SUSTAINABILITY CONSIDERATIONS IN ENGINEERING CURRICULUM

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ABSTRACT

A comprehensive definition of sustainability encourages implementers to consider what they aim to sustain in terms of individuals, organizations or systems, and the outcomes of their actions. Sustainable development is a continuous transformation at global, regional, and local levels to secure good living conditions for current and future generations. It requires decisions and actions that balance environmental, social, and economic factors within Earth's carrying capacity and biodiversity. Integrating sustainability into Master's-level engineering education is essential for strengthening the knowledge base of future engineering leaders. This paper outlines the development of two new Master's degree programmes within the Faculty of Technology at LAB University of Applied Sciences, highlighting how sustainability has been embedded in their design. The aim is to establish a foundation for future initiatives in sustainable curriculum development. One degree programme focuses on circular economy solutions, while the other addresses technological leadership transformation, embedding sustainability as a core element of future leadership. Both programmes were developed in parallel to offer scholars flexible opportunities to design their own study paths, culminating in two Master's degrees with sustainability at the heart of their core competencies.

KEYWORDS

Sustainability, Sustainable development goals, Curriculum development, Standards: 2-4

INTRODUCTION

Engineering education aims to equip future engineers with the knowledge and skills necessary for successful careers in the field (Routaharju 2025). In a constantly changing world, the understanding of future skills also evolves. However, no one can deny the importance of sustainability understanding. Engineers play a central role in shaping a more sustainable future, and therefore, the sustainability perspectives of engineering education require attention.

Sustainability, especially environmental sustainability, is featured in the Conceiving - Designing - Implementing - Operating (CDIO) approach (Edström et al. 2020). To support holistic sustainability and align with the United Nations (UN) Sustainable Development Goals (SDGs), an even more comprehensive approach is needed. This article presents the inclusion of sustainability in Master level engineering education curricula at LAB University of Applied Sciences (LAB) in Finland.

LAB's strategy aims to develop "Responsible, sustainable, and regenerative growth" (LAB 2025a). This is achieved through developing key competences in Intangible Value Creation, Multipurpose Materials and Human Well-being. Sustainable development and responsibility are in the core of the strategy; thus, the joint goal is to integrate sustainability perspectives in all curricula over time.

The concept of sustainability originates from the concern about poor resource management and environmental degradation (Kopnina 2017). In 1972, after the publication of 'The Limits to Growth' by the Club of Rome, environmental awareness emerged even stronger (Meadows et al. 1972). An ongoing debate about the earth's capacity to sustain human economic growth started. Sustainable development as a term was introduced from a political perspective in 1987 by the United Nations (UN) (Sneddon et al. 2006; UN 1987). Here sustainable development is defined as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs', thus underlining that it comprises environmental, social and economic aspects (UN 1987).

Since sustainability was introduced, it has been commonly understood that the linear economy for generating economic growth in which raw materials are extracted, manufactured, used and thrown away cannot lead to sustainable development (Hoekstra and Wiedmann 2014; Millar et al. 2019). The concept of circular economy arose as a way to increase effectivity while reducing the use of resources (D'Amato et al. 2017). The holistic perspective of the circular economy emphasizes all aspects of sustainable development: environmental, social and economic (Desing et al. 2021). Especially, the circular economy has been seen as a solution for combining the possibilities of economic growth and environmental sustainability (Vanhamäki et al. 2021). The circular economy presents a context for concretizing the implementation of sustainability in an economic model and bringing the context closer to practice.

In 2015, the UN General Assembly established the Agenda for Sustainable Development, which defined 17 SDGs outlining urgent and essential actions required globally (UN 2015). These goals and targets address interconnected ecological, social, and economic challenges that are vital for the future of humanity and the planet (UN 2015). LAB has identified seven UN SDGs as key focus areas in its 2030 strategy (LAB 2025a; 2025b). Through its education and research, development, and innovation (RDI) activities, LAB aims to contribute to these goals in various ways:

- SDG 3: Good health and well-being – LAB trains healthcare professionals who integrate sustainability principles into their practice, contributing to more sustainable healthcare solutions.
- SDG 8: Decent work and economic growth – LAB promotes sustainable economic growth by supporting RDI initiatives and fostering collaboration between students and businesses.
- SDG 9: Industry, innovation, and infrastructure – LAB encourages eco-friendly technological solutions by incorporating circular economy principles, innovation, and design expertise.
- SDG 11: Sustainable cities and communities – LAB actively participates in designing safe, sustainable, and livable environments that meet societal and individual needs.
- SDG 12: Responsible consumption and production – LAB focuses on developing methods for sustainable consumption and production, emphasizing resource efficiency and waste reduction.
- SDG 13: Climate action – LAB takes action against climate change by increasing awareness and innovating technological solutions to reduce environmental impact.
- SDG 17: Partnerships for the goals – LAB fosters collaboration between researchers, students, and businesses to drive sustainable innovation and scale impactful solutions. (LAB 2025b.)

