

# **INTEGRATING SUSTAINABILITY THINKING IN INFORMATION SYSTEMS – EXPERIENCES FROM AN ENTERPRISE ARCHITECTURE COURSE**

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## **ABSTRACT**

The rapid changes in the environment and our societies have raised the importance of incorporating Sustainability Thinking in all our courses. However, this is more challenging for some subject areas than others. Although Sustainability Thinking has long been a tradition in some of the engineering subjects, this is a far greater challenge for students of more abstract subjects such as Computer Science and Information Systems. The challenges in understanding sustainability are not only for our students; it is also hard for teachers to conceive how Information Systems could impact the UN SDGs in positive and negative ways. The question that many Information Systems teachers are asking is how we could incorporate Sustainability Thinking into the courses. This paper is aimed at sharing experiences from an Information Systems course on Enterprise Architecture for Enterprise Innovation, where we have integrated the ideas of Sustainability Thinking and sustainable innovation in enterprises. We have taken a step-by-step approach to introduce the basic ideas of Sustainability Thinking and to integrate them into the learning activities. The main research question addressed in this paper is how to integrate Sustainability Thinking into a course on Enterprise Architecture and Enterprise Innovation. The approach that we have taken is to integrate Sustainability Thinking as a part of the contents and activities in the course rather than enhance the syllabus by adding sustainability related content as an additional subject. The paper describes the course and how Sustainability Thinking has been integrated into the curriculum and the learning activities. An assessment of students' awareness of sustainability and their attitudes to applying the ideas in their future work in designing IS are also presented.

## **KEYWORDS**

Sustainability Thinking; CDIO Optional Standard 1; Enterprise Architecture; Information Systems; Education.

## **INTRODUCTION**

Sustainability has become an increasingly important aspect of modern life, as we strive to balance economic growth while protecting the natural environment and our societies. The need to understand sustainability and to raise awareness about Sustainability Thinking has become an essential part of education and research, independent of the study discipline, e.g. sustainable value creation and addressing real world challenges now have a place in university strategies

(Norwegian University of Science and Education (NTNU), 2018). Information Systems (IS) and Information and Communication Technology (ICT) have been identified as one of the enablers of sustainable value creation as they play a central role in many aspects of modern life (Jeffrey D. Sachs et al.). The need to raise awareness of sustainability of the ICT applications that we develop to achieve sustainability by ICT, or ICT as an enabler of sustainability, has been identified as a need to be addressed in educating ICT solution developers (Pattinson, 2017). One of the reasons for the challenges in managing the sustainability of digital information and IS is due to a lack understanding of sustainability in all the stages of the lifecycle of such systems. It has been argued that this is due to a lack of focus on this in Information Science research (Chowdhury, 2013) and that the different aspects of sustainability (social, economic and environmental) and their implications must be introduced to the designers of such systems; our students would play this role in the future. Yet, there are few studies that describe the integration of sustainability into their curricula in IS courses. Moreover, there are studies that identify the lack of focus on sustainability and environmental issues in IS curricula (Rubio et al., 2019).

Designers of ICT solutions and requirements engineers lack adequate understanding of sustainability to make it a priority in their solutions (Chitchyan et al., 2016). Several IS courses, such as the one described in this paper, focus on the requirements and design phases of ICT solutions, where an understanding of sustainability and the implications of the design are of utmost importance (Becker et al., 2016; Penzenstadler et al., 2014). The CDIO 3.0 syllabus has been motivated to include external drivers, such as sustainable development, in the CDIO standards (Malmqvist et al., 2022). As such, the need to integrate sustainable development into the curriculum has been defined as CDIO Optional Standard 1 (Malmqvist et al., 2017; Malmqvist et al., 2020).

Incorporating Sustainability Thinking into IS studies, and particularly subjects such as Enterprise Architecture that reside at the intersection of business and ICT strategies for an enterprise, can have positive impacts on the financial bottom line of organisations and could help enterprises to attract and retain socially responsible customers and employees. Therefore, as students of IS, it is important to be aware of the importance of sustainability and to understand the various ways in which it can be incorporated into technology solutions.

