REFORMED CURRICULA: TOOL FOR PROVIDING PROFESSIONAL GROWTH FOR STUDENTS

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ABSTRACT

The engineers need a good knowledge of their special technical field but also, *e.g.,* social, analytical thinking, problem-solving, language skills, and especially how to combine their own knowledge with other specialists. Furthermore, there are always new areas of expertise that engineers should master, for example, bio and circular economy, which joins different sectors and experts together. The Lapland University of Applied Sciences (LaplandUAS) has reformed curricula of educations. The new curricula are based on competence and problem-based learning. The Mechanical Engineering curriculum consists of the academic years, and CDIO-type semester project courses are arranged in each semester. The curriculum permits flexibility to the contents, and it can be updated if there are new subjects from the engineering field to be taught for the students. For example, in the Mechanical Engineering studies, the circular economy is integrated into various courses. The students will have the know-how of the utilization of circular economy principles in their future careers. The academic year themes in the Mechanical Engineering are *Learning about Work of Mechanical Engineers*, *Engineer's Toolbox*, *Creative Engineers,* and *Pre-Engineers*. First year's semester projects are "On the way to Becoming an Engineer" and "Language of the Engineers." The second year's projects follow CDIO project steps more clearly so that C-D phases are taught in the autumn semester and I-O phases in the spring semester. The subject of the project is given by the teachers, and the students need a different kind of competence. The new curricula require collaborative teaching and development of the learning methods and environments. New themes and knowledge demand of the industry and society to future engineers direct teachers to update the content of the courses. All these new elements of the new curricula have increased the motivation of the students. Additionally, the level of dropouts has decreased, which indicates that the changes are heading in the right direction.

KEYWORDS

Development of curriculum, competence and problem-based learning, sustainability, bio and circular economy, motivation, Standards 1, 2, 3, 4, 5, 6, 8, 9, 10, 11

INTRODUCTION

Working in the technological field requires the 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. One example of

this kind of change is the engagement of bio and circular economy in different areas of the industrial field. In the short term, bio and circular economy have become a megatrend that joins different sectors and experts together, providing several development possibilities in the vast technological field.

The transfer towards industrial bio and circular economy demands an educated workforce, who have the knowledge and understanding of how circular economy is implemented in their work. The Lapland University of Applied Sciences (LaplandUAS) has reformed curricula of the educations based on these identified demands. The new curricula started in the autumn of 2017 and are 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 semester has a CDIO- type semester project course and various study modules reflecting the competences. In the Mechanical Engineering studies, the themes of the circular economy are taught in various courses, *e.g.,* material sciences, manufacturing, designing, energy technology, and maintenance. Additionally, the themes of the circular economy are also present in the semester projects.

During the update of curricula, LaplandUAS made an alignment of engaging the bio and circular economy to be part of the engineering education. The development work has been done through a 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 aim of the project was to engage bio and circular economy in engineering education. The development work was planned together with regional industries, due to most of the graduated students are hired in local industries. In this way, the graduated students have the expertise which is most likely to benefit their future employers.

HEADING TO SUSTAINABLE DEVELOPMENT AND CIRCULAR ECONOMY

Global warming and environmental issues have become to the point where we must make changes globally. In Europe, the European Union has taken a guiding role and set up strategies and targets for the next decades to decrease environmental gas emissions. Additionally, the EU has been supporting the implementation of new, more sustainable technologies and solutions. Important progress has already done, but there is still constant pressure to move forwards, *e.g.,* in sustainable development in cities or industrial activities. Achievement of these demands requires significant investments and research to develop new technologies, energy efficiency, and potential ways to utilize new energy sources and raw materials. Above all, the EU needs educated engineers who can work with multidisciplinary fields of industry.

Alongside actions towards a more sustainable way to act, the EU has set targets for the implementation of a circular economy action plan. (EU Circular Economy Action Plan, 2020) EU has collected 54 actions, which will shape the economy towards a climate-neutral and more circular economy. Actions will minimize the impacts on natural and freshwater resources as well as ecosystems. Implementations are focused especially on the lifecycles of the different kinds of products. According to the estimations, the circular economy can offer benefits by decreasing the EU's carbon emissions by 450 million tons by 2030. Additionally, it will save 600 Mrd € for EU businesses and create 580,000 new jobs.

