Introducing sustainability in IT education:
The case of a course in user-centred design

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Abstract—**This work-in-progress paper addresses how to include sustainability in higher IT-education. We consider the challenge of modifying a course by adding sustainability content to underpin the existing learning outcomes in the course. Based on a case from a user-centred design course we show that existing sustainability frameworks can be used to connect learning tasks and outcomes to sustainability competences and aspects. We conclude that further work is needed on how a similar approach can be used to include sustainability in other courses in the IT-curricula.**

Keywords—IT education, sustainability, case study

I. INTRODUCTION

Climate change and its consequences will provide enormous challenges over the next decades [1], [2]. Society needs to address these challenges by mitigating and adapting. IT plays an important role in this. The need for the IT-field to address sustainability has been acknowledged in several sub-fields [3]. The impact of information technology can be seen as direct and indirect effects of the technology used [4]. Direct effects such as energy consumption are what Hilty et al. denote first-order effects. Second-order effects include the consequences of processes being changed because of IT use. Third-order effects are seen as long- and medium-term change in behaviour, such as change in consumption patterns, and economic structures. These effects come with considerable challenges. For instance, increased effectiveness of an system might lead to extensive use and the first-order effect of using more energy. The need for more transportation of goods might be a second-order effect of extensive use of an app connected to a web shop. The change in purchasing habits of a large number of people can lead to the third-order effect of physical shops in city centres closing. Those responsible for creating/acquiring/adapting the IT solutions have to be aware of such consequences to be able to take well-informed decisions and give good advice e.g. to clients. From being an expert comes responsibility for awareness, information seeking, collaboration, and concern for the long-term good.

On the basis of these requirements for competence among professionals [5], IT education needs to make sure to provide this competence to meet the needs of society and work life.

There are various ways to integrate sustainability into computing education.[6] sees three options; 1) have a new green computing course, 2) integrating sustainability modules in existing courses, 3) integrating sustainability content into a new computing curricula. An example of option 2 is reported in [7], but this is not widely supported, and it is acknowledged a need to do more both by actually including sustainability aspects, and by generating knowledge about how [8]. This paper is mainly a theoretical argument of how to approach this in IT education, supported by early findings from an empirical case. We first present more of the background to the field. In section III we present the case, whereas we in section IV discuss the case methodology in more detail. Section V includes the results, before we conclude the paper.

II. BACKGROUND

Research literature on sustainability in computer science education was addressed in [8], which pointed to a need for further research while acknowledging the contributions from sub-fields of IT such as Software Engineering (SE) (e.g. [7],[9],[10],[11]) and Human Computer Interaction (HCI) (e.g. [12], [13]).

Sustainability beyond IT is characterized by complex challenges in need of general competence crossing professional and disciplinary boundaries, what is referred to as key sustainability competencies (KSD) [14]. Wiek et al. [15] conducted a widely cited literature review on sustainability research and problem solving, using it to develop a framework including five KSDs needed to address complex sustainability challenges: *Systems thinking competence* is "the ability to collectively analyse complex systems across different domains and across different scales (local to global), thereby considering cascading effects, inertia, feedback loops and other systemic features related to sustainability issues and sustainability problem-solving frameworks". *Strategic competence* is "the ability to collectively design and implement interventions, transitions, and transformative governance strategies toward sustainability". *Normative competence* is "the ability to collectively map, specify, apply, reconcile, and negotiate sustainability values, principles, goals, and targets". *Anticipatory competence* is "the ability to collectively analyse, evaluate, and craft rich 'pictures' of the future related to sustainability issues and sustainability problem-solving frameworks". *Interpersonal competence* is "the ability to motivate, enable, and facilitate collaborative and participatory sustainability research and problem solving". Later, Giangrande et al. [14] have elaborated the framework further.

We note that the definition of competence used by Wiek et al: "a functionally linked complex of knowledge, skills, and attitudes that enable successful task performance and problem solving" reflects a common understanding of the term and is also close to the understanding of competence in computing education [5]. Furthermore, the KSDs can be seen as consistent with competencies needed from IT professionals, such as systems thinking [16], problems solving and critical thinking [17], and interpersonal competence. Along the same vein, Semerikov et al [18] outline a set of general professional competences for sustainability in SE. From this, we conclude that research on integrating sustainability in IT education strongly benefits from research on sustainability in higher education more generally, especially with regard to KSDs.

