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Author	Kantanen, Mari-Selina;Hendriksson, Katri
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Project-based studies strengthening expertise in circular economy and responsibility– case Mechanical Engineering

Kantanen Mari-Selina¹, Hendriksson Katri¹

¹Department of Mechanical Engineering, Lapland University of Applied Sciences, Finland

mari-selina.kantanen@lapinamk.fi

Abstract

The evolving demands of professional knowledge require engineering education to incorporate new subjects, particularly those related to the circular economy, sustainability, and responsibility. Future engineers must understand not only their technical fields but also the complexities of sustainable development and how these principles integrate into industry. To address these challenges, many universities have developed their engineering curriculum by embedding circular economy themes into various courses. As a regional developer, Lapland University of Applied Sciences (LUAS) collaborates closely with local businesses and stakeholders to ensure that engineering graduates possess the skills needed for sustainable industrial transformation.

Several universities' curriculums are structured around competence- and problem-based learning. Through project-based courses, students engage in real-world problems from the first academic year to the final semester, often tackling circular economy and sustainability-related challenges. These projects, conducted in collaboration with companies and research and development initiatives, offer students hands-on experience while providing businesses with innovative solutions.

This paper presents how knowledge of circular economy and sustainability are implemented in mechanical engineering education, especially by working-life project works. Strong partnerships with businesses, municipalities, and development organizations ensure that education remains aligned with evolving industry needs. If the collaboration is systematic, planned, and mutually beneficial, then it supports the strategic objectives of all parties and enhances both regional and national vitality. Work-life-oriented education, combined with RDI activities that renew the business sector, strengthens students' expertise while providing companies with new insights and sustainable solutions. By integrating circular economy themes into education and fostering strong industry connections, universities ensure that graduates are well-prepared to contribute to the advancement of sustainable technologies and business practices.

Keywords: Curriculum development, Circular Economy, project-based learning, work-life relevance

1 Introduction

In recent years, various actions have been taken to reduce factors contributing to global warming. The European Union has developed strategies and goals to reduce greenhouse gas emissions. Additionally, the EU has been supporting implementation of new, more sustainable, technologies and solutions. Alongside actions towards more sustainable ways to act, the EU has set targets for the implementation of circular economy action plan (EU Circular Economy Action Plan, 2020). Important progress has already been made

but there is still constant pressure to move forward e.g. in sustainable development in cities or industrial activities. Activities aligned with the circular economy enable the transition from a linear economic model toward a more sustainable future. Higher education institutions (HEIs) play a key role in educating new innovators to the workforce who can consider aspects related to sustainable development.

Working in the technological field requires an ability to update knowledge and skills due to the continuous change of working life. Engineers should master new areas of expertise, and they should recognize the different ways to utilize their expertise in new situations. The transfer towards an industrial circular economy demands an educated work force, who have the knowledge and understanding of how circular economy is implemented in their work. In addition, the digitalization of industry and the expertise of new technologies, as well as their integration with the circular economy, also require collaboration with companies. Students' work-life skills can be developed if the work-life-oriented projects are implemented further the studies progress (Chandrasekaran *et al.*, 2015). According to Lakkala *et al.* (2023) the learning of work-life-based competences and –practices become more efficient and motivational for the students, if the studies include real-life project topics. The most important working-life skills are e.g. creative problem-solving, entrepreneurial mindset, flexible and open-minded thinking, ability to handle increasing complexity and communication skills (World manufacturing foundation, 2024). These important skills can be strengthened through work-life-oriented projects.

Lapland University of Applied Sciences (later LUAS) has actively taken measures to respond to these new skill requirements. The curricula of engineering programs have been developed, and the content of courses has been enhanced with themes related to circular economy. In Finnish universities of applied sciences, the competencies of degrees are defined as both education-specific and common competencies. Common competencies are areas of expertise shared across different education programs and degrees, forming the foundation for functioning in the workplace, collaboration, and the development of expertise. The Rectors' Conference of Finnish Universities of Applied Sciences (ARENE) updated the recommendations for common competencies of degrees in 2021. One new common competency introduced into the degrees of universities of applied sciences is sustainable development, according to which students should be familiar with the principles of sustainable development, promote their implementation, and act as responsible professionals and members of society (ARENE, 2021).

