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VIRTUAL STUDIES IN LEARNING OF SOLVING SUSTAINABILITY CHALLENGES

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ABSTRACT

The research introduces the green methodologies applied in the virtual project- and problem-based learning (PPBL) courses in years 2019-2022.The implementation was done in the environmental engineering study programs and in B.Sc. and M.Sc. levels in the LAB University of Applied Sciences (LAB), Finland.
First, the paper discusses about the theoretical green management methods, selected for the course implementation. The selected methods were regarded suitable for solving the sustainability challenges', given by the university's regional partners as they deepen the knowledge of sustainability. Second, after defining challenges and discussion between students and commissioning organisations. the implementation of the projects starts. The expected output is to find solution(s) for the given challenges. The first course for the research started in the spring 2019 and now, in the beginning of the fourth year, it is time to report about the mid-term results of the study. The research has been carried out as an in-depth, multi-method case study collecting data from the students and commissioners and in oral and written form. Third, and finally, the results have important implications for the deepening knowledge in teaching and learning of the sustainability. Moreover, the relevance of the topic area is increasing as the ability to act as a sustainability maker is becoming as a norm.
The main limitation of the study is the uniqueness of each project case and the amount of the gathered project cases so far. Anyhow, the results give material and guidance for the further development of green project management studies.

KEYWORDS

Green Project Management, Sustainability Challenge, Sustainability Education, Virtual Studies

1. INTRODUCTION

Sustainable development and the interplay between its ecological, social, and economic dimensions can be regarded as a highly complex task. As a logical consequence, educating for sustainable development also has a complex character (Steiner & Posch, 2018) The dimensions are interlinked is to have balance between them. The sustainability measures are activities that do not compromise the ability of future generations to meet their needs.

Three main challenges have been identified to address global learning needs: a) self-directed learning options for the development of competencies, b) transdisciplinary settings to

make knowledge applicable and effective in real-life situations, and c) overlapping the boundaries of academic versus nonacademic learning to achieve a holistic approach to lifelong learning (OECD, 2020).

Furthermore, there are two sides of education that can be seen as complementary:

• Learning *for* sustainable development: By both facilitating changes in what we do and promoting (informed, skilled) behaviors and ways of thinking, where the need for this is clearly identified and agreed (Adomsset, 2011)

• Learning *as* sustainable development: By building the capacity to think critically about (and beyond) what experts say and testing sustainable development ideas, as well as by exploring the contradictions inherent in sustainable living (Vare & Scott, 2007)

At the same time, the weakness in the relationship between development activities and knowledge production is one of the sources of the persistence and consequences of unsustainability and underdevelopment (Dzisah & Etzkowitz, 2008). Based on all above-mentioned key principles, the LAB UAS has taken an ambitious goal to show and develop practical implementation capability in these areas for the regional development and sustainability change management. This is a challenge with high expectations and requirements from the regional stakeholders as the community-based implementation of the sustainable principles is only possible as the stakeholders own these principles and, thus, create the basis for participatory, transparent, democratic, and above all, peaceful conditions for action. Peaceful contexts are necessary for communities to achieve the socio-ecological transformation that is necessary to mitigate climate change and to build models of a sustainable coexistence that preserves our common good, which is, first, the environment (Obrecht, 2022.).

At LAB it seen that environmental engineering students, and in Bachelor and in Master level, should have the curriculum links with the sustainability engineering courses and social change with specialized labs (lab works in certain course project types) that enhance technological and social-institutional sustainability literacy and build team-based project collaboration skills (Bacon et al., 2011). Furthermore, project-based learning (PBL) is a good method for letting the students explore an engineering project that considers the sustainability, environmental and social aspects (Gaughran et al., 2007). The overall aim at LAB is that the student will be able to work as sustainability agent in the working places.

The research has indicated that future professionals require knowledge from a variety of disciplines, but also competencies to accomplish real-word change. And, in this study, also to gather real-world learning experiences in the education of sustainability professionals (Heiskanen et al. 2016). The best way is to use problem and project based learning (PPBL) methodology. Teachers’ new role and tasks are well summarized in the commonalities section in the following figure.