Although Sustainability Thinking has long been a tradition in some of the engineering subjects such as production systems where the products are tangible and their lifecycles are easier to follow, this is a far greater challenge for students of more abstract subjects such as Computer Science and IS. A survey among 3<sup>rd</sup> -5<sup>th</sup> year university students studying Enterprise Architecture for Enterprise Innovation (the course reported in this paper) showed that only 3.3% of the students have had courses that relate sustainability to ICT, enterprises and innovation, and 13.3% of them have had courses related to sustainability or that incorporated sustainability in the study program. The challenges in understanding sustainability and the UN SDGs are not only a challenge for our students; it is also hard for teachers to conceive how information systems could impact the UN SDGs in positive and negative ways. Thus, it has been neglected for far too long and it is now time to act upon this important and urgent issue so that our future designers of IS make well-informed and wise choices, taking into account the well-being of the people, our societies and the environment. The question that many ICT teachers are asking is how we could incorporate Sustainability Thinking into our courses. We believe that currently there is no perfect blueprint for this, or a best practice, and therefore sharing experiences and learning from one another may be one of the best ways forward in this endeavour. This paper is aimed at sharing experiences from a course on Enterprise Architecture for Enterprise Innovation, where we have incorporated the ideas of Sustainability Thinking and sustainable innovation in enterprises since 2020. We have taken a step-by-step approach to introduce the basic ideas and to incorporate them into the

learning outcomes and learning activities. Our overall approach has been the systematic integration of sustainability into the existing syllabus rather than introducing a new topic on sustainability. We started by identifying the topic in the syllabus where it was easiest to integrate sustainability ideas and continued by integrating it into a few more topics in the curriculum. Furthermore, we have included groupwork and students' reflections as a part of the learning activities.

The main research question addressed in this paper is how to integrate Sustainability Thinking into an IS course on Enterprise Architecture and Enterprise Innovation. The approach that we have taken is to integrate Sustainability Thinking as a part of the contents and activities in the course rather than enhance the syllabus by adding sustainability related contents as an additional subject. The paper describes how Sustainability Thinking has been integrated into the current course curriculum and students' responses to a survey which asks them about their awareness and attitudes towards sustainability in enterprise innovations and design of IS solutions. Thus, the main contribution of this paper is the experience and lessons learned from the endeavour, which may be beneficial for teachers and researchers in the field of IS.

The rest of this paper is organised as follows: Section 2 provides a brief overview of Sustainability Thinking in higher education and IS courses; Section 3 describes the method; Section 4 describes the course and how CDIO is implemented in the course; Section 5 describes how Sustainability Thinking is integrated in the course; Section 6 shows the results from an evaluation; Section 7 discusses the limitations of the study and Section 8 concludes the paper.

## **SUSTAINABILITY THINKING IN HIGHER EDUCATION**

Sustainability Thinking has been identified as a skill that is a requirement for our future engineers (DAMVAD Analytics, 2022). It can be described as the "capacity to engage effectively with social, environmental and economic change and challenges in the contemporary world" (Le Trobe University, 2015). Systems Thinking and Responsible Futures are two main ideas in Sustainability Thinking. Systems Thinking involves considering the complex interactions between different factors, and Responsible Futures, involves reflecting upon the effects of one's own actions and decisions. This involves understanding the complex interactions between nature, economy, society and our culture and being able to reflect on our obligations to future generations. Successful integration of Sustainability Thinking depends on the approach to engineering education. A learner-centred approach, where the students are able to contribute with ideas, learning material and actively participate in the learning activities is considered as important for enhancing Sustainability Thinking among university students (Huntzinger et al., 2007). Interaction with teachers and other actors have also been identified as a means of integrating sustainable development into educational programs (Holmberg et al., 2008). One such approach is using debate as a means of improving students' understanding of sustainability and critical thinking skills (Alaswad & Junaid, 2022). Groupwork (Newstead & Reinwald, 2022) and empowerment of students as a part of their learning process have also been identified as means to enable the development of their critical thinking skills (Cheah et al., 2022), which is also an important skill in Sustainability Thinking (Minott et al., 2019; Straková & Cimermanová, 2018).

