Sustainability integration in a higher education computer science department – a case study

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Abstract.
Integrating sustainability into teaching practices in higher education is a challenge that is addressed both from the top down through institutional policies and from the bottom up through individual contributions. In this article, we present the approach taken to integrate sustainability topics into the teaching practices of a computer science department at a Norwegian university. We provide an overview of the current state of the art and the results of interviews and focus group discussions with educators and researchers. We adopted a feedback-based approach and engaged relevant stakeholders in achieving desired learning objectives and highlight key areas that need to be addressed in order for faculty to integrate sustainability. We conclude with a set of solutions reported both in the literature and by members of the department.

Keywords: Sustainability, Computer Science, Higher Education

1 Introduction

Global warming, depletion of finite resources, and exponential economic and population growth are of great concern to humanity and require a global shift toward more sustainable action [1]. Sustainability is often referred to as "meeting the needs of the current generation without compromising the ability of future generations to meet their own needs" [2]. This definition formed the basis for the globally accepted definition of the United Nations, which refers to the improvement of living conditions around the world, taking into account environmental concerns and economic development [3].

Information technology (IT) is seen as an important factor for sustainability, either by paving the way for sustainable development (IT4Sustainability) or by making IT systems themselves more sustainable (Sustainable IT) [4]. Therefore, teaching sustainability as part of IT education is considered important to equip students with the necessary knowledge, skills, and dispositions to meet the challenges of the future [1], [5].

The Norwegian government is committed to the 17 Sustainable Development Goals set by the United Nations (UN) in 2015, which state that higher education institutions play a crucial role in developing a sustainable society [6]. The strategy plan for research and higher education presents sustainable development as a central theme that shall be supported through research and education [7]. Visions and strategy plans that promote sustainability in research and higher education are further presented at the institutional level [8]. Putting these visions and strategies into practice is often the responsibility of departments and their faculty. The literature is replete with strategies for integrating sustainability issues into teaching practice, including strategies specific to the field of computer science. Strategies include integrating sustainability topics into courses with and without changing course structures within a degree program. For example, Krogstie and Krogstie [9] and Burden and Sprei [10] integrated sustainability by changing only the project component of the course. Müller et al. [11] proposed the integration of sustainable development into an empirical research methods course. Fisher et al. [12] presented several examples of how sustainability can be integrated at both course level and course-component level, that is, lectures, exercises, and projects. Robila [13], [14] developed sustainability modules that can be integrated into an introductory computing course or other courses. Several authors ([15]–[18]) presented courses specifically designed to teach sustainability aspects using various sustainability topics and teaching methods. Other strategies include the provision of a series of guided electives that may be offered to any engineering and/or computer science student [19] or the development of study programs that have sustainability at the core of their curriculum [20]–[22]. While some scholars focus on the integration of sustainability topics, others address the learning objectives of a course [23]. Using challenge-based learning, Membrillo-Hernández et al. [24] focused on the development of sustainability competencies.

Despite the growing literature on sustainability and IT education, integrating sustainability into IT education remains a challenge for many institutions. Key challenges described by several scholars include a lack of resources, training, and priority [5], [20], [25], [26]. Argento et al. [26] pointed out that the intrinsic motivation of teaching staff may not last if they do not receive necessary support from the administration and organizational structure: "*Dialogues within and across disciplines are needed to overcome silo thinking and stimulate cooperation within a trans-disciplinary approach"* [26].

While many scholars present the strategies they use, the process of developing this strategy is less present in the literature. This paper fills this gap by examining the approach taken by the Computer Science Department (IDI) at the Norwegian University of Science and Technology (NTNU). To address the challenges of integrating sustainability issues into teaching practice, the department supports a bottom-up approach that allows faculty to shape the process. Using an integrated approach of literature review, interviews, and focus group discussion, we ask the following research questions:

1: How is sustainability currently addressed in the teaching practices in the department?

2: How can the integration of sustainability be improved?

The results show that sustainability is addressed in some courses, but integration depends on the intrinsic motivation of course coordinators. To integrate sustainability into all IDI courses, faculty must be provided with sufficient resources, training, and knowledge. To help move down this path, we have developed a feedback-based method to engage faculty in integrating sustainability and propose a method for monitoring the evolution of this integration.