2. SUSTAINABILITY COMPETENCES AND USE OF PPBL

The majority of the environmental engineering graduates from the universities of applied sciences will be employed in the business or public administration, where they must solve sustainability challenges. Wiek et al. (2011) point out five competences, which must be integrated to solve sustainability challenges and in research and in practice: 1) systems-thinking competence, 2) anticipatory competence, 3) normative competence, 4) strategic competence, and 5) interpersonal competence. These competences have a strong interplay, and they can be combined in different ways They underline, that competence in sustainability research and problem-solving means having the knowledge, skills, and attitudes necessary for successful task performance and problem solving with *respect to real-world sustainability challenges and opportunities*. Wiek et al. recommend ascertaining how the sustainability competencies translate to real-world sustainability research and problem-solving.

As the sustainability is a holistic approach and problem-driven, but at the same time solution oriented, the competences, which graduates are going to have, must also be holistic and co-create knowledge and action for sustainability. This, and the need to have experiments, which test key competences for or against the value of the key competences (WIEK et al. 2011). At the same time, the sustainability competences allow to use different learning styles because learning activities are outcome focused, and students may approach each activity from several different directions.

Table 1. Main features of sustainability competences (Wiek et al. 2011)

Sustainability competence	**Main feature**
Systems-thinking competence	ability to understand the intermediate and root causes of complex sustainability problems
Anticipatory competence	capacity to think systematically about the future and future generations
Normative competence	to understand concepts of justice, equity, social–ecological integrity, and ethics
Strategic competence	ability to collaboratively design and implement interventions and governance strategies with the sophistication necessary to address sustainability challenges
Interpersonal competence	capacity to motivate and facilitate sustainability research and problem-solving

As stated above, learning environments in higher education are increasingly geared towards competence development, with a problem-oriented approach, and real-life context. Sustainable engineering poses a difficult set of challenges for engineering teachers. To add, project-based learning is also a good method of delivering the concept of engineering design within a framework of sustainability to students (Lamborn, 2009). Together, problem-based learning offers the option to students to link theories to practice and project-based learning offers the option to a student to orchestrate his/her own learning process (Mulder et al., 2015). Mulder et al. also assumed that such a form of learning, like problem-based learning, might combine autonomy with connection to others, and eventually also reflection and self-fulfillment. Clearly such forms of learning are motivating. They raised the question, how to combine motivators Autonomy, Reflection, Connection and Self-fulfillment in courses and curriculum and how to combine motivators for the different goals.

Even if the problem- and project-based courses (PPBL) often fail to fully incorporate sustainability competencies, they are regarded as powerful educational settings for building students‘sustainability expertise (Brundiers & Wiek, 2013). The problem and project-based approaches have commonalities, which are indicated in the figure below.

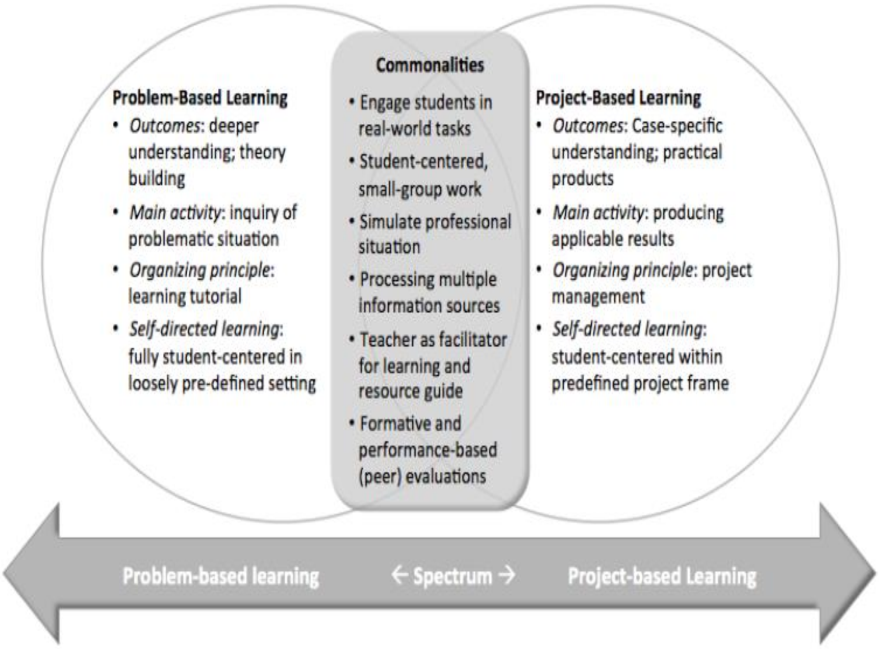

Figure 1. PPBL as a continuum of a constructivist, experiential learning approaches
(Source: Brundiers & Wiek, 2013)

Brundiers & Wiek (2013) also introduce a framework for PPBL courses in sustainability, developed by the several researchers. The model has four phases, Orienting, Framing, and Doing the research, as well as Implementing the solution options. The model illustrates processes, steps, actors involved and expected outcomes and has analytical and evaluative questions for each phase with literature references. This framwork is applied in the Solutions.now course, which is one of the cases of this paper in the chapter 4.