By concentrating on these seven SDGs, LAB strategically aligns its efforts to make a tangible impact on sustainability and global development. This paper looks at two Master level engineering degrees, and their sustainability. The research question of the study is: How is sustainability integrated into the curriculum of Master level engineering programmes? The aim of the paper is to present a case example of how sustainability is embedded in the curriculum of two Master's level degrees, as defined by the UN SDGs.

METHODOLOGY

Empirically, this study is based on a qualitative analysis of two Master's level engineering programmes developed at LAB during 2024. The data consists of the two programme and course descriptions, curriculum documents and the author's' reflective observations as program developers, analyzed through a case study and action research approach. This study adopts a qualitative and contextual approach. In other words, it explores the perspectives of selected university representatives, focusing on their emotions, preconceptions, and motivations within the framework of research, development, and innovation (RDI) activities related to the development of online Master's degree programmes (Gray 2017). Two approaches were applied in this study: a case study approach and an action research approach. Case studies are an adequate and necessary method for certain research tasks. The case study method has been used extensively across fields, particularly in education, and is well suited to solving complex problems (Montes-Rodríguez et al. 2019). The study was conducted ex post by systematically examining the completed curricula and mapping course content and learning objectives against the SDG's. This was done to identify how sustainability themes are embedded across the programme's and to assess the extent the SDG's are addressed at the programme level.

While sustainability and the UN SDGs are explicitly emphasized in LAB University of Applied Sciences' institutional strategy, the degree programmes were not designed through an explicit SDG-by-SDG curriculum planning process. Instead, sustainability principles guided programme development at a strategic level. The systematic mapping of course content against the SDGs was conducted ex post as part of this study. The ex post analysis therefore

serves both as a reflective evaluation of curriculum alignment with strategic sustainability objectives and as a tool for identifying development needs for future curriculum iterations.

The action research approach is a method of systematic inquiry that university lecturers perform as researchers of their own practice, constantly questioning the practices and methods in use and being active drivers for change. The inquiry involved in action research is often visualized as a cyclical process, as shown in Figure 1.

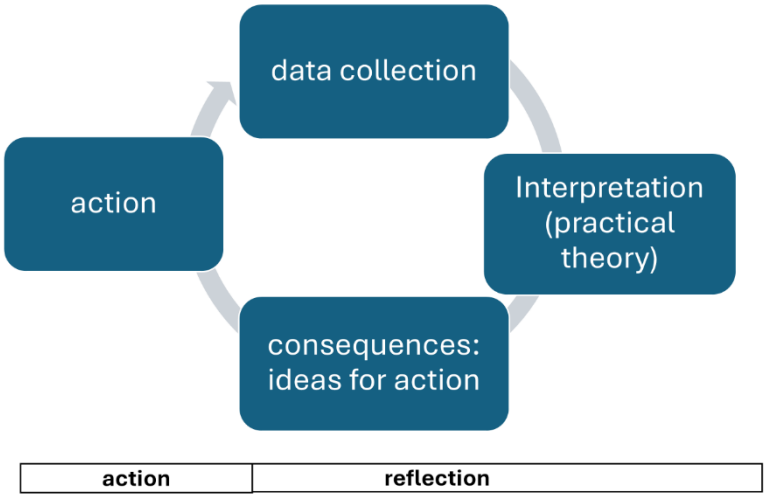

Fig. 1: The circle of action and reflection (Altrichter et al. 2007)

Action research focuses on problems, problem-solving abilities, and community. It influences the functions and environment of the researched phenomenon by enhancing and developing the community's problem-solving skills. Active participation in the community's practices related to the research phenomenon is essential for conducting action research. It begins with practical actions that provide data through scientifically recorded observations (Brusila-Meltovaara et al. 2022).