The need for integrating Sustainability Thinking into Software Engineering education has received attention in recent years (Becker et al., 2015), and examples of integrating it into teaching programs have been reported in the literature, e.g. (Penzenstadler et al., 2018). Proposals for incorporating sustainability and the relationship to ICT in Computer Science and IS curricula have been addressed in the literature. Some of these include topics such as the key concepts of

sustainability, Systems Thinking, ICT and Ethics and Green IT (Özkan & Mishra, 2015). Guidelines for incorporating sustainability in existing IT courses, based on the ACM/IEEE guidelines 2017 for Information Technology have been proposed in (Mishra & Mishra, 2020).

## **METHOD**

This paper reports the experiences from a course on Enterprise Architecture for Enterprise Innovation (*TDT4252 - Enterprise Architecture for Enterprise Innovation, 2022*), where Sustainability Thinking has been integrated into the curriculum. It is a Masters level IS course module offered by the Department of Computer Science, which is taken by students from several faculties including Engineering, Industrial Economics and Technology Management. The overall research approach that has been used for the course is Action Research (Water-Adams, 2006), where a cycle of planning, action and reflection is considered, to improve the course every year, by systematically inquiring and analysing qualitative data that can stimulate self-reflection, critiquing and improving the practice of teachers (McCutcheon & Jung, 1990). As a part of this improvement cycle, the course is also upgraded to meet the emerging needs of students as well as internal and external drivers, such as the global need to meet sustainability requirements and the university's strategy (Norwegian University of Science and Education (NTNU), 2018). As such, we have taken a step-by step approach to integrating Sustainability Thinking into our course. Integration of sustainability into the existing syllabus was prioritised rather than enhancing the syllabus with new content. The first step was to identify where it was easiest to integrate the ideas into the syllabus. Then, we identified where the students could apply the ideas of sustainability best in their learning activities and enhanced the learning activities to learn about sustainability. We are currently working on integrating the ideas in the entire course.

For the specific study described in this paper, the main data collection method was a survey given to the students at the end of the course. The survey was aimed at obtaining feedback from the students. Students were given some statements related to Sustainability Thinking and asked to indicate their level of agreement to the statement, where the levels were Strongly agree, Agree, Neither agree nor disagree, Disagree and Strongly disagree. The survey was administered using a university approved online survey tool. Respondents consent was obtained and no privacy data was collected.

## **COURSE DESIGN**

The learning outcomes of the course include theoretical insights into business and Enterprise Modelling, service innovation, methods for analysing organisational situations and modelling them, and to develop competences on the broader technological, business and social context related to the impact of IS in society (*TDT4252 - Enterprise Architecture for Enterprise Innovation, 2022*). Students should acquire the skills to analyse business and enterprise situations using Enterprise Modelling skills. The curriculum covers Enterprise Modelling and Architecture, Innovation, Service Design and Business Modelling methods. Hence, the course is designed as illustrated in Figure 1, where students first learn to analyse business and enterprise situations and model them using Enterprise Modelling and Enterprise Architecture methods. The students are required to identify a real or a realistic case to model, which they find motivating. Then, they are asked to innovate their enterprises using ideas from Open Innovation (Chesbrough, 2011), Service Design and through incorporating digital technologies. They are then required to refine their enterprise models to include the new innovations and services. An example case could be a shop that has challenges in keeping an overview of their stock and the sales personnel do not have an overview

of the stock or have a good means of updating the stock based on the sales. An innovative idea could be the introduction of a mobile application to support this process, where the shop personnel as well as the customers could benefit from the innovation.

As one of the main skills that the students should acquire is Enterprise Modelling, the first two steps (in Figure 1) focus on this. It is a complex task with several sub-learning goals, e.g. learning modelling skills and understanding the broader business and social context of an enterprise and this task could have a high cognitive load (Sweller, 1988) on the students.

