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THE INFLUENCE OF THE SUSTAINABILITY AGENDA ON LEARNING OBJECTIVES IN INNOVATION COURSES FOR ENGINEERING STUDENTS?

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ABSTRACT

Sustainability is an increasingly important topic all over the world and engineers have an important role. This calls for a new generation of innovative engineers who contribute to solutions with sustainability awareness. But how can we educate for this? With this contribution, we wish to contribute to an emerging dialog about how to formulate learning objectives that incorporate sustainability in innovation courses. In theory, sustainability is a capacious term that can be discovered through numerous lenses. In our study we examine how the phenomenon of sustainability is described in theory and in practice. We aim to unfold the multiple dimensions of sustainability rather than identifying the dominant discourse. Our research is based on insights from literature and empirical data from course descriptions that incorporate sustainability in learning objectives for innovation courses in engineering education. Our results show that despite study programs ambition to incorporate sustainability into educations the translation from an overarching ideology into concrete assemble learning objectives is not completed. Learning objectives most often are centered “about” and “for” and only few on “how-to”/ “through” . We also see a focus on management and strategy rather than on finding solutions. Basic knowledge about higher level decision making, strategizing and business modeling in organisations is relevant, however the ability to create new solutions, i.e. entrepreneurial competences, is paramount.

1 INTRODUCTION

1.1 Section 1

We can no longer not care - Our environment is beyond self-recovery [1]. This is the main driver for the prominent sustainability agenda, which is embodied through the UN Sustainable Development Goals (UN, u.d.) adopted in September 2015 as the most widely accepted agenda for sustainable development today [2]. The SDG’s provide a political framework for communication about contribution to sustainable development.

Higher education plays an important role in the context of sustainable development and has a significant influence on the way in which future generation of engineers will deal with the sustainable challenges [3]. Entrepreneurship and innovation can be the engine for transforming our world and overcome the diversity of the global sustainable challenges [4].

Even before the SDG's was launched in 2015, there was a focus on sustainability and how higher education could play an important role in sustainable development and about which competences were needed. [5] describe how all engineering students at DTU must obtain a relevant level of competences for understanding sustainability and qualitatively assessment of sustainability with the focus on integrate Life Cycle Assessment (LCA) and life cycle thinking in education. [5] suggest sustainability to be part of all study programmes starting with few courses at a bachelor level and then to progress into more courses at master level. With this progression the course content should become more complex as the curriculum progresses and with a higher level of Blooms taxonomy (knowledge, comprehension, application, analysis, synthesis and evaluation). [4] have summarized seven competences which are important for sustainable development; (1)systems-thinking, (2)foresight-thinking,(3) normative (values, principles and target for sustainability), (4)embracing diversity and inter-disciplinarity; (5)interpersonal, (6)action and (7)strategic management. In higher education these competences portrais similarities with competences associated with innovation and in theory these competences could serve as sustainability learning objectives. But what is done in practice to embed sustainability into engineering education?

In this study, we want to explore how sustainability is transferred into learning objectives used in the innovation courses for engineering students (BSc and MSc level) at three different universities in Denmark. One could refute that adhering to the sustainability agenda in engineering education goes beyond innovation courses. However it is decided to focus on these courses because they evolve around how to change current practice. We aim to unfold the multiple dimensions of sustainability rather than identifying the dominant discourse and therefore we will provide examples and not at complete mapping of all learning objectives. Our research is based on insights from empirical data from course descriptions that incorporate sustainability in learning objectives in the context of innovation courses. In this study we will focus on innovation course but it will also be relevant for other topic/courses. We look for patterns and qualify the learning objectives with regards to sustainability.

2 METHODOLOGY

2.1 Section 1

This study sets out to explore how sustainability in innovation is addressed in learning objectives at three different universities in Denmark. The learning objectives were collected based on an online search in the course databases using the search word "sustainable innovation". The inclusion criteria was only courses for engineering students. At one of the universities only courses that had sustainable

innovation in the course name were shown, the other two universities yielded all courses where sustainable and innovation was in the course description. The searches yield 147 courses across the three universities. The data is cleaned for duplets and only engineering courses are examined. 11 innovation courses were sampled with the purpose of having diversity. Seven courses are at master level and four are at bachelor of engineering level. Three of the courses are credited with 10 ECTS and eight are 5 ECTS courses. 105 learning objectives are identified. Out of these 56 are not specifically focusing on sustainability and are labeled "General learning objectives". These are grouped in themes. The remaining 49 learning objectives with a sustainability focus are selected for the further analysis. The learning objectives were sorted by learning *about*, *for* or *through* sustainable innovation.