This study was undertaken within LAB and it covers the construction of two new multidisciplinary Master's degree programmes specifically during the new curriculum design period spanning the entire year 2024. The completed curriculums were officially approved in December 2024. The overall strategy of LAB gave the framework for the degree development. The strategy is constructed on enabling responsible, sustainable, and regenerative growth (LAB 2025a). Sustainability and responsibility are promoted by LAB in education, RDI activities, stakeholder cooperation, and also operating methods in everyday life at campuses. Climate change mitigation and carbon neutrality in 2025 are also seen as strategic choices by LAB. (LAB 2025a).

The degrees in focus of the study are 1) Circular Economy Solutions (CES) and 2) Technological Transformation Leadership (TTL). The development of these two multidisciplinary degrees began at the beginning of 2024, where the degree titles and participating faculties were decided upon by the board of directors of LAB. Both multidisciplinary degree programmes are led by the Faculty of Technology. CES was planned

and will be implemented together with the faculties of business and design, while TTL is carried out in cooperation with the faculty of health and wellbeing. (Brusila-Meltovaara et al. 2025) The scope and length of the Master's degree studies in accordance with the length of the first degree i.e., the Bachelor's degree. The total amount of credits one obtains by completing both a Bachelor's and Master's level degree is 300 ECTS. The credits required for completing the design or technology Master's degree are 60 ECTS as the Bachelor's degree consists of 240 ECTS. Each course is 5 ECTS.

RESULTS

LAB aligns its education and research activities with the SDGs, emphasizing seven key objectives in its 2030 strategy (LAB 2025a; LAB 2025b). The TTL and CES programmes integrate these sustainability goals into their curriculum, ensuring that graduates are equipped with the knowledge and skills to drive sustainable change in organizations.

The TTL and CES curriculums incorporate sustainability aspects into multiple courses, contributing to selected SDGs through practical applications, theoretical frameworks, and industry-relevant case studies. Tables 2 and 3 illustrate potential ways in which these goals are reflected in TTL and CES courses. Furthermore, students are encouraged to consider SDG perspectives in their thesis projects, ensuring that sustainability themes are integrated into their research and practical work.

Table 2: Integration of SDGs in TTL courses

Course	SDGs	Example
Change Mgmt Knowledge Mgmt	SDG 8 SDG 17	Students will analyze company case studies that have successfully navigated workforce transitions through digital transformation while ensuring employee well-being and career development.
Modern Technologies & Megatrends	SDG 3 SDG 9 SDG 13	Students will assess the impact of key megatrends and explore how emerging technologies contribute to better medicines, improved health outcomes, & enhanced healthcare accessibility.
Process and Project Mgmt	SDG 8 SDG 12	Students will explore sustainable project mgmt methodologies ensuring resource-efficient & ethical business practices.
Emerging Technologies in Innovative Solutions	SDG 9 SDG 13	Students will develop business models that integrate technology-driven sustainability solutions, such as smart infrastructure and resource-efficient industrial processes.
Lean Innovating of Digital Solutions	SDG 9	Students will innovate strategic solutions, apply Lean thinking and evaluate their added value from sustainability perspectives.
Leading Digital Trans-formation	SDG 8 SDG 17	Students will work with industry partners to design digital transformation strategies that promote both economic growth and social responsibility.
IoT and Cloud Services	SDG 3 SDG 9 SDG 11 SDG 12 SDG 13 SDG 17	Students will develop smart IoT and cloud-based solutions, enhance wellness technologies, & improve industrial efficiency through predictive maintenance. They will design energy-efficient infrastructures & create global collaboration platforms, promoting sustainable practices and partnerships.
Data Analysis and Visualization	SDG 8 SDG 9 SDG 13	Students will analyze & visualize datasets to develop models improving energy efficiency & supporting climate action & sustainable industry practices. Data analysis & visualization skills will be developed to foster sustainable growth & promote decent work.
Machine Learning and AI	SDG 9 SDG 12 SDG 13	Students will design machine learning models to optimize material usage & reduce waste in manufacturing processes, while applying techniques to predict maintenance needs & minimize waste & energy consumption.