LUAS has been engaged in long-term efforts towards sustainable development for several years, and the related themes are also central in the strategy. Among the strategic priorities is, for example, the digital green industry, with the aim of promoting the green transition and industrial circular economy (LUASa, 2024). LUAS is committed to promote bioeconomy and circular economy through its activities and both themes are integrated into education and research and development (R&D) activities across almost all areas of expertise within the organization. The aim is that all graduates from LUAS will possess knowledge of bioeconomy and circular economy as part of their field of study. Within R&D activities, the promotion of bioeconomy, circular economy, resource efficiency, and low-carbon practices will be further strengthened.

2 From region collaboration to meaningful partnerships

LUAS engages in close collaboration with various organizations across different sectors. This co-operation yields mutual benefits, particularly in the areas of education and research, development, and innovation (RDI) activities. Active collaboration with companies can help respond to changes in the operational environment life-oriented education and RDI activities that renew the business sector are based on trust and strong partnerships (LUASb, 2025). Partnerships between LUAS and specific partner organizations involve planned, systematic, and mutually beneficial long-term collaboration. The goal of such partnerships is to support the strategic objectives of both parties, thereby enhancing vitality both regionally and nationally.

In addition to established official partnerships, LUAS engages in partnership-type collaboration with other regional actors. A great example of this is the long-standing cooperation with Kemi Digipolis Ltd. This company is a business development orientated and operating in the Kemi Industry Village -area and is deeply involved in the development efforts of the Sea-Lapland's region as well as the broader Lapland area. The collaboration with the company typically takes the form of project-based cooperation and the sharing of up-to-date information.

Close collaboration with regional companies, organizations, and various stakeholders strengthens the university and guides the development of education. The primary mission of a university of applied sciences is to educate up-to-date professionals who transfer their expertise to complement the competencies of local businesses. Bioeconomy and circular economy have also been widely integrated into teaching through numerous implemented educational development projects. Projects carried out in collaboration with companies also bring new insights into teaching content, and they are often addressed through student projects or theses.

3 Acceleration lane of the circular economy

LUAS and Kemi Digipolis Ltd launched a joint circular economy-themed project starting from the beginning of 2024, aimed at giving a new innovative perspective to Lapland's industrial circular economy innovations. The project is called "Acceleration lane for industrial circular economy in Lapland" and it will be finished by the end of the year 2025. The goal is to strengthen the region's industrial circular economy by focusing particularly on enhancing collaboration among various stakeholders. The total budget of the project is 748,276 €, which contains 598,280 € ERDF-funding provided by the Lapland Regional Council.

The project will shape an "accelerator lane" strengthening the industrial circular economy, facilitating more efficient dialogue between project stakeholders and local businesses. The project's content is designed so that the Accelerator Lane model supports the activities of project stakeholders, regional circular economy developers, and local SMEs engaged in circular economy practices. The project's content will notably impact the circular economy development work of SMEs, providing companies with an easily accessible entry point. The main idea of the project is to offer practical tools and resources to help companies incorporate circular economy principles into their operations. Local businesses may, for example, discover new ways to reduce waste, optimize resource usage, and develop more sustainable business practices.

The Accelerator Lane model implemented in the project also promotes networking and collaboration among different stakeholders, potentially unlocking new opportunities for innovation and business development. The “Acceleration lane for industrial circular economy in Lapland” project is part of a broader effort to promote sustainable development and environmental responsibility in the region.

4 Semester Projects promoting competence of the circular economy

The mission of LUAS is to provide higher education based particularly on the demands of working life and its development, as well as research activities (Hendriksson & Kauppi, 2020). The collaboration between educational organizations and companies (work-life relevance) is highly important in educating future experts. Active collaboration ensures that teaching contents align with the needs of the working life, and companies can also provide up-to-date information to the study modules. The working life offers various development ideas and problems for the study modules, which students from different fields can solve as part of their studies. Providing internships and thesis topics enables networking between students and various stakeholders from companies (Hendriksson, 2022). For many students, the first steps of their career path come through these various forms of collaboration with working life. The RDI projects carried out in collaboration between LUAS and other entities operating in the region have a significant impact on enabling these various forms of collaboration with the working life.

