2020, and these programmes are based on the UN Sustainable Development Goals. Thus, many HEIs have started to bring sustainability into the activities of education and everyday practices and focused their teaching and research more on sustainability solutions. This work has been encouraged especially in engineering education also by the CDIO optional standard 1, Sustainable development.

SD Programmes in Finnish HEIs

In Finland, higher education institutions, both universities and universities of applied sciences, published their programmes in the end of the year 2020 to advance sustainable development (SD) in education. These programmes cover the promises and practical steps for embedding sustainability issues in education. The topics which are covered are especially how to foster sustainable development (so-called handprint)

- in all study fields and programmes, which contents should be covered, and how learning best takes place,
- how SD can be integrated in RDI (research, development and innovation) activities of HEIs
- how SD is implemented in HEI management and staff development and
- how to mitigate carbon emissions and diminish environmental impacts of HEIs' activities (so-called footprint)

In addition, sustainable development is aimed at also in the regional, national and international outreach and partnership of HEIs.

Because sustainable development and responsibility programmes are rather fresh, their implementation is not fully covered yet. However, all universities and universities of applied sciences are progressing in their SD activities. Their web pages communicate about their sustainable development activities and progress in various ways, and the majority of HEIs have also included sustainability in their strategy and mission statements.

The Optional CDIO Standard 1

There have been several independent proposals for potential optional CDIO standards since 2008, but Malmqvist, Edström, & Hugo (2017) provided the first combined proposal of optional CDIO standards. The optional standards have then been discussed and worked on in CDIO meetings, round tables and workshops. Finally, in June 2020, the optional standards were approved in the council meeting. The optional standards are fully available on the CDIO website and more broadly presented in a paper by Malmqvist et al. (2020).

The four optional standards are:

- Optional Standard 1: Sustainable development

- Optional Standard 2: Simulation-based mathematics
- Optional Standard 3: Engineering entrepreneurship
- Optional Standard 4: Internationalization & mobility

With these standards, the CDIO community has agreed on new key competences to CDIO programmes to support their development activities. With optional standard 1. Sustainable development, the aim is that

- the programme identifies the ability to contribute to sustainable development as a key competence of its graduates
- engineering studies are rich with sustainability learning experiences, developing the knowledge, skills and attitudes required to address sustainability challenges.

Although CDIO is typically connected to engineering education, there are several universities where the CDIO approach is used in other fields as well (Malmqvist, Leong-Wee, Kontio, & Trinh, 2016). The new optional standards do not make an exception is this general suitability. Rosen et al. (2021) write that "Although the SD standard was developed for engineering education programs, it could probably be applied for education programs in other disciplines as well." They continue that this new standard on sustainable development is concluded to be a useful tool for evaluating, promoting, guiding and integrating sustainable development, in basically any engineering programme. It is recommended that the new standard is used for setting university-wide goals and for providing teachers and programme directors with a framework for enhancing the future relevance of engineering education programmes.

IMPLEMENTING SD EDUCATION AT TURKU UAS

Turku University of Applied Sciences has its own programme for sustainable development and responsibility based on a joint programme of HEIs. In its strategy, Turku University of Applied Sciences (Turku UAS) has committed itself to achieving climate goals of the region, and the goal is to be carbon neutral by 2025. However, the development of education is seen as the main role of Turku UAS in sustainability work. The aim is that all students have at least a basic knowledge of sustainability issues, and that most degree programmes include a significant number of studies in sustainability in relation to that field of study. In addition, an important role in the SD work of Turku UAS is played extensively by the establishment and implementation of research and development projects for the region and its operators. Research, development and innovation (RDI) is and will therefore be directed towards projects that clearly implement the objectives of SD work. Key research and development themes in SD at Turku UAS include clean water, circular economy, renewable energy production and energy storage, and the production and use of open information to prevent climate change.

Turku UAS' unit of Future Learning Design supports degree programmes and trainings to integrate SD issues into studies. The goal of Turku UAS' pedagogical approach, innovation pedagogy, is that the graduating students have the prerequisites for a good life, and knowledge, skills and attitudes to participate in creating a sustainable future. This requires that the students, teachers and other UAS staff understand the concept of SD and its hierarchical and systemic nature and are aware of that they can make a sustainable impact for the creation of the future by their own and joint activities. This goal has been described in Turku UAS' joint learning plan, the Innopeda curriculum, which gives also concrete tips and ideas to increase SD understanding in all study fields and degree programmes. There is not a separate compulsory SD course for all students, but degree programmes can decide themselves how to integrate SD issues in the studies.