According to the EU, the circular economy consists of general measures such as product design, production process, consumption, from waste to resources (secondary raw materials),

and innovation, investment, and other cross-cutting issues. (EU Circular Economy, 2019) Additionally, the EU has determined actions for specific materials and sectors, which are plastics, food value chain, critical raw materials, construction and demolition, biomass, and bio-based products, as well as a review of fertilizer legislation. These materials and sectors are most likely facing challenges as they are heading towards a circular economy, therefore needing an educated workforce to implement changes.

Alongside with EU, there are foundations such as the Ellen MacArthur Foundation (Ellen MacArthur Foundation) and the Finnish Innovation Fund Sitra (Sitra, Circular Economy), which are making a remarkable work at the European level as well as globally, to boost transformation towards bio and circular economy. Both have been funding development work of circular economy in the R&D sector as well as in the educational sector. They are continuously publishing new reports about circular economy activities. In 2016, Sitra published the world's first national road map for a circular economy. The focus of attention was on the role administrations can play in enabling things, on the encounters of different operators in society, and on cooperation between companies. The road map was updated in 2019. "Critical Move" describes the vision, strategic goals, and concrete actions accelerating the transfer towards a circular economy in Finland by 2025. (Sitra Critical Move, 2020)

The main idea of a circular economy is to avoid linear "Make-Take-Waste" economy and design systems so that material, components, products, and value bound to them circulates inside the system as long as it is possible. Production and consumption should be designed to avoid loss and waste. In the long term, material and energy efficiency creates environmental, as well as financial benefits. Alongside products, a circular economy is adding value by creating services and digital solutions based on intelligence. Transformation towards a circular economy requires systemic change, and therefore the changes must be made in policy actions as well as in municipalities or strategies of industries. The transition will also require knowledge and know-how, and above all, open-minded cooperation between operators. (Sitra Leading the Cycle, 2016)

The systematic transition towards a circular economy in the industrial sector will require a new kind of expertise and ability to utilize know-how in new ways with experts from various sectors. Therefore, there is a need for educational development to increase the understanding of the sustainability of the students.

CURRICULUM DEVELOPMENT AS A TOOL FOR ALLOWING FLEXIBILITY INTO TEACHING CONTENTS

The curriculum of Mechanical Engineering consists of projects and various study modules reflecting the competences. The learning and/or problem-based project is in the center of every semester's theme, and the contents of the different study modules are integrated into the content of the semester project. The names of these projects and study modules are inspiring and modern and try to illustrate better the theme of the academic year to the students. (Kantanen & Ruottu, 2017) The professional growth of the mechanical engineers proceeds gradually from the first academic year to the last year in every academic year and semester themes. Figure 1 presents an example of a semester project and how the study modules support this. (Kangastie & Mastosaari, 2016)

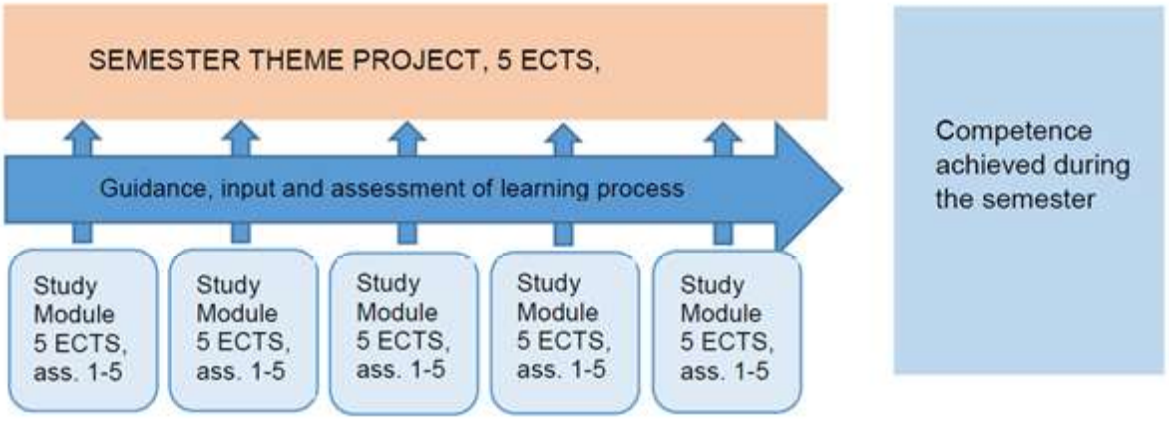

Figure 1. An example of the semester theme. (Kantanen & Ruottu, 2017)

In the first academic year, the students practice basic subjects of Mechanical Engineering combined with natural science, language, and social skill studies. The field of Mechanical Engineering becomes familiar to the students. First year's autumn semester project is *On the way to Becoming an Engineer* in which the students are familiarized with different kinds of industries of the Lapland region. In this project, the students learn some basics of the circular economy (*phase C - Conceive*), and they study how this theme is shown in the mining, steel, paper, forest, energy and machine workshop industries (*phase D - Design*). The semester project culminates with a fair where the students introduce their semester project results (*phase I – Implement)*, and the companies introduce activities and practical training possibilities for the students *(phase O - Operate*). The fair also contains competition for the teams. The participants of the fair can vote for the best poster and the best performance among the projects (Figure 2).