2 The case

The case examined in this study is IDI and its efforts to integrate sustainability related topics into the curriculum. IDI (Norwegian: Institutt for datateknologi of informatikk) is located at both Trondheim and Gjøvik and has about 340 employees. It offers a total of 12 study programs at bachelor's and master's level. IDI is part of the Faculty of Information Technology and Electrical Engineering (IE), which has included sustainability in its strategic plan for 2018-2025:

1. IE shall train candidates who create smart, safe, and sustainable development
2. IE shall create opportunities for sustainability
3. IE shall set the agenda for sustainability within our professional areas
4. IE shall demonstrate sustainability in its operations.

IDI, being subordinate to IE, shares these goals and is currently investigating different strategies to implement sustainability into its teaching practices.

3 Research design

The research was conducted in three subsequent steps: 1) a literature review, 2) interviews, and 3) focus group discussions.

Each phase informed the following one: the literature section was used to design the interview guide, and finally participants discussed the emerging results in the focus groups.

3.1 Literature Review

The first step of our research consisted of a literature review based on the guidelines proposed by Webster and Watson [27]. Our aim was to achieve a broad understanding of the concepts, frameworks, and initiatives related to sustainability in higher education and specifically in computer science education.

A total of 89 articles were reviewed of which 34 were considered very relevant, 33 of moderate relevance, and 22 of low or very low relevance. The databases used were Scopus and Google Scholar, as well as the publisher Emerald insight. The following search terms were used:

- sustainability at research institutions
- sustainability in software course
- sustainability AND higher education
- sustainability AND university
- ecological PRE/2 campus (i.e.: ecological precedes campus within 2 words)

In addition, we snowballed articles from references of relevant articles.

A content analysis was used to identify recurring themes within the relevant articles. They were then grouped into different topics based on the content analysis to gain a better overview. A summary of the identified topics is presented in the results section.

3.2 Interviews

The second method of data collection consisted of interviews. Our goal was to capture the perspectives of IDI educators and researchers from a variety of perspectives. The interviews helped to understand participants' attitudes toward sustainability, their roles in the department, their relationships with sustainability-related activities, and their opinions and ideas about integrating sustainability into their teaching. We asked participants how they define sustainability and whether they address the issue by adopting sustainability practices. We also wanted to know how sustainability is or might be related to their field, whether they actively integrate sustainability into their teaching, and whether they know of any sustainability initiatives at IDI, NTNU, or other institutions. Finally, we asked about the type of guidance and resources that would be needed to successfully integrate sustainability and what they saw as the greatest challenges in pursuing this goal.

Participants were selected based on two different methods: personal referral and random selection among IDI staff. A total of 19 semi-structured interviews were conducted in person or digitally using Microsoft Teams.

3.3 Focus Group Discussions

The goal of the third phase was to validate the findings from the previous two phases and to further investigate the emerging relevant topics. Three focus group discussions with three participants in each were carried out. Participants were recruited using purposive and snowball sampling. The discussions were conducted in person or as a hybrid session where 1-2 of the participants or the facilitators joined digitally. Two of the focus groups included a total of 6 members of the department that had not previously participated in the interview phase. One third of the focus group involved three members that had been previously interviewed. We applied the same selection criteria as in the interviews phase.

The focus group discussions focused on questions about teaching issues related to sustainability. The goal was to explore what learning outcomes and competencies are

considered relevant in teaching sustainability topics and how these topics can be taught. The group discussed various strategies that emerged from the literature review. In addition, the question was raised as to whether IDI faculty might need training or support to integrate sustainability topics into their courses, and if so, what kind.

4 Results

We present further the results in each of the phases and how they were used in the following phase.

4.1 Literature

The relevant literature has been divided into four different topics. These are: (i) papers that evaluate different strategies for implementing sustainability in teaching, (ii) papers that discuss learning objectives, topics, and teaching resources, (iii) papers that discuss staff motivation and training, and (iv) papers that address challenges and barriers. The following is an overview of each topic.

(i) We identified four main strategies from the literature that were applied to integrate sustainability into the teaching practices. The include (a) implementation without changing the course structure, changes are made e.g. only to the project component of the course [5], [9], [10], [12], [13]. (b) Courses to teach sustainability [15]–[18], (c) Courses with transferable skills across programs [19]; and (d) ICT study programs with a focus on sustainability [1], [20]–[22].