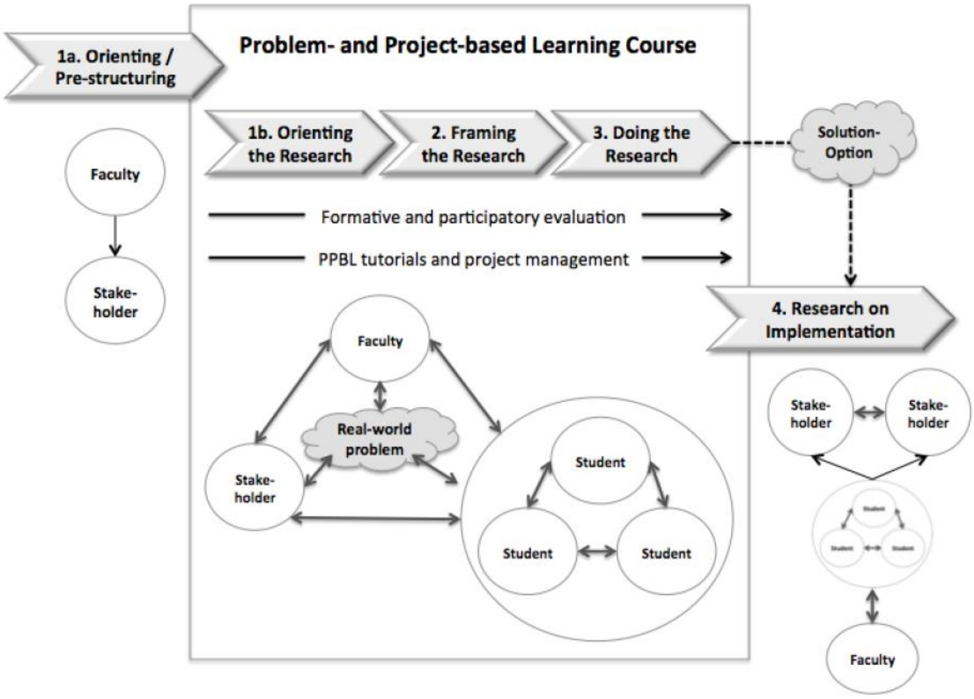

Figure 2. Process model of PPBL courses. (Source Brundiers & Wiek 2013)

3. GREEN PROJECT MANAGEMENT METHODS AND VIRTUAL LEARNING DEVELOPMENT

The basics of three applied green project management methods are introduced. These theoretical methods are applicable in any project, but according to experience of student groups from the last three years, these methods have not been known for the students beforehand, from earlier studies or from their working experience. As concerning any theoretical approach, the mixed implementation of these methods is possible and even recommended, depending how reasonable they are for the project case.

3.1 Method 1- Green + Quality = Greenality

Maltzman & Shirley (2010) introduced a new word, ‘greenality’, which shows the relationship between green and quality. The equation is indicated in the title above. It is a new method for a project’s green quality. According to the authors, the famous quality gurus like Crosby, Deming and Juran laid the foundation for this new quality concept as there are many parallels between greenality and quality. The process of the project and its outcome should serve sustainability and greenality is an integrated activity for both the product of the project and the process of managing a project.

Even if projects differ in the amount of environmental sustainability aspects they contain and how the aspects manifest themselves, in greenality thinking all project have some element of green. Maltzman & Shirley (2010) categorized projects as follows: 1) Green by definition (GBD), which means that this type of projects are all about sustainability or environment, 2) Green by project impact (or the lack thereof) is a project, which may not have immediate positive impact on the environment, like manufacturing electric cars or building underground. As known, whatever we do, it has an impact on the nature environment. Still, in this project type, the long-term impact may be positive, 3) Green by product impact is a project, which focus is not to be green project itself, but the steady state operation of the end product has, and 4) Green general project, actually multitude of project, which not seems to have green elements at the first glance. In this case it is especially project manager's duty to improve projects greenality.