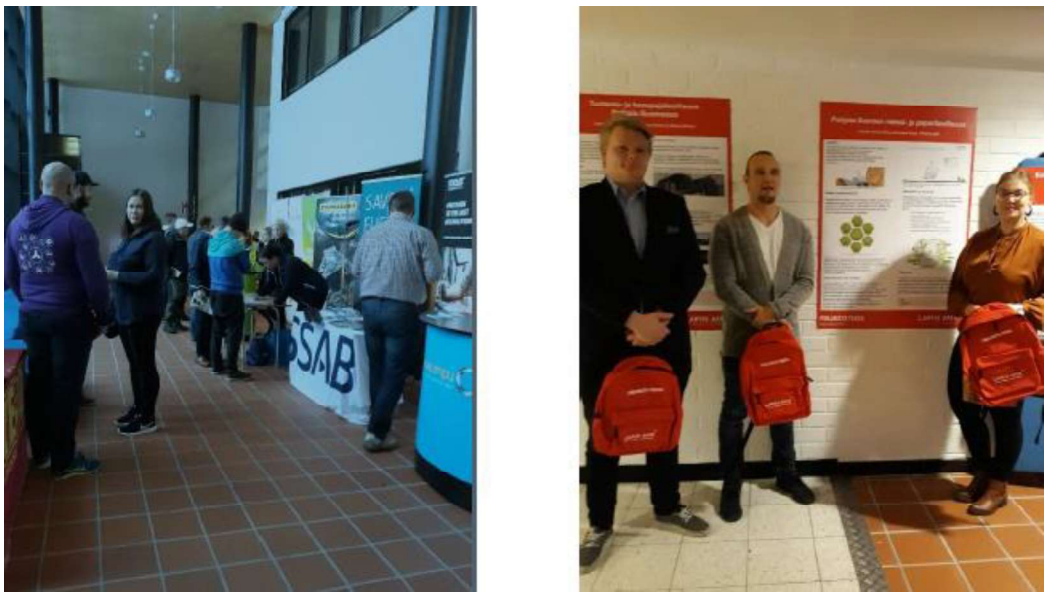

Figure. 2. The company booths at the fair (left) and the winners of the student projects (right).

First year's spring semester project is called as *Language of the Engineers*. In this project, the students build spaghetti bridges in smaller teams. The building of the spaghetti bridges requires competencies such as designing and technical mechanics. This project follows the CDIO-phases, where the students *Conceive* the structures of the bridges in project groups, and then they *Design* the selected structures with CAD programs. The *implementation* is made by building the structures, and finally, the *Operation* of the learning process is made by demonstration of the structures and strength tests of the bridges. The results are presented in the Project seminar day, arranged for the co-operative companies and other partners of the LaplandUAS. During the seminar day, student teams are also competing for the best implementation of spaghetti bridges. The participants of the fair vote for the greatest bridge, which is awarded at the end of the day. (Kantanen & Ruottu, 2019)

In the second academic year, the basic tools of Mechanical Engineering become more familiar, and the students learn how to apply all the knowledge they have achieved. The students can also work on the projects, and they can apply different kinds of problem-based methods. 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.

The autumn semester project, *Engineer's Toolbox*, is a product development project. The theme of the project is to design a table fan in a smaller group, and the theme is given by the teachers. Supporting courses, such as *Engineer's Mathematics*, *CAD as a Tool*, *Technical/Engineering Mechanics*, and *Automation Solutions,* are provided for the students to build up the required knowledge for the product development. The students participate in the designing process, CAD labs, material selection, and planning the designing and functions of the product. They also draw up technical drawings and charts, as well as evaluate the expenses and cost-effectiveness of the product. The exchange students are also participating in the project; therefore, teaching is also given in English, also providing internationalization for the Finnish students at home. (Kantanen & Ruottu, 2019)