Table 3: Integration of SDGs in CES courses

Course	SDGs	Example
Circular Economy for Global Sustainable Transformation	SDG 8 SDG 9 SDG 11 SDG 12 SDG 13 SDG 17	Students will get an understanding of the connections between sustainability and circularity from regional strategy and industry perspectives, and the importance of design in implementation of sustainable and circular practices.
Circular Economy R&D Methods&Cases	SDG 9 SDG 11 SDG 12	Students will increase abilities in circular economy RDI, while enhancing project preparation skills with strategic and innovative insights.
Sustainable Processes and Product Development	SDG 9 SDG 12 SDG 13	Students will assess and develop organisational/industrial and product related processes to align with sustainability and circular economy principles & identify business opportunities. Students develop renewable energy solution skills.
Materials in Circular Economy	SDG 9 SDG 12	Students will understand material circulation in the circular economy for sustainability, focusing on polymers & biobased materials. Students will learn to utilize audits, implement waste solutions, maximize reuse, consider extended producer responsibility & identify sustainable alternatives from production & consumption perspectives.
Circ. Economy Technologies & Data Mgmt	SDG 9	Students will understand the role of technologies & data in the circular economy.
Climate Change Mitigation and Adaptation	SDG 11 SDG 13 SDG 17	Students will be able evaluate urban climate interactions, compare mitigation strategies, assess climate change effects & adaptation strategies & understand climate-smart governance.
Impact Assessment of Circular Economy	SDG 9	Students will be able to apply life cycle assessment, carbon footprint & nature impact assessments, understand reporting requirements, utilise & develop circular economy metrics.
Managing Urban Sustainability Change	SDG 11	Students will apply sustainable change mgmt methods & circular economy principles at the community level, use forecasting techniques & understand sustainability strategies & smart city technologies.

While the TTL programme contributes to several SDGs, the strongest emphasis is placed on SDG 9 and SDG 13. These goals align with the core themes of the programme, which focuses on leveraging technology for sustainable technological transformation. Furthermore, the programme highlights SDG 8, SDG 12, and SDG 17 to ensure that technological

transformation supports inclusive economic growth, sustainable practices, and cross-sector collaboration. Similarly, the CES programme also emphasizes SDG 9. However, a strong focus is also put on SDG 11 and SDG 12. All these are central in developing a circular economy. Furthermore, SDG 13 is also fundamental in the sustainable circularity change, which also shows through the curriculum analysis. Table 4 summarizes how frequently each SDG is addressed across the courses.

Table 4: Integration of SDGs in TTL and CES courses

SDGs chosen in LAB's strategy.	Number of courses addressing the SDG	
	TTL (n=9)	CES (n=8)
SDG 3: Good health and well-being	2	0
SDG 8: Decent work and economic growth	4	1
SDG 9: Industry, innovation, and infrastructure	6	6
SDG 11: Sustainable cities and communities	1	4
SDG 12: Responsible consumption and production	3	4
SDG 13: Climate action	5	3
SDG 17: Partnerships for the goals	3	2

At programme level, SDGs are embedded across core courses, while the specific SDG focus may vary depending on course implementation and elective choices. As the programmes are in their early implementation phase, initial observations indicate strategic alignment with sustainability, while future iterations are needed to ensure consistent SDG integration at course and teaching practice level.

CONCLUSIONS AND IMPLICATIONS

This study provides a case example of how SDG's can successfully be incorporated in the curriculum of master level engineering studies. Both CES and TTL have the SDG's incorporated into their curriculum in line with the overall strategy of the university. The CES programme, is constructed around the perspective of fostering sustainable development through promoting circular economy, thus, especially the resource efficiency-related SDGs are integrated to the entire content. In contrast, the core competences gained through TTL often contribute indirectly, yet significantly, to achieving the SDGs, as the degree focuses on leveraging technology for sustainable transformation. However, further work needs to be undertaken with respect to finding synergies between the two degrees. As course implementation varies by teacher, the actual embedding of SDG related topics in each course is not certain. Future research should be directed towards the actual SDG topics in the course implementations and towards examining student feedback in relation to the SDG content, which should be followed by continuous yearly improvement with regards to course content based on the received feedback. Engineers are central in shaping a sustainable future, which calls for an integrated and holistic approach to sustainability within engineering education. Beyond technical expertise, curricula must encompass environmental, social, and economic dimensions to prepare engineers as responsible leaders capable of addressing complex global challenges.

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BIOGRAPHICAL INFORMATION

Kristiina Brusila-Meltovaara, has a PhD degree in business. She acts as a Principal Lecturer at the Technology Faculty of LAB University of Applied Sciences. Kristiina has extensive industry experience and experience in lecturing, curriculum development, e-learning, development of teaching materials, and commercializing training and university services. Current research interests include innovation, commercialization, leadership and management, ethics, sustainability and the leadership thereof.

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