Another perspective on sustainability with implications for the IT profession and education, are the distinction between different dimensions of sustainability. The Brundland report considered environmental, social and economic aspects [19]. Becker et al. [9] looked into how IT can affect sustainability on five dimensions. *The environmental dimension* covers the use of natural resources. *The social dimension* covers relationships between individuals. *The economic dimension*

covers financial aspects. *The individual dimension* covers freedom and agency. *The technical dimension* covers the ability to maintain artificial systems. We will refer to the model as the pentagon model (reflecting its shape e.g. in [9]). For each dimension, the model distinguishes between immediate, enabling and structural effects, cf. the first-, second- and third-order effects in [4]. The effects are interrelated. The model has been used in the development of a model for sustainability evaluation of ICT projects [10]. It has also been used in the teaching of Requirements Engineering [9,10]. In IT education, the model can be considered a reference framework for effects of solutions.

On this basis, when considering a case of integrating sustainability in IT education, e.g. in designing or evaluating a course, we propose using the KSDs along with sustainability effects on different dimensions/levels as an analytical lens. In addition, the integration of sustainability needs to be closely linked to the practice and research of the particular sub-field of IT, e.g. user-centred design.

III. Case: A Course in User Centred Design

Turning to our illustrative case, a course in user centred design, we will start by elaborating on key aspects of this field. A subset of requirements for a software system are user requirements, which are grounded in an understanding of users' needs. The significance of close collaboration with users, typically in an iterative development process, is seen in software development methodologies like Scrum and participatory design. User centred design can be seen as "a broad term to describe design processes in which end-users influence how a design takes shape. It is both a broad philosophy and variety of methods. … the important concept is that users are involved one way or another» [20].

A popular way of representing user needs is through personas and associated scenarios. A persona is a hypothetical archetype of an actual user and is defined by their goals [21]. Personas are typically developed based on systematic investigation of the relevant user groups. A persona description typically includes a (fictious) name and picture, some demographics, knowledge/skills/experience, goals, worries/concerns, personality traits, maybe a motto, and an expected use pattern of the solution being designed. Personas can be used throughout the design process to help the designers empathize with their users. Associated scenarios are stories describing how personas reach their goals by use of the software/product in question. These aspects of the practice of user centred design can be utilized in handling challenges related to many areas, including climate change. By focusing on the goals and challenges of the users, competence in user centred design can help an IT professional enable people and organizations handle such challenges, whether they relate to immediate, enabling, or structural effects. If there are social and political goals for the software being designed, personas and associated scenarios can be related to these goals, for instance by providing the personas with social values and willingness to take action [12]. If for instance action towards climate change is a goal for the software, one may try to capture aspects of the personas that are relevant to their behaviour in this regard; The latter can also be captured in user scenarios. As an example, it is known from climate psychology that people react in different ways to the threat of climate crisis [22]. Also, climate psychology is proposing ways to address challenges by helping people change their mindset [23]. On this basis, personas and scenarios can be

considered as a way of capturing and representing relevant aspects of users and how their actions are likely to unfold in light of climate-related challenges. At the same time, personas and scenarios can support reflection and discussion among designers and other stakeholders (typically users and clients) about how to support and increase the likelihood of desired scenarios. This potential of UCD combined with the authors' interest in sustainability in IT education and one of the authors' responsibility for a UCD course over several years, led to the initiation of the study reported in this paper.

The UCD course is, in slightly different versions, part of two different bachelor programs in IT. As this is meant as an illustrative case, we aim to provide just enough information to give the reader a high-level understanding of the course and how we have included sustainability-related aspects. The course ran first time in the autumn 2016 and has been continuously improved based on student feedback. The course has a practical orientation, with project-related assignments playing an essential part towards the learning outcomes. Assignments and exams over the years show that the students generally achieve the desired knowledge and skills in user centred design, which means the course is largely successful. A premise for making changes related to sustainability was that they should not negatively affect the learning outcomes.