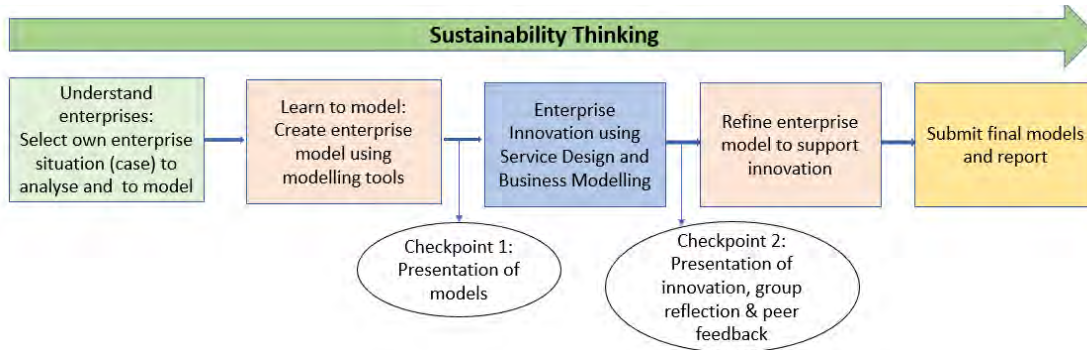


Figure 1. Course design and overview

The course work includes working on the case and the enterprise model throughout the semester. The final grade is based on the final models, a report and a few learning activities, such as presentations in checkpoint 1 and groupwork in checkpoint 2.

### **CDIO and Optional Standard 1**

The course includes elements from many of the CDIO standards (CDIO Office, 2022b) as shown below:

- Standard 3 - Integrated Curriculum: Students participate in group activities, do presentations, provide feedback to one another and do peer reviews to develop inter-personal skills such as communication and providing constructive feedback.
- Standard 5 – Design-implement experiences: Students design and implement Enterprise Architecture models and customer journeys and blueprints for their innovations and improve them through feedback from peer students and the teaching staff.
- Standard 6 – Engineering learning workspaces: Students engage in appropriate group learning activities, which serve as workspaces to support reflection and social learning.
- Standard 8 – Active learning: Students contribute to the learning contents by identifying and describing their cases to model, which are unique and contributions by the students. They also define their own innovation for their case enterprises. Furthermore, they engage in active learning experiences through group discussions, presentations to the whole class and their groups and peer feedback.
- Standard 11 – Learning assessment: Students are assessed using a variety of methods and through several activities. Their analytical and modelling skills and knowledge are assessed through their models and the final report. Participation in the numerous activities designed to develop interpersonal skills (CDIO standard 3) are taken into account in the overall assessment.

Most importantly, CDIO Optional Standard 1 – Sustainable Development (CDIO office, 2022a) has been implemented. Sustainability is integrated as a part of the curriculum and is presented

as an essential part of the topics taught is the course. Learning activities are designed to support students' awareness and understanding of sustainability as an important topic in their future work. It is also integrated into the final assessments of the students.

## INTEGRATING SUSTAINABILITY THINKING

Since 2020, we have integrated Sustainability Thinking into the curriculum. We have taken a step-by-step approach to introduce the basic ideas and to incorporate them into the learning outcomes and learning activities, which is shown in Figure 2. Our overall approach has been the systematic integration of sustainability into the existing syllabus rather than introducing an additional topic on sustainability. In the first two steps of the course (as shown in Figure 1), the students were made aware of the importance of sustainable enterprise solutions. Students are asked to bring their own enterprise cases to model, empowering students to contribute with learning resources and to create interesting and challenging discussions among them. Empowering students as a part of their learning process can enable the development of their critical thinking skills (Cheah et al., 2022). The focus on sustainable innovations, services and solutions, where sustainability was presented through its many definitions and perspectives (e.g. economy, environment, society), was during step 3 (in Figure 1), when the students had to innovate their enterprises through developing a new service using digital technologies, and create sustainable business models for the new service(s).