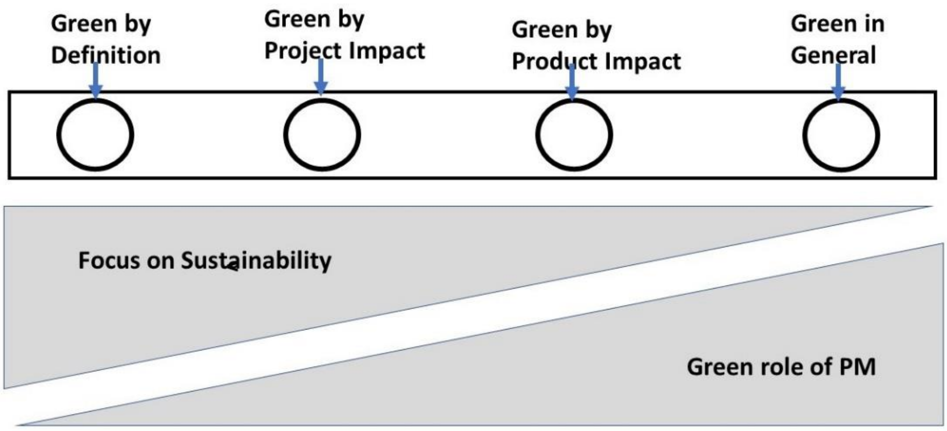

Figure 3. Role of the project manager as greenality focus changes. (Source: Maltzman & Shirley, 2010)

If the project's focus is less and less green, the project manager must assert a stronger and stronger role to have a positive effect on the sustainability of the project. It is important to know that the role of the project manager changes as the focus on green changes.

3.2 Method 2 - 4L

The second method (Maltzman & Shirley, 2010) for the green project management is 4L, inspired by the lean methods. Four Ls are Lean-Learn-Linked-Lasting (*Figure 2 below*). It indicates how these aspects can be linked to the projects and to project managers. The practical guidelines are 1) how to lean – it is to be aware of the operational counterparts and their efforts to reduce waste and make operations more efficient. It is to apply to the project and its products; 2) to learn – it is to collect project artifacts, lessons learned, and share benefits from the community of project managers with respect to environmental/sustainability and to grow organisationally; 3) linked – to connect with your organisation's environmental management plan and break downs organisational walls; and 4) lasting – encourages to thing long-term and of the lasting effects of your actions as project manager, not only for this and future projects, but also in terms of the product of your project.

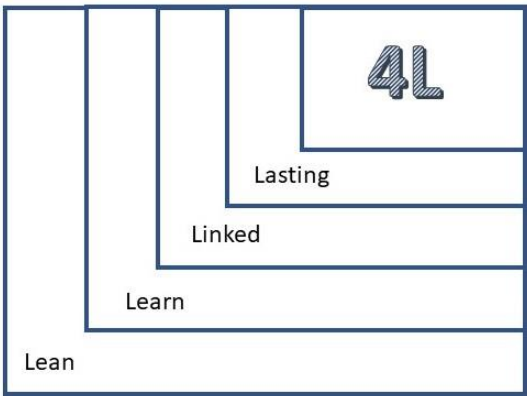

Figure 4. The 4L approach. (Source: Maltzman & Shirley, 2010)

Lean means to work for the efficiency. That is any kind of efficiency and avoidance of all kinds of unnecessary structures and bureaucracy. Learn means that the project always generates something to learn for individuals, teams and organizations. Linked underlines the importance of the internal and external stakeholders as well as system thinking, which is essential in the sustainability. The special attention is for the principle of Lasting. That is essential for all sustainability activities and the sustainability is to work in the long run, for the future.

3.3 Method 3 - Industry 4.0 and Biosphere Rules

Fourth Industrial Revolution (Industry 4.0) propagates an increasing digitalization and intelligentization of production processes and projects. Intelligent production systems requires subsystems to be well equipped with sensors, embedded software and actuators that continuously and ubiquitously generate and exploit data to be able to plan and execute concrete actions. Industry 4.0 does not explicitly refer to ecological sustainability of production systems as a major objective. However, the production technology and operations research community has addressed ecological impact and sustainability in various ways throughout the past decades (Erol, 2016.).