A layered model of design for user experience [24] is used as a framework in the course. To describe user needs, the students learn to develop personas and scenarios and use them in testing [25] in the iterative development of their solution. The course also addresses gamification for motivating users, and collaborative aspects of website development.

The students work in teams of 3-4 to design and implement a solution on a web platform. This takes place through three course assignments that must be passed for a student to be admitted to the final exam. The assignments relate to the development of a web site for a housing cooperative (HCo). HCos are a standard way of organizing housing in the country of our study, and thus the concept is familiar to all students, many of whom are or have been themselves HCo residents. A great variety of real-life examples of HCos and associated websites can be found and used for inspiration.

Our study comprises four classes taking the course, one class during autumn 2019 and three in spring 2020. Two of the classes had their three HCo-related assignments distributed over the semester. The two other classes started with two individual assignments on different topics, followed by the three HCo assignments covering ca 2/3 of the semester. These differences between the versions of the course were caused by changes to the study programs in question and are not considered relevant to our study.

The first HCo assignment entails describing the HCo (including structure, vision, key activities and objectives), a set of user groups and personas representing the users of a planned HCo website, and scenarios in which the personas use the website to achieve their goals. The next assignments involve implementing the solution, including scenario-based testing and refinement of personas and scenarios at need.

From a pedagogical perspective, a key element of the assignments is the freedom given to the student teams to construct significant parts of their case, thereby gaining ownership. The students use their prior knowledge and experience and their creativity in inventing a HCo with a plausible set of personas and scenarios. The latter are intended

to be realistic while covering different user groups and needs, serving as a tool for empathizing with different types of users and testing out use of the solution with these users in mind.

The present study is starting point for research exploring three questions: 1) After the changes to the assignments, does the work delivered by the students still demonstrate that the original learning objectives in user centred design are met? 2) Do we see the desired effects of the changes made to the course in the direction of addressing sustainability? 3) If so, can we use the results as a step towards suggesting a more general approach to integrating sustainability into courses in IT education? Our aim is not to compare the use of personas and scenarios to other HCI techniques, but to look into the integration of sustainability in a course which already works well towards its learning objectives with the techniques in use.

IV. Research method

The paper presents a case study for which we have completed early analysis of data and conceptualized findings within a theoretical framework. For the school year 2019/2020 a set of changes had been made to the UCD course to include sustainability issues. This was done without changing the syllabus, only the project-related assignments. The HCo was to explicitly take into account environmental sustainability. Constraints to the HCo case description were added in the following way: *"The HCo shall have a climate friendly profile which clearly shows in the goals and vision of the HCo and in the concrete activity undertaken there. The HCo wishes to encourage the residents to provide suggestions for measures to make the HCo more climate friendly. Have in mind that the HCo wants to participate in a competition over being the most climate friendly HCo in town. Climate measures must be credible, and the web site should have a role in helping the HCo implement them."* We considered it essential to the success of these changes that the climate focus be perceived by the students as a credible, integral part of the challenge to be addressed in the assignments and as relevant to real-life user centred design work. Resources (found at various web sites) about climate measures that a HCo can take, were provided. Personas/scenarios were to reflect different attitudes to the green objectives/action points in the cooperative: *"At least one of the personas should have a positive attitude to the climate friendly profile of the HCo and have a role in one or more scenarios illustrating how the HCo achieves to be climate friendly. At least one (other) persona should be skeptical or negative to climate actions and have a role in one or more scenarios illustrating how the HCo addresses negative attitudes to climate measures."*. The changes made to the task description are summarized in Table I.

Having the students invent the scenarios relating to climate measures, we stuck to the existing pedagogical principles in the course. With the changes, we expected to see effects on case descriptions, personas, scenarios and proposed solutions indicating that students gain competence w.r.t. sustainability.

In the paper, to avoid confusion, we use the term "submission" for the handed-in answer to an assignment. There were 3 groups handing in submissions in the autumn 2019 and 30 groups in spring 2020. The data explored in our study consists in the first HCo assignment handed in by these groups. This assignment can be considered particularly important in the course, as students here invent/design their HCo including a gallery of personas and scenarios for the use of the website to be developed in the two last assignments.