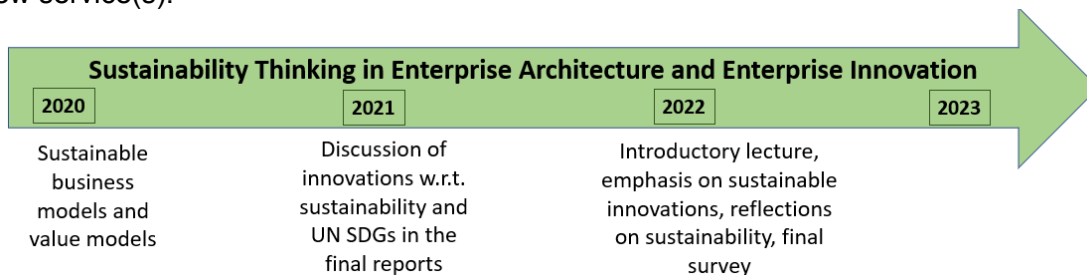


Figure 2. Step-by-step integration of Sustainability Thinking into the course

In 2020, we started by identifying the topic in the syllabus where it was easiest to integrate sustainability ideas (the low hanging fruit), which was business models. Methods for creating sustainable business model were available at that time, such as the Triple Layered Business Model Canvas (Joyce & Paquin, 2016) and the Flourishing Business Model (Van den Broeck, 2017). In 2021, we emphasised on sustainable innovations by introducing the United Nations Sustainable Development Goals (UN SDGs), through class discussions and by asking the students to describe how their enterprise innovations may affect the UN SDGs. In 2022, we built upon this by presenting a lecture on sustainability at the beginning of step 3 (in Figure 1).

We also introduced a group activity, labelled as Checkpoint 2 in Figure 1, which included students' presentations of their innovations including how they relate to UN SDGs, peer feedback and group reflections. Furthermore, we have included students' reflections on sustainability related to their cases as a part of their final report, and included sustainability related questions in the final survey, designed to obtain feedback on the course.

## RESULTS AND EVALUATION

The main aim of the evaluation is to assess if the students have increased in their awareness of Sustainability Thinking during the course, and if they have been able to relate their enterprise cases, their models and the design of IS systems (digital solutions) to sustainability. After the enterprise and innovation step, at Checkpoint 2 (in Figure 1), we conducted a Mentimeter survey (an online, interactive survey tool) where we asked the students what new knowledge they had gained from the Checkpoint 2 group activities. The Wordcloud of the responses showed sustainability as one of the bigger and bolder text, indicating that several respondents mentioned it. 30 students (70% of the class) responded to the Mentimeter survey.

In the final survey at the end of the course, students were asked to indicate their level of agreement to a number of statements related to Sustainability. 20 students (46.5% of 43 students who completed the course) responded to the final survey, and the results are shown in Figure 3. Based on these responses, while it may be hard to claim that students have increased their awareness of sustainability from this course, it is reassuring to see that most of them Agree or Strongly agree that Sustainability is important to them in their future work as designers of innovative solutions and ICT systems. More importantly, 65% of the respondents (13/20) agreed to the statement “I think this course has increased my knowledge of sustainable innovations in enterprises”. Furthermore, 5% of the respondents strongly agreed and 35% of the respondents (7/20) agreed to the statement “I think this course has increased my awareness of sustainability”.