Turku UAS has three faculties, Engineering and Business being the biggest of them. In this faculty, the CDIO approach is followed, not only in engineering programmes but in business and administration programmes as well. In early 2021, all CDIO optional standards 1–4 were introduced for the faculty's degree programme leaders and their personnel. Each programme chose their programme representatives for each optional standard to join the faculty wide development process.

The process of adopting these new optional standards is presented in figure 2. *The first stage* "Why" was conducted during the spring of 2021, by the degree programmes discussing how they understand the standard and how they see its importance in their programme. The programme representatives had joint meetings to share their thoughts and ideas. *The second stage* "Where are we" started in the late spring. A self-assessment form was created to find out the position of the programmes in the rubric scale, to identify the rationale confirming it, and to consider whether they can improve it. All degree programmes conducted this self-assessment process. The findings were collected and discussed together. *The third stage* "How" to identify actions and next steps to support implementation of the standard and to make preliminary plans for the steps and to identify what it is needed will start in early 2022. In practice this means preparing an implementation plan to be presented first for the faculty management group. In late 2022 it can be evaluated how the implementation process has started.

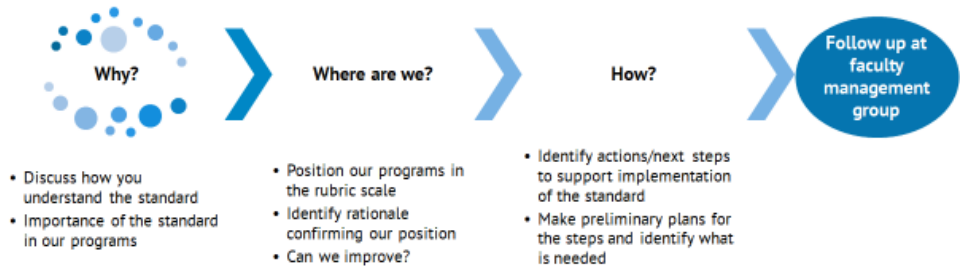

Figure 2. The adaptation process of optional standards at Turku UAS' faculty of Engineering and Business

CONCLUSIONS

The joint programme for the sustainable development and responsibility of universities of applied sciences in Finland encourages to act, and it is relevant that universities of applied sciences have raised sustainable development to the strategy level in their decision-making and made action plans for concrete progress. The CDIO standard supports the work in practice, but the actions are still at the early stages, and it is important to take care of the plans being implemented and monitored.

The change process is challenging and time-consuming. The HEI staff plays a crucial role when redesigning education towards sustainability. Especially the teaching staff needs support and further training when education aims at the desired direction. The reform needs to be led

so that the participants themselves perceive the need for change, and thus a will to do things differently, in a new way. In other words, there are needed changes in ways of thinking before the ways of actions will change. The hierarchical and systemic nature of sustainability issues requires deep understanding of SD topics and their interdependencies. This usually requires time and plenty of discussion and inclusion, for example encouraging open discussion and offering opportunities for sharing ideas and good practices.

Turku UAS is working towards integrating sustainable development and responsibility in all its actions and in all study fields and disciplines. At Turku UAS, further training of the whole staff, encouraging discussion and participation as well as sharing best practices are seen as relevant tools in making the changes.

The Turku UAS approach concerning sustainable development in education is very much in line with the CDIO concept of an integrated curriculum (Standard 3), meaning that sustainable development should not just be considered as a couple of separate courses but instead be integrated with existing studies. Also, Rosen et al. (2021) recommend SD be interwoven with the learning of disciplinary knowledge and its application in professional engineering. The process of adopting the CDIO optional standard in SD is still in progress. However, the process has good opportunities to succeed, because the staff is participating the process in all its stages and there is room for open discussion and sharing ideas. In addition, further training in SD is offered for the staff, in its contents and in pedagogical solutions as well. This far, the findings show the faculty staff being committed to the process of adopting the optional standards well and striving for their successful implementation.

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