Still, there are many doubts towards digital technologies, what is their impact on the nature, is it more harmless than the enthusiastic technology people claim. Value creation might positively contribute to a sustainable development in many cases. Anyhow, in some countries, especially critical areas with expected negative contributions are related to the quantity of materials used, primary energy consumption, and working conditions in the sphere of the Industry 4.0 (Stock et al., 2018). The Biosphere Rules (Unruh, 2018), which is a biomimicry-inspired management method for circular economy initiatives. The rules are also potentially keys in the emergence of a true circular economy that will bring about environmentally sustainable manufacturing. Rule #1 is called Material Parsimony, which means eco-design concept of mononmateriality. This enables efficient reuse and recycling of material. Rule #2 Value Cycling refers to actual cycling of materials from one high-value to another one. Rule #3 Power Autonomy is to maximise energy efficiency and use renewable energy forms.

Sustainable Product Platform is the principle of the Rule #4 meaning to mimic the scope and scale of the nature in the commercial production. Rule #5 Funciton over Form is inspired by the function of the nature: as conditions change, the function is not lost. In practice, internet and open access databases take on the role of the DNA.

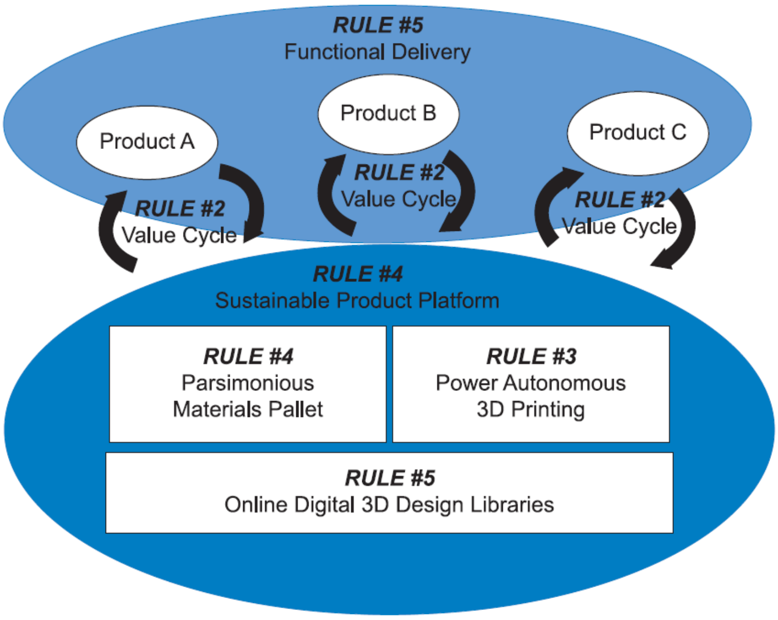

Figure 5. Schematic of a 3D-printing-based circular economy founded on the biosphere rules (Source: Unruh, 2018)

According to the experience from LAB student projects, Biosphere Rules are especially applicable in manufacturing pilot projects, laboratory works and ICT projects aiming at decrease of harmful environmental impact – which should be a starting point of any project. In any student project, the students should not be "thrown into the deep end" (Lamborn, 2009), they are to lead through the process by teacher-mentors.

3.4 Current Development Directions of Virtual Learning

Virtual learning occurred in the mid 1990's. Educause's report (2021) reminds us of the new solutions for online learning and new models for student-centered course design will be effective only to the extent that faculty understand why and how to use them. The reports states the opininion, that learning models that enable flexible movement between remote and in-person experiences will help institutions minimize disruption and ensure continuity of course delivery through future crises. In practice, that is an important point in all situations, because from the environmental engineering students it is expected concrete solutions and that leads to the fact that they should at least visit in project sites quite often. During the pandemic time the challenges were in such form, that the implementation was possible to do virtuaally. Since that, it has changed and the PPBL courses may include site visits, usually optional ones and everything else is in a virtual form.

According to a national survey in Finland, cooperation between research and business institutions is considerable compared to European countries, however,currently the trend in the amount of cooperation is declining (Koski et al. 2021). Along with the constraints and with virtual learning, there are undoubted pros that facilitate university-business collaboration. While being no longer connected to the same time and/or place, the collaboration can co-create and co-deliver courses on virtual platforms (Chakir, 2022). Accordingly, if we have a goal of graduated students to be competitive in the labor markets, we must have a look in the future perspectives. The Norwegian Business School researchers Jevnaker & Olaisen (2022) foresee, that the future work will be done more as distance work and through virtual teams. The needed skills are technical, information management, knowledge management, project management, collaboration, communication, rhetoric, virtual team, creativity, and green problem-solving skills. There is also need for ethical, cultural, tolerating, and sexual awareness and they summarize the needs as creative, sustainable, social and perception manipulation intelligence. They conclude, that the knowledge of the future will be complex, and the knowledge worker will handle multiple skills in different situations. We can assume, that all this requires ability to tolerate uncertainty.