The curriculum of Mechanical Engineering is based on competence and problem-based learning. The professional growth of the mechanical engineers proceeds gradually from the first academic year to the last year. Every academic year and semester, the curriculum focuses on project courses. Projects in the first and second years introduce and engage students in the field of study, while themes of the projects in the third and fourth years are real working-life problems. The various courses throughout the semesters support the competences needed in projects (Kantanen & Ruottu, 2019). Many project topics originating from the working life are related to the circular economy. In Mechanical Engineering studies, the themes of the circular economy are taught in various courses *e.g.* material sciences, manufacturing, designing, energy technology, and maintenance, Figure 1. The development work to reinforce the competence of the circular economy was done through European Social Fund (ESF)-funded “*Development of a study module for circular economy and industrial side flows and piloting it in cooperation with companies*”-project together with Kemi Digipolis Ltd. The development work was planned together with regional industries, due to most of the graduated students are hired in local industries (Kantanen & Tyni, 2020).

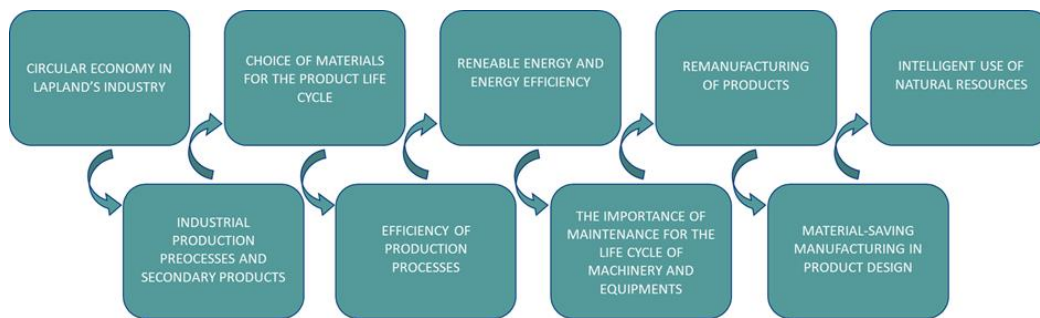


Fig. 1 The content of the circular education in Mechanical Engineering (Kantanen & Tyni, 2020).

The academic year projects are learning and problem-based CDIO-projects. The CDIO model is divided into the academic year so that phases C (Conceive) and D (Design) are implemented in the autumn semester and the phases I (Implementation) and O (Operate) in the spring semester. In the first two years the projects are familiarizing the students to field of the mechanical engineering and to the companies of the region. In the third year of the studies the semester projects are company-based and real working life problems (Study Module: Project: Working life-oriented project). In the fourth year of the studies there is project only at the autumn semester, all the CDIO model phases are implemented during semester (Study Module: Project: Innovation project). The project topics are mainly given by LUAS RDI projects. The final spring semester of the studies is reserved for the thesis work.

In the region of Lapland, there are steel, paper, energy, mining, design and engineering workshop companies so the subjects of the projects can vary a lot. In recent years, many of the projects undertaken by companies have been related to the circular economy. In project studies, in addition to the course teacher, project workers from LUAS's RDI unit also act as student supervisors. Through joint guidance of the study module, cooperation between teaching and RDI actors has been intensified. With project topics rooted in working life, students have tackled issues such as utilizing side stones from the mining industry in line with sustainable development, controlling dust in the steel industry, developing process equipment for plastic materials used in jewelry, improving occupational safety in machinery used in ore prospecting, and developing recycling point solutions for LUAS's learning environments, among others. All these activities strengthen the students' knowledge of circular economy during the studies (Figure 2).