3 RESULTS

Sustainability and awareness of climate changes have been part of the curriculum for engineering (innovation) courses for many years. The incorporation of sustainability into the courses have been done in many ways. Inspired by entrepreneurship education [6] the approach to teaching sustainability can be divided into education *about*, *for* or *through* sustainable innovation. The *about* approach is focused on acquiring theoretical knowledge about sustainability. Learning *for* sustainability can include applying tools, analysing and evaluating solutions. Finally learning "through" sustainability is about developing sustainability competences in experience based learning designs, where the students learn to develop solutions/opportunities by themselves.

In the following sections the findings are presented, first with a focus on general learning objectives (Table 1) and then the sustainability learning objectives (Table 2). Out of the 11 sampled courses four had a major focus on sustainability, more than half of the learning objectives for the course included sustainability. The rest had half or less of the learning goals, down to one, centered on sustainability. This testifies to the fact that in practice the emphasis on sustainability in learning objectives varies on a broad spectrum. The courses represent different levels (BSc and MSc), however explicit signs of progression were not detected as [5] recommended. Moreover, it also varies how these learning objectives are acquired. One course explicitly gains practical work experience and participation in experimental setup work, while other courses articulate groupwork, stakeholder interaction, prototyping, testing and simulations as methods to developing knowledge, skills and competences.

In the next two sections examples of the general learning objectives and the sustainability learning are presented.

3.1 General learning objectives

The general learning objectives (Table 1) reflect the context in which the sustainability is embedded. Some courses have a discipline specific focus i.e. biotech or aquatic resources. Learning objectives, which relate to higher level of decision

making such as strategy, management, business modelling and business planning, are also constitute to a context. Other courses focus on the design process of sustainable solutions and some go into production specifics.

Table 1. Examples of general learning objectives categorised according to topic

Topic	Examples of learning objectives
Discipline Specific contexts	<ul style="list-style-type: none"> Describe a biotechnological production company with respect to substrates, organisms and processes
Management and strategy	<ul style="list-style-type: none"> Knowledge about the role of management and humans in intelligent production.
Business models/ planning	<ul style="list-style-type: none"> Define a value proposition using methods in innovation and business development
Design and production	<ul style="list-style-type: none"> Perform detailed design and analysis of the selected solution
Entrepreneurship	<ul style="list-style-type: none"> Evaluate the business opportunity with potential users and customers and argue for actions and choices taken based on the evaluation

Finally, entrepreneurship is also seen as a context, where sustainability is embedded into the process and to creation of new ventures.

3.2 Learning *about, for and through* sustainable innovation

The sustainability specific learning objectives can be divided into learning *about, for and through* sustainability. Learning *about* sustainability relates to theoretical knowledge on the topic, examples of popular topics can be found in Table 2.

Table 2. Learning objectives divided into learning about, for or through

Category	Examples of learning objectives
Learning About	<ul style="list-style-type: none"> Demonstrate knowledge on different theories learned throughout the classes such as: Depletion of natural resources, Eco-design, Life-cycle assessment, Sustainable Development Goals, Circular Economy, Cradle to cradle, scares resources, overexploitation Explain the broad meaning of sustainability (environmental, social and economic)
Learning For	<ul style="list-style-type: none"> Evaluate environmental performance using the life cycle assessment framework Model and interpret multi-criteria decision-making problems in sustainable design Criticize and assess the strengths and weaknesses of approaches for sustainable design Must have the competencies to apply principles of agile and sustainable production to company cases and design intelligent production and service systems

	<ul style="list-style-type: none"> • Perform an analysis of "governance" and development of regulation and legislation within the field, and discuss social and environmental advantages and risks of the new technology, and relate to examples of these aspects
Learning Through	<ul style="list-style-type: none"> • Apply entrepreneurial methods and processes to develop a sustainable business opportunity based on the defined problem.