4. RESEARCH METHODOLOGY AND IMPLEMENTED CASES

The LAB University of Applied Sciences locates in three campuses, in cities of Lahti and Lappeenranta in the South-Finland and it also has a virtual campus. The study is carried out as an in-depth, multi-method case study, which allows to utilize a range of research methods (Yin, 1984) following the grounded theory, which is designed to inductively build a substantive theory regarding some aspect of practice depending on the research questions (Mahdiuon et al., 2017). To summarize, this method aims at rich information, which is interrelated. Additionally, to address the ever-changing and emerging problems of sustainability, constructivist solutions are needed because they capture the complexity of the phenomenon; onstructivism and sustainable development may be defined as a dynamic relationship between knowledge construction, learning, and sustainability (Kalsoom, 2019). There is also the constructivist gounded theory, which is traced to Corbin & Strauss, who first described this theory in 1990's. Continuation for this was Charmaz's paper (2000), which stated that discovered reality arises from the interactive process and its temporal, cultural, and structural contexts.

The first study period was spring 2019 – spring 2022 sustainability project courses. The study is continuing with the new study period. This paper introduces mid-term results.

Multiple methods of data collection were applied to allow for triangulation and to ensure the validity (Creswell & Clark, 2017). The empirical data was gathered from four course rounds from bachelor and master students' courses with sustainability challenges in 2019-2022 by observations and interviews, from course project reports (students' group reports to commissioning companies and public employers), feedback assessment forms and interactive feedback sessions with students as follows:

- Observations n = 55 (mentoring sessions with students, meetings, and events), unstructured, real-time fieldnotes

- Interviews to the graduated students, n = 8 participating students, recorded by Zoom/Teams
- Course project reports to the commissioner, n = 19, feedback from commissioners n = 19 (11 oral and 8 written), real time hand notes and written files
- students' feedback assessment form, n = 69, written files
- separate three feedback sessions, n = 69 students, Zoom recording

The cases, which are introduced as follows, are from the Lahti campus and the virtual campus of their environmental engineering (B.Sc.) or sustainable urban environment (M.Sc.) study programs. The teaching method, study level and the main sustainability method is indicated:

Case 1: Environmental engineering energy innovation competition
Study level: B.Sc.
Teaching method: classroom teaching, virtual mentoring
Sustainability method: Biosphere Rules

In the spring 2019 two student teams from participated in the Inssiforum 2019, an annual engineering students' competition among Universities of Applies Sciences. The competition targeted to the student teams' project, which are from the energy innovation field. The purpose of the competition was to raise innovation spirit, to pay attention to the climate change locally and globally, to position students as key stakeholder group of the forum and as a remarkable part of the engineering education development and to emphasize joy of learning, multi-sectoral approach and problem-solving skills by doing real innovation projects. LAB students' proposal "Bike, walk, run with clean energy" got the second place and the winner was "So Boss", a new solar energy IoT application that uses sensor technology to analyse, control and maintain solar panels.

Case 2: Future Use of New Industrial Zones of Hollola Municipality
Study level: M.Sc.
Teaching method: virtual teaching and mentoring + site visit
Sustainability method: Greenality

In the autumn 2020 six student teams conducted a study project within the Urban Sustainability master program's course Managing Urban Change. The commissioner was the municipality of Hollola. The students investigated two industrial zones, Hopeakallio and Paassilta, how the development plans fit with the sustainability goals of the municipality and the region. and suggested various future scenarios and activities. As a result of the project, the municipality got six different reports, where sustainability was emphasized as a key asset for the development and future steps. The students were motivated to test their skills in the real-life challenges and learn new sustainability approaches and applications.

Case 3: Climate Partnership of Päijät-Häme Regional Council
Study level: M.Sc.
Teaching method: virtual teaching and mentoring
Sustainability method: Greenality

In the autumn 2021 three student teams conducted another study project within the Urban Sustainability master program's course Managing Urban Change. The commissioner was the regional council of Päijät-Häme. The students have three different tasks, first, for the non-Finnish speakers and exchange students, to benchmark climate partnership/ networks in other countries. Second, to guide companies to set up climate action goals suitable for different type of companies including indicators /effectiveness for monitoring. The output was a concrete set of tools how a company cans start own climate action program and join into this network. Third, to implement a survey for students and residents in the Päijät-Häme region on selected roadmap themes.