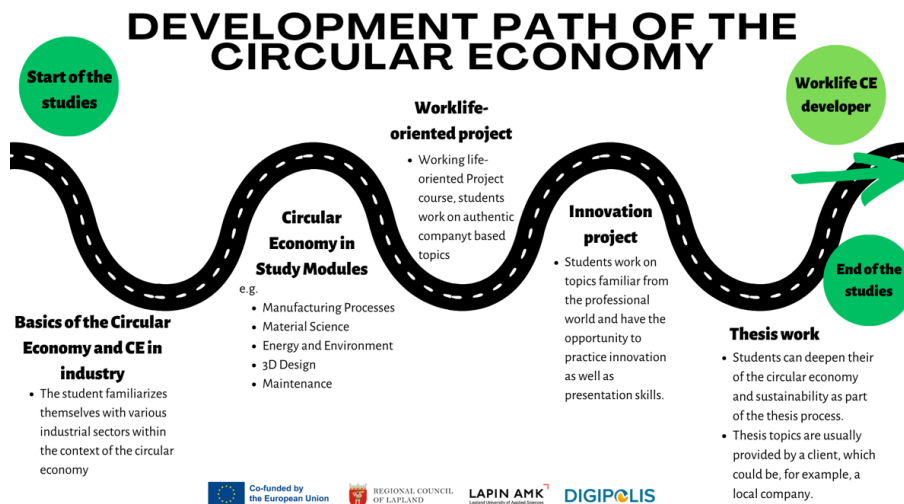


Fig. 2 Development path of the Circular Economy in Mechanical Engineering Education.

In these project-based courses, long-term collaboration has been established with companies operating in the region. Solutions generated by students in previous years can be further developed and new solutions sought. Project solutions created by students from previous years can still be further developed and new solutions can be sought. Some development ideas evolve into thesis topics, within which the focus can be more precisely directed towards the specific problem being addressed.

5 The future developers of the circular economy

Collaboration with companies plays a significant role in strengthening and developing students' expertise. The majority of LUAS engineering students' study while working (adult students), and most of them are already employed in roles that support their field of study. Internships are also a key part of the studies, which engineering students mainly complete during the summer in industry, filling in for employees at companies. The development work to reinforce the curriculum with the competence of the circular economy was made in the year 2017 and there have been some minor reinforcements in the years 2019 and 2023. In spring 2020 and 2024 the Webropol questionnaires were arranged for the second- and third-year students to receive feedback on visibility of the circular economy during the studies. In the questionnaire made in 2020 a total of 37 responses were collected (n=37) and in the questionnaire made in 2024 a total of 44 responses were collected (n=44). In both questionnaires, most of the answers were from adult students (year 2020 68% and year 2024 93%). The volume of the circular economy themes in different courses has increased over the years, and the students evaluated that the circular economy has been actively present during the studies in several ways, Figure 3.

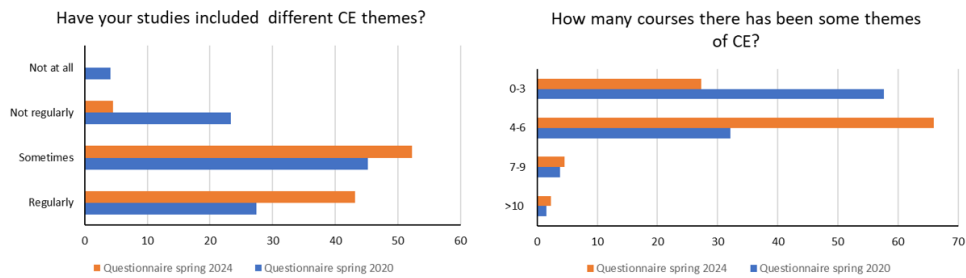


Fig. 3 The presence of the circular economy themes in teaching.

The students evaluated that the circular economy has been actively present during the studies in several ways, Figure 4. In the option “other” was commented that circular economy is as a continuous theme throughout the entire studies.

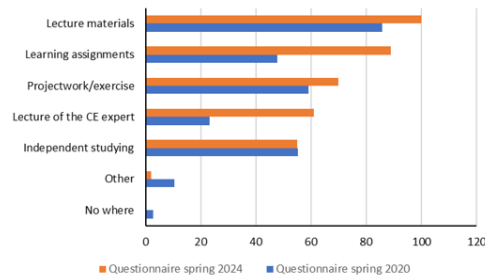


Fig. 3 Circular economy as a part of course implementation.

The students were asked how significantly they perceive the role of the circular economy as being part of their future job tasks. Additionally, they were asked in which specific areas they think the circular economy might emerge. Most of the students find out that circular economy plays a role in their future work. There is a lot of industry in the Lapland region, and perhaps because of this, students believe that circular economy themes will particularly emerge through the development and design of processes or equipment, material reuse, waste management, and predictive maintenance, Figure 5. According to students, the circular

economy will be least evident in new business ventures, as well as in aspects related to digitalization and logistics, which raises considerations for the development of education. The goal is to keep local businesses thriving, and circular economy business models, together with digitalization, create new opportunities for business development.