(ii) Choosing the right learning objectives, topics, and resources for courses related to sustainability can be the first obstacle for educators. Albert and Uhlig [23] presented a framework utilizing the UNESCO's learning objectives for Education for Sustainable Development to classify sustainability-focused topics, and Mann et al. [28] developed a "framework" computing education for sustainability (CE4S) that can help educators to choose the right resources to integrate sustainability into their teaching curricula. Other authors proposed sustainability criteria for customers in customer-driven courses [29], or evaluated sustainability topics regarding student motivation [30]. Marcus et al. [31] and Svanström et al. [32] both developed a set of sustainability learning outcomes for general study programs.

(iii) Motivation of training and staff is considered a key criterion for successful integration of sustainability into teaching practices. Authors present strategies that focus on the development of arenas for discussion and knowledge exchange [33], [34]. Another strategy included the development of a competence framework to support the integration of inter- and transdisciplinary competencies [35].

(iv) Several authors investigated the main challenges and barriers to integrating sustainability into teaching curricula and concluded that a lack of resources, training, and priority are the main challenges [5], [20], [25], [26].

4.2 Interviews

In considering the four topics in the literature review, first, some of the responses pointed to the need for a "human touch" in addressing this topic, but also to success stories about teaching methods that integrate sustainability into highly technical topics.

Respondents reflected on what the current inclusion of sustainability in their courses looks like or what improvements they think would benefit their courses, for example:

- Computer architecture courses address sustainability by emphasizing the importance of efficient computing, which would be an entry point to illustrate why one should also pay attention to resource consumption.
- Project based courses educators involve the stakeholders that define the project requirements for the student development teams by asking them to include a sustainability related goal.
- Artificial Intelligence educators require their students to reflect on the sustainability of the computing power required to perform the training of models.

Second, limited prior experience with sustainability issues prevents teachers from confidently engaging with the topic. Therefore, they reiterated the need for a guiding structure for the content they should include in their curricula.

Third, the issue of incentives for faculty was also raised, as was the ability to freely choose the most relevant topics to include in the course.

Finally, an education-related argument was the need for continuing education. In their view, this would lead to a more efficient use of the resources already available.

In summary, educators acknowledge their ability to integrate issues related to sustainability, even with an interdisciplinary dimension, but lack a clear understanding of what skills, knowledge, and competencies students should acquire related to sustainability. At this stage, it was clear that faculty were concerned about translating sustainability issues into measurable learning outcomes related to sustainability. Participants cited workshops and reflection sessions, as well as collaboration with faculty from departments that already focus on sustainability, as possible solutions.

4.3 Focus Group discussion

Initially the participants were presented with three different approaches that emerged from the literature review. These are:

- *Horizontal approach* – introducing (at least) one course in the study plan addressing sustainability.
- *Vertical approach* – introducing sustainability topics in most of the existing courses of the study plan.
- *Mixed approach* – introducing modules or course units into existing courses addressing sustainability specifically and integrating it with the existing course contents.

Participants preferred the mixed approach, sometimes with slight variations. However, there was agreement that a course or module with a sustainability focus could be added at the introductory level, either as a new course or as part of an existing course, and that sustainability topics should be included in courses where appropriate. A “repeated" presentation of the “sustainability” theme is seen as more fruitful and necessary to shift student mindsets toward sustainable thinking and decision making.

The interviews revealed that the design of learning objectives and competencies are the main needs of the members. We followed up on the needs identified in the interviews, and the focus groups highlighted the following priorities:

- Understanding how to build a model to understand sustainability from a CS educator’s perspective and methods to apply this knowledge.
- Understanding how sustainability impacts relationships with industry partners, and data sharing practices between them and academia, especially regarding the usage of AI technologies in research and teaching
- Sustainable usage and development of software solutions – such as Open Sourcing software, reusage of data etc.