The first author of this paper is course coordinator. They did the evaluation and commenting (pass/fail + comments) of the 33 submissions in collaboration with another teacher and a student assistant. The author drew on insights from evaluating similar assignments in earlier course versions.

TABLE I. SUSTAINABILITY-RELATED TASKS IN THE FIRST HCO ASSIGNMENT

a) include climate-friendliness in the tailored case description (HCo vision, goal, activities)
b) Include personas with differing views on climate measures
c) Have scenarios show how the personas reach their goals (including climate-related ones) by use of the solution;

The author's reading of the submissions had the additional purpose of research in the form of early analysis to explore students' response to the newly introduced constraints imposing sustainability-related challenges. The three main questions presented in the case section guided the exploration. To answer the second question, the assignments were viewed in light of the frameworks of KSC and sustainability effects. The key question at this stage of research was to investigate the potential of using the frameworks to analyse how sustainability is addressed in the submissions.

To demonstrate the potential of the approach, we compiled a summary of a submission from one of the groups. This enables us to show how elements relate to each other within one case, such relationships being among the things we look for. The particular submission was selected based on being representative (informally) of the 33 submissions in our sample, but also being of high quality in terms of thoroughness and plausibility of HCo, personas and scenarios. For the compilation we used parts of the submission of particular interest in light of our research questions. We compiled it to a description (Table II) just long enough to illustrate key points and help address the third question in the discussion section of this paper. We start by turning to the first two questions.

V. Results

Learning outcomes compared to earlier versions of the course (briefly and informally assessed): The groups present HCos, personas and scenarios that are generally plausible, illustrating various needs and concerns of relevant user groups and the potential role of the website in helping the personas meet their objectives. The personas and scenarios are linked through personal relationships (positive and negative) and processes of communication and collaboration. The individual as well as community dimension are visible in how the groups conceive their HCos. This is similar to what we have seen in previous versions of the course. Although the quality of the submissions varies somewhat, all are acceptable. A comparison of grades with prior versions of the course was not feasible due to a change from A-F to pass/fail.

Regarding elements related to climate friendliness:

The tasks appear to be understood. All teams integrate climate-friendliness in the HCo description, personas and scenarios. In particular, the task of having personas explicitly positive and negative to climate measures seems to be an important leverage point for depicting and resolving a credible HCo, disagreement over climate measures being a main theme in most of the submissions. Nothing indicates students perceiving this part of the assignment as irrelevant or meaningless. Climate issues are integrated in the everyday discourse in the HCos in a way that seems to reflect how the students think about them, and how they believe different

types of people think about them. Solutions regarding how to make a climate friendly HCo, including the website (to be developed in the final two assignments), show great variety, ambitions ranging from moderate to over-the-top.

To give a more concrete illustration of these findings, we use our compilation of one of the submissions (Table II). In Table III we relate it to theory by pointing to what specific sustainability competences might be involved in developing the specific HCo description, personas and scenarios, and what aspects from the pentagon model (type and level of sustainability effects) are addressed. In the table, we have also included learning task d) for completeness, which is part of the two last assignments.

TABLE II. A COMPILATION OF EXCERPTS FROM A SUBMISSION

The objectives of the HCo include gauging the total consumption of water and electricity. The goal is to increase composting. The HCo would also like to see more use of bikes, including electric bikes. This can be measured by counting the number of reservations on the website. Also, the HCo plans to install solar panels on the roof. The total electricity production from the panels should be displayed on the website.

Tatjana (39, board member) wants to live with as small carbon footprint as possible. She cycles to work, bringing her son in the bike trailer. Tatjana is very environment conscious and a proponent of reuse and of reduction of food waste. She would like the HCo to have a common shed where sports equipment and other equipment can be lent out to families. This would include equipment owned by the HCo, like ladders and pressure washers but also privately owned equipment like skates, ipads and waffle irons. Tatjana visits the HCo website daily. She uses the website to update her neighbours about environmental measures and concerns. As a board member she has the rights to edit the website. She shares new information whenever she gets across it.