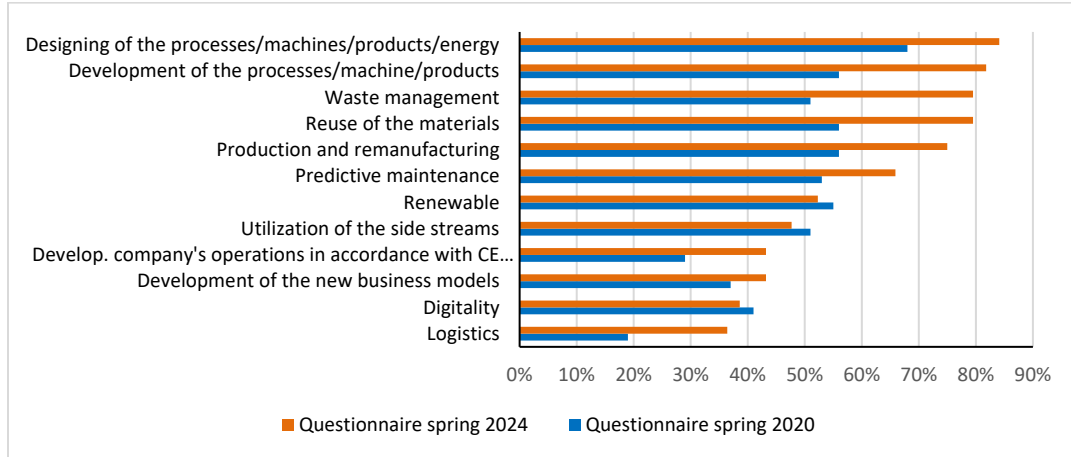


Fig. 5 Role of the CE in the work of Mechanical Engineers.

Awareness related to sustainable development is increasing in society all the time, and therefore the basic knowledge related to the circular economy of new, first year students was surveyed in the middle of the autumn semester 2024, Figure 6. In this Webropol questionnaire a total of 29 responses were collected (n=29), all the answers were from adult students. Students recognize many aspects of the circular economy, with waste management, recycling, and energy efficiency being the most prominent topics. Students also recognize aspects of the circular economy in business operations, particularly those related to recycling and energy efficiency. Waste reuse is acknowledged as an important aspect, but it is not specifically observed in business operations. More focus is needed on life cycle thinking, sustainable production, resource efficiency, low carbon solutions, and renewable energy through education to ensure that this expertise is transferred to the workforce.

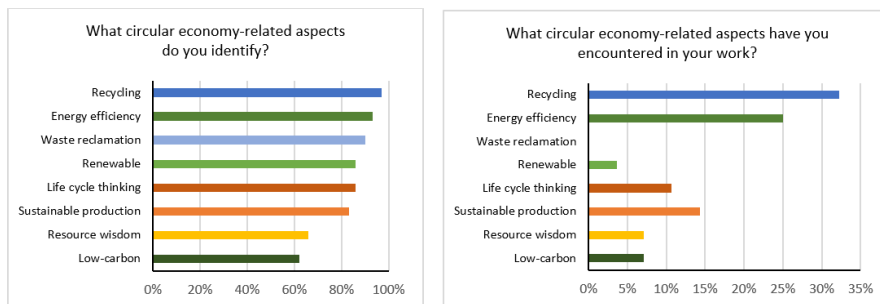


Fig. 6 First year students' knowledge of the circular economy.

There is still much to be done in developing companies' operations to be more responsible although awareness and actions related to the circular economy is growing all the time. As new students also recognized, issues and actions related to recycling and energy efficiency are most identified and possibly implemented, but especially in terms of lifecycle thinking, sustainable production, resource wisdom, and

low carbon practices, more actions are needed. For these various aspects of the circular economy to advance in companies as well, universities must ensure that new professionals and developers of working life graduate with sufficient circular economy expertise. One tool for that is development of the curriculum, as can be seen from the results of the student surveys presented in this publication. Therefore, universities of applied sciences should actively collaborate with local companies and other stakeholders. The development work on circular economy continues strongly as part of LUAS' engineering education programs. With graduating students, new experts are brought into the industry to develop companies' operations towards a more sustainable future.

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