Learning *for* sustainability includes a variety of process tools and analytical tools that can be used to access solutions on different sustainability parameters. Learning *through* sustainable innovation include learning goals that requires action/experience based learning [7]. These learning goals are complex to design for and require that students move from thought to action and reflection. Each mode (about, for or through) are not mutually exclusive, on the contrary they compliment each other and can be found in a mix in learning designs.

4 DISCUSSION AND SUMMARY

The learning objectives that belong to the category "about" can be categorised as knowledge reproduction on the levels of remember and understand, and are at the lower level of Blooms taxonomy. On the next levels learning "for" relates to applying tools, analysing and evaluating solutions. Only learning "through" sustainability reaches Blooms top level, create, where learners combine parts to make a new whole. Experiences from entrepreneurship education show that this the way of learning is challenging for both educators and students but also highly effective in terms of influencing behavioural intent [8], [9].

[4] highlighted the relationship between innovation/entrepreneurship and sustainable and mentioned the following as important for both: complex problems, the importance of novelty, the importance of self-involvement and the engagement with others. The learning objectives reported in this study showed the same pattern. But we also see a focus on management and strategy rather than on finding with solutions. The focus on management and strategy which could be the first way to go, but the future engineer is expected to be able to solve the challenges and make solutions, thus more action and focus on implement and operate have to be taken. Given the unique potential for engineers as solution makers, one could argue that basic knowledge about higher level decision making, strategizing and business modeling in organisations is relevant, however the ability to create new solutions, i.e. entrepreneurial competences, is paramount.

In extention the context dependency of innovation and entrepreneurship [10], [11] also makes learning objectives related to the disciplinespecific context essential. Out of the seven competences [4] have summarized which are important for sustainable development, the major focus seems to be on strategic management, systems-thinking, foresight-thinking, normative and interpersonal competences. There is only a minor or no focus on embracing diversity, inter-disciplinarity and

action. This could give food for thought for next generation of development of sustainable innovation learning goals for teaching practice.

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Appendix 1: Tabel 1 extended

Topic	Examples of learning objectives
Discipline Specific contexts	<ul style="list-style-type: none"> • Describe a biotechnological production company with respect to substrates, organisms and processes • Evaluate the potential for biotech development in different Cultural and geographical contexts • Discuss regulatory constraints on bio-production. • Emerging tech • Aquatic resources
Management and strategy	<p>knowledge about the role of management and humans in intelligent production.</p> <ul style="list-style-type: none"> • Create a plan for organization and operation of the business • Suggest strategies for innovation. • Judge the economic potential of an innovation
Business models/ planning	<ul style="list-style-type: none"> • Define a value proposition using methods in innovation and business development • Create an economic assessment of the business • Create a plan for organization and operation of the business • Create a business plan
Design and production	<ul style="list-style-type: none"> - Perform detailed design and analysis of the selected solution • Account for patent issues
Entrepreneurship	<ul style="list-style-type: none"> - Identify and collaborate with relevant stakeholders inside and outside the university to develop the business opportunity - Evaluate the business opportunity with potential users and customers and argue for actions and choices taken based on the evaluation - Make a realistic budget for the business - Pitch a business opportunity

Appendix 2: Table 2 extended

Category	Examples of learning objectives
Learning About	<ul style="list-style-type: none"> • Demonstrate knowledge on different theories learned throughout the classes such as: Depletion of natural resources, Eco-design, Life-cycle assessment, Sustainable Development Goals, Circular Economy, Cradle to cradle, scarce resources, overexploitation • Explain the broad meaning of sustainability (environmental, social and economic)
Learning For	<ul style="list-style-type: none"> • Evaluate environmental performance using the life cycle assessment framework • Apply theories, methods, and tools for sustainable design of product and production systems to real-world problems • Model and interpret multi-criteria decision-making problems in sustainable design • Criticize and assess the strengths and weaknesses of approaches for sustainable design • Evaluate the sustainability of the production by means of a life-cycle analysis • Must have the competencies to apply principles of agile and sustainable production to company cases and design intelligent production and service systems • Perform a life cycle check of the technology and analyse paths for environmental optimisation of this a.o. collect new information and perform a basic life cycle screening of the technology in relation to competing options • Perform an analysis of "governance" and development of regulation and legislation within the field, and discuss social and environmental advantages and risks of the new technology, and relate to examples of these aspects
Learning Through	<ul style="list-style-type: none"> • Apply entrepreneurial methods and processes to develop a sustainable business opportunity based on the defined problem.