During the spring semester's project, *Pouch the toolbox,* the students complete the designing of the products (*I – Implementation* phase) and prepare a prototype (*O – Operate* phase). Therefore, they need competencies, *e.g.,* in material science, 3D design, effective production methods (Lean, 5S), as well as energy technologies. The students can utilize 3D printing or machining steel into the manufacturing of the parts of the table fans. The manufacturing of the parts can be done at school, home, or at work. It is also required to pay attention to the life cycle of the product and make improvements in the product design. Additionally, Operation and maintenance are considered, and students learn how to productize products and services. The designed and manufactured table fans are demonstrated in the semester Project seminar day together with the first-year student's spaghetti bridges (Figure 3). (Kantanen & Ruottu, 2019)

During these two first years of studies, the bio and circular Economy themes are taught to the Mechanical Engineering students in different courses. The teachers are selected what themes suites best to the content of the course. In Mechanical Engineering Education, all of the students accomplish extensive knowledge of the bio and circular economy, Figure 4.

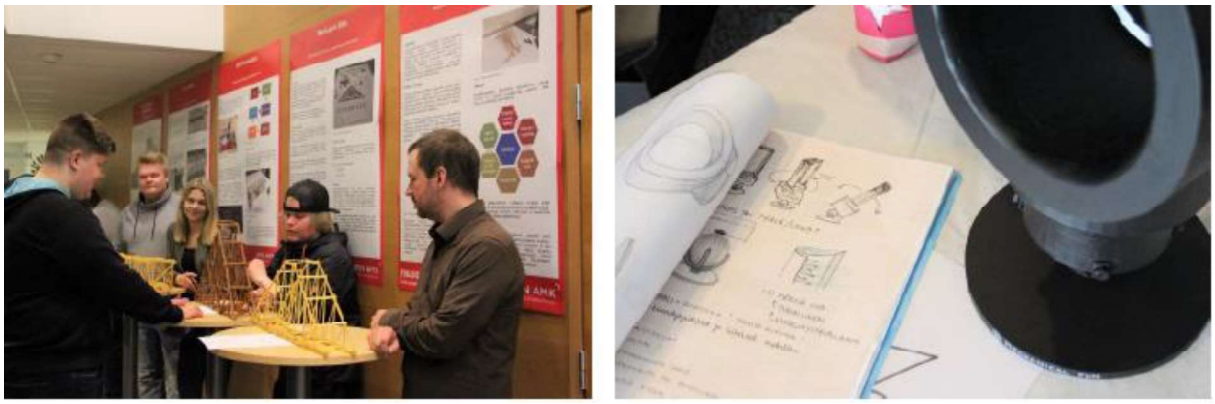

Figure 3. The first year's students, presenting spaghetti bridges (left) and a winning table ventilator solution by the adult student team (right).

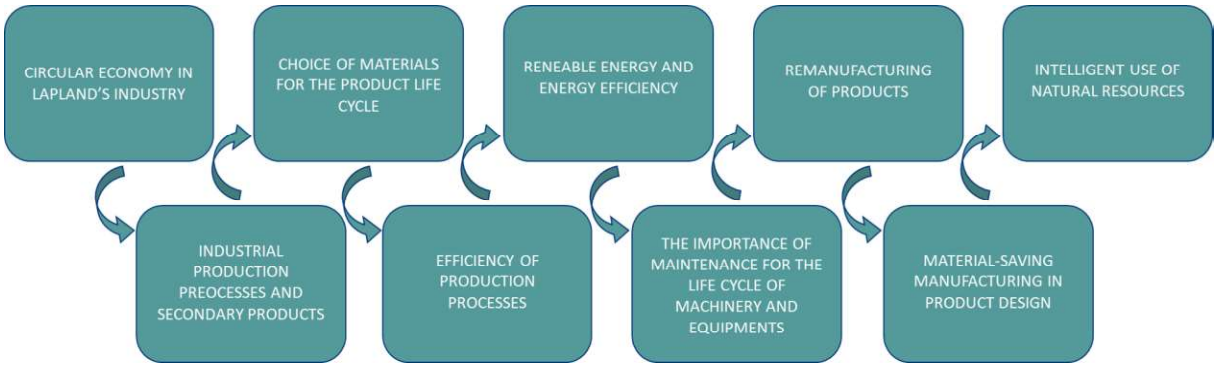

Figure 4. The content of the bio and circular education in Mechanical Engineering.