Resident **Paul (73, janitor)** believes that the climate is managing itself and that we need to utilize the resources we have and rather change our habits gradually over time. He is not interested in lending out his equipment, as young people do not know how to take care of it. El-bikes are a combination of two evils: Cyclists who believe they own the road, and yet another thing in need of charging. Paul wants an extra parking space for his veteran car, and <in his scenario> visits the web site to contact the board to get permission.

Doris (32, potential buyer of a flat) is a green activist. As she is not a resident of the HCo, she does not have access to the entire website. The part about environmental measures is largely open, and she is frequently visiting to see if she can get ideas fitting her lifestyle, and to see if a suitable flat is put on the market. Doris wants the website to show actual results of environmental measures in the local area, e.g. effect of road tax on air quality, but also the effect of the measures taken by the HCo specifically, e.g. the solar roof panels and the reduction of waste.

In this specific case, we see indications that the students through their submission demonstrate strategic, normative, interpersonal and anticipatory competence. As for sustainability effects addressed, we note that effects on environmental, individual and social sustainability are addressed, whereas the development of the HCo website solution in the final assignments might potentially also have (hypothetical) technical effects. We also note that the effects generally are on the enabling level, whereas the web site itself might be considered as having immediate effects as well as (hypothetical) effects on the structural level.

VI DISCUSSION AND CONCLUSION

We have briefly shown that a table like Table III might be used as a framework to analyse and evaluate the outcomes of individual or collaborative coursework. A similar framework might also be used to evaluate outcomes of students' learning activities on an aggregate level. Further research needs to go into more detail on how the various competencies and

sustainability effects can be recognized as relevant to a particular product of learning or design for such learning.

TABLE III. THE ASSIGNMENT VS. KEY SUSTAINABILITY COMPETENCIES (KSC) AND SUSTAINABILITY EFFECTS

Sustainability-related learning tasks	Expected (hoped-for) outcome	Relevant KSC	Relevant aspects of the pentagon model
a) Include climate-friendliness in the tailored case description	Case meets existing criteria + including climate related vision and/or goal + activities/climate measures	Strategic, Normative	Environmental (enabling)
b) Include personas with differing views on the climate measures	Personas meet existing criteria + have clear, plausible views on climate measures	Interpersonal	Individual, social (enabling)
c) Have scenarios show how personas reach their goals by use of the solution	Scenarios are plausible, testable etc. (existing criteria for good scenarios) Scenarios show chains of events	Anticipatory, Interpersonal	Individual, social (enabling)
d) Iteratively develop a solution based on personas and scenarios	Seeing final solutions meeting the needs, clearly showing a "green" profile	Anticipatory	Environmental (enabling and potentially structural). Pot. also technical (im.)

Additionally, to address our third main question, we see the table as an early step towards a framework that can be used in curriculum planning to ensure sustainability is systematically included on a course and study program level. The KSCs and effects that we have borrowed from the existing literature and combined in our approach are not a blueprint for what a course or study program in IT should cover. However, it lays out a map encouraging a holistic perspective. This can be a starting point for a top-down approach to curriculum planning, seeing that the total set of courses cover aspects that meet the overarching sustainability-related learning outcomes.

The proposition to include another topic in the IT curriculum (e.g. as defined in the ACM Curricula [26]) is typically met with the argument that the curriculum is already filled with important topics. To accommodate more aspects, one needs to have a synergy with what is already there. This could be about fitting sustainability related content and learning outcomes into existing courses as seen in the case.

From a pedagogical viewpoint, to integrate sustainability we need to look for the overlap between good practice in IT, e.g. in user centred design, and good practice of addressing sustainability challenges. To avoid sustainability-related topics being perceived as an irrelevant "add-on" to a course plan, sustainability should be linked to the practice of a community that can be seen as including both teaching staff and students [27,28] and also includes partners in work life. This involves meaning and identity. For instance, *as an expert of user centred design*, I am able to recognize and describe various stakeholders' attitudes to environmental measures. We see the alignment of IT practice and work on sustainability challenges as a creative process for which experience as an educator AND member of a professional community are essential. Our further research will address how the alignment/integration process can be facilitated.

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