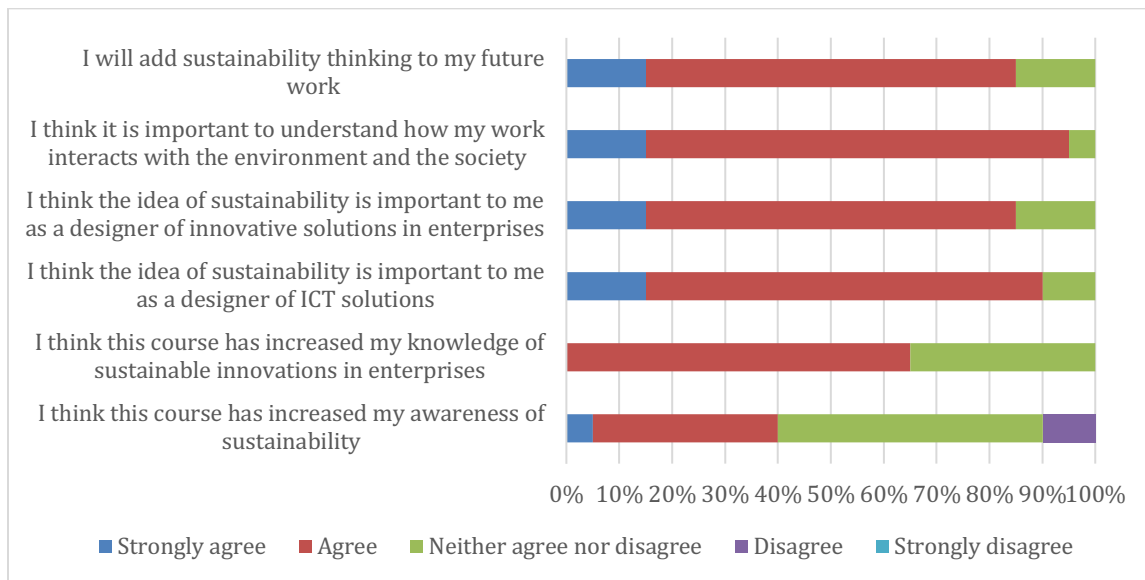


Figure 3. Students' responses to Sustainability related questions in the final survey

A possible explanation for these results could be that students are, in general, aware of sustainability and therefore their awareness was not necessarily increased by this course. Note that the background survey conducted at the beginning of the course indicated that 3.3% of the respondents have had previous courses that relate sustainability to ICT, and 13.3% have had courses that related to sustainability. The global and the university's focus on sustainability, where sustainability is one of the university's strategic areas, may also have contributed to the students' general awareness of sustainability, prior to this course. However, awareness about a subject does not indicate that they have knowledge about the subject, where knowledge includes facts, information and skills. The students may lack the basic knowledge about sustainability, in

particular, the knowledge about sustainability in the context of innovations in enterprises, which is the subject of the course reported in this paper. The responses to the statement “I think this course has increased my knowledge of sustainable innovations in enterprises”, indicate this.

The results also show that a high percentage of the students (85%-95%) of the students agree or strongly agree on the importance of sustainability in the design of ICT solutions and that it is important to understand how their work interacts with the environment and the society.

## **LIMITATIONS OF THE STUDY**

This study is limited as it has been conducted as a part of the evaluation of the overall course and not as a study focused on teaching sustainability. Hence, the part of the survey that was related to sustainability was limited and did not ask detailed questions about the topic of sustainability. Therefore, the results do not provide a precise understanding of the students' knowledge or the depth of their knowledge about sustainability. Furthermore, it was voluntary to respond to both the background survey at the beginning of the course and the final survey, and the participants were not identified. Therefore, a baseline for the results shown in Figure 3 was not available.

One of the weaknesses of this data is the low number of respondents. Students seem to experience survey fatigue due to the abundance of online surveys they are asked to complete. The end of the courses is also when students prepare for their exams and thus, the survey may have been seen as an interference in their exam preparations.

## **CONCLUSION**

This paper describes how Sustainability Thinking has been integrated into an IS course on Enterprise Architecture for Enterprise Innovation, which is a Masters level course at university, offered by the Department of Computer Science. The main research question addressed in this paper is how to integrate Sustainability Thinking into an IS course on Enterprise Architecture and Enterprise Innovation. The paper describes the step-by-step approach taken in the course to introduce sustainability and relate the concepts to the contents and learning activities of the course such that sustainability is integrated into the curriculum. The evaluations show that the students have increased their awareness of sustainability and consider that it is important to include Sustainability Thinking in their future work as designers of IS solutions.

Our plans are to enhance the integration of Sustainability Thinking into the learning goals, the curriculum and learning activities in the course. We aim to seek insights from literature and experience from other teachers that could benefit our teaching approach. One of the main challenges that we need to address in the future is how to assess if the students have acquired an understanding of sustainability related to their subject and if we have indeed achieved the desired learning outcomes. We are also working on improving the means for assessing the knowledge and attitudes of the students.

Given the urgency of incorporating Sustainability Thinking into all our courses, this step-by step process may not be the most effective approach. We hope that this learning experience could help other teachers in designing more effective means of integrating sustainability into there IS and other courses.



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