Case 4: Solutions.now sustainability challenge course
Study level: B.Sc. and M.Sc.
Teaching method: virtual teaching and mentoring
Sustainability method: Greenality

Climate University is a Finnish university network, which gives free online courses everyone who wants to make the sustainability transition in the society real (Climate University, 2022). The courses are made in multidisciplinary collaboration of several universities in Finland. The network was originally funded by the Ministry of Education and Culture, Finnish Innovation Fund Sitra and the participating universities, but now working only by funding of the universities in the network. LAB University of Applied Sciences is one of the original members, a co-developer and producer of Solution.now project course. In this annually organized and totally virtually conducted project course students produce sustainable solutions for real-life challenges presented by companies or other employer organizations. During the course students from several universities work together with their project in multidisciplinary groups in connection with the company. Teachers are involved as mentors in this process and to be able to follow and support the projects.

The course uses PPBL Framework and sustainability competences development. Approximately 150 students have participated in the course and solved around 20 sustainability challenges of the companies and public sector employees (years 2020-2022). The course will be implemented again in the spring 2023.

Case 5: Basics of natural stone industry in circular economy
Study level: B.Sc.
Teaching method: virtual self-teaching and mentoring (if necessary)
Sustainability method: Greenality and 4L

The case is still on its way, and it is to collect all interested students from Finnish universities of applied sciences to get the basic knowledge of the natural stone industry from the circular economy and sustainability point of view. It is planned in collaboration with the association KIVI – Stone from Finland, which represents 76 companies of natural stone industry in Finland. The goal is to transfer knowledge to the students that later they could participate in project challenges and get interested in this industrial field. The course pilot is also a pilot of the Sustainable Horizons project, where European university partners implement new pilot project in their regions.

5. CONCLUSIONS AND DISCUSSION

In this paper, the background, development goals, and practical implementation cases of the green student project management have been presented. Although the concept is very multidimensional and complex, three main points can be identified after three years (spring 2019 - spring 2022):

- Students work in a small team to which their commissioners undertake the sustainability development. The basic idea is to work on this collaborative team-based project. The communication and dynamics of this small team, in all cases and so far only between students, has caused more challenges for mentoring teachers and students themselves than the challenges as such. The possible problems arise because of this, not because of the content-based difficulty.

- Sometimes students feel the project goals unclear and timetables stressful, but after the project end, they are much more satisfied and feel more self-assured. The impression of unclarity is driven from the commissioner, which does not have the clear picture or answers before the project start. Both sides work as peers, but the majority of students expect clear and easy tasks rather than work with the uncertainty and find novelty and innovative solutions.
- Students are not used to take big responsibility as the teaching norm is more top-down and they expect that teacher solves and it is not their duty. Sometimes a commissioner is active in tutoring the project, sometimes they are not available at all. This, of course, makes every case for a teacher unpredictable.

Finally, let us consider a generally accepted opinion about the abstract characteristics of the sustainability, which makes it practical implementation and learning difficult. According to the experience of the LAB environmental and sustainability technologies' study programs, the important is just to start the implementation as it is mostly about learning by doing. And, keeping in mind the core idea of quality – continuous improvement – shows the track to go on. Every new implemented project case brings added value, new learning, and experience and for the participating students, commissioning companies and the regions, where student works. Furthermore, the used green methodology is able to improve students' learning outcomes and horizontal development.

On the other hand, outside environmental engineering teachers, many teachers of other technology fields do not have the background to undertake the role of teaching engineering within a sustainability context. That is why the results looks very positive. There is a practical solution also for this challenge. Either environmental engineering teachers could join other study program's course and share the teaching and during the course learning happens also in teachers' side or other technology study program's teacher can visit environmental engineering project course, when there is such content in the commissioner's challenge that the deeper knowledge would serve better the goal of the challenge, e.g. in material knowledge, ICT solutions, which are typical examples of today's development areas in the environmental field.

Three years after the start of the implementation it looks like convincing, that students made progress on the learning about the sustainability and getting more motivation for solving sustainability challenges. The way towards wider deployment of the method(s) it is to pilot and integrate in other study programs, units and faculties.

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