The theme of the third academic year is *Creative Engineers,* and the semester projects are based on the real working life problems provided by regional companies. There are three different kinds of alternative professional study options in the Mechanical Engineering education curriculum. The students are allowed to choose one of them to be completed during the third academic year. These alternative professional studies are *Industrial Professional*, *Product Development Professional*, and *Mining Professional*. In the region of Lapland, the industrial sector is mainly consisting of steel, paper, energy, mining, design, and engineering workshop companies; therefore, the subjects of the projects can vary a lot. The student is allowed to pick up the project subject suiting best for his/her career plans. One theme is also related to the circular economy or contains aspects of it. (Kantanen & Ruottu, 2019) First company-based projects, implemented with a new curriculum, started in autumn 2019 with C and D phases. The I and O phases are going to be progressed during the spring semester 2020. In their last academic year, the students deepen the Mechanical Engineering competence before they graduate at the end of the year.

DEVELOPING ENGINEERING EDUCATION WITH ESF-FUNDED PROJECT

Since 2017, Lapland UAS has been developed engineering education to contain bio and circular economy alongside engineering education. Development work has been done in the 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 project is also called *CircularSchool,* and it will be finished by the end of the year 2020. The total budget of the project is 230,352 €, which contains 184,280€ ESF-funding provided by the North Ostrobothnia Centre for Economic Development, Transport and the Environment (ELY Centre).

The project was planned to develop bio and circular economy contents inside the engineering studies and study projects. The theme is broad, and therefore every study field has its own perspective, how the circular economy is conducted inside specific themes. Mining, steel, and forest industry are the main industrial fields in the Finnish Lapland. Production is concentrated on material production; therefore, the production of final products is rare. Bio and circular economy underline the circularity of the systems and reusability, recycling and remanufacturing are the ways to improve the systems to be more sustainable. In the future, the aim is to improve the utilization of industrial side flows as a raw material for other industrial processes.

The transfer towards industrial bio and circular economy demands an educated workforce, who have the knowledge and understanding of how circular economy is implemented in their work. In Finland, especially in scarcely populated areas such as Finnish Lapland, there are difficulties in getting enough workforce in the companies. Usually, people who have born and studied in the area are most likely going to stay there, and therefore it is highly important to provide high-quality education for the residents in the area.

The development of the circular economy education was done together with regional companies. Lapland UAS implemented meetings and interviews with regional companies to discover the needs of companies especially related to bio and circular economy. On this basis, the new bio and circular economy contents were planned to be fitted inside the engineering education. The cooperation with regional companies especially appears in the semester projects. Companies can offer themes or subjects for the students to be solved during the projects. The challenge to be solved by the students might be related, *e.g.,* to an industrial side flow, which the company would like to utilize as a raw material for the production of another product. As mentioned above, the supporting subjects are provided alongside the project so that the students have the required knowledge to solve the challenge.

CONCLUSION

The new curricula in LaplandUAS are based on competence and problem-based learning. The curricula require collaborative teaching as well as the development of the learning methods and environments. The students learn working life skills alongside their engineering studies. Additionally, they have to take more responsibility for their studies. The Mechanical Engineering curriculum consists of academic years. CDIO-type semester project courses are arranged in each semester, and different courses are integrated into the projects to give an overall insight into the contents of the semester theme. The challenges in lifelong learning and development of the competencies require educators to develop the contents of the degree programs. The new curriculum permits flexibility to the contents by providing the possibility to be updated if new subjects are popping up from the engineering field. In the case of the circular economy, the students will have the know-how of the utilization of circular economy principles in their future careers.

The ESF Funded *CircularSchool* project has enabled the bio, and circular economy contents are included inside the engineering studies and study projects. The development of the circular economy education was done together with regional companies, which assure that the teaching contents are relevant and the companies can get a skilled workforce now and in the future. The theme is broad, and therefore every study field has its own perspective, how the circular economy is conducted inside specific themes.

The attractiveness of the engineering studies can be improved with the development of the curriculum and teaching contents. This is especially important in scarcely populated areas such as Finnish Lapland, where different industries and companies need a skilled workforce. With all these efforts, made in engineering education in the Lapland University of Applied Science, the diversified professionals are educated for the industries and companies. It has also been seen that dropouts of the studies have decreased by the two-year experience of this new competence and problem-based curriculum. Additionally, the motivation of students to their studies has improved, and the students are interested in the new themes, such as bio and circular economy, in their studies. The development of teaching is continuing.

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BIOGRAPHICAL INFORMATION

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