In addition, participants were asked how these skills and competencies could be taught, i.e., what strategies and tactics might be useful. Participants referred to existing frameworks, such as UNESCO's eight sustainability competencies, that every adult should have to meet professional challenges that focus on sustainability.
These are:

- Systems thinking – the ability to recognize and understand relationships and to analyze complex systems.
- Normativity – the ability to understand and reflect on the norms and values that underlie one’s actions and to negotiate sustainability values, in a context of trade-offs, uncertain knowledge, and contradictions.
- Collaboration – the ability to learn from others; to understand and respect the needs, perspectives, and actions of others (empathy)

- Self-awareness – the ability to reflect on one's own role in the local community and (global) society; to continually evaluate and further motivate one's actions.
- Anticipation – the ability to understand and evaluate multiple futures—possible, probable, and desirable—and to create one's own visions for the future.
- Strategy – the ability to collectively develop and implement innovative actions that further sustainability.
- Critical Thinking – the ability to question norms, practices, and opinions; reflect on one's own values, perceptions, and actions; and take a position in the sustainability discourse.
- Integrated Problem Solving – the overarching ability to apply different problem-solving frameworks to complex sustainability problems and develop viable - integrating the above-mentioned competencies.

Participants suggested that there are immediate actions that every relevant course could use to implement sustainability-related topics, yet in addition a more planned structural change is necessary to aptly cover curriculum wide sustainability objectives.

5 Discussion

Integrating sustainability into classroom practice is an important issue for many institutions around the world. But unfortunately, there is no one-size-fits-all solution, nor is it desirable. In the following, we will discuss the findings on each of the research questions and present a way forward for integrating sustainability at IDI, NTNU.

1: How is sustainability currently addressed in the teaching practices in the department?

The interviews and focus group discussions revealed that several faculty members have taken bottom-up initiatives to address sustainability in multiple courses. We note that the integration of sustainability depends on the intrinsic motivation of the course coordinator. The approaches taken by course coordinators are similar to strategy i.(a) Implementation without changing the course structure as presented in the literature review [9], [10]. Instructors inserted sustainability into their course content where it could be easily integrated, e.g., in the form of an additional lecture, use case, or project description. While some course topics can be easily related to sustainability, instructors described challenges with highly technical or mathematical courses.

Discussion of actions and strategies also revealed some concerns. These include time and resource constraints, teacher knowledge of sustainability, and loss of control over their courses. Time and resource constraints are challenges that are also addressed in the literature [5], [20], [25], [26]. Argento et al. [26] pointed out that the intrinsic

motivation of teaching staff may not last if they don't receive necessary support from the administration and organizational structure. Thus, it is important to invest in a support structure that fosters dialogue and cooperation among teaching staff.

2: How can the integration of sustainability be improved?

Based on the interview responses and focus group discussion, we now present a set of guidelines for integrating sustainability into IDI courses.

Sustainability competencies and sustainability learning outcomes were considered highly relevant and thus a good starting point for developing guidelines. Defining a set of sustainability competencies and learning outcomes can address several of the challenges that educators face. These include finding relevant topics and resources, teaching methods, and a clear vision of what students should achieve. At the same time, it provides structure and is applicable to all IDI courses.

Sustainability competencies are such knowledge, skills, and dispositions needed to promote sustainable development. Developing these competencies in students is therefore considered necessary for enabling individuals to contribute to societal, economic, and political change as well as to transform their own behavior [36].

In the literature we identified several frameworks and guidelines that address either Sustainability Competencies (SC) or Sustainability Learning Outcomes (SLO) [31], [32], [36].

We recognize that these SLOs could be defined more specifically in relation to computer science topics. However, sustainability topics are so broad that only a small subset of these SLOs are not applicable to all areas of computer science. These SLOs could be discussed within the department and customized to meet individual departmental needs.

Using the SLOs identified in the literature, we defined a tool to track the incorporation of sustainability into teaching activities, synthesized from [26], [28], [32]. First, we translated the SLOs proposed in [32] into Sustainability Objectives (SOs), which are more general aspects that instructors may want to address, each related to a facet of sustainability. The SLOs proposed in [32] were considered suitable as they address sustainability on a broad level for education and learning (SLO 1-6) and on a discipline specific level (SLO 7-12). Each teacher or program coordinator can further define the corresponding SLOs for a particular course or program by specifying the context, action, and learning level of each aspect. We then combined it with the evaluation matrix from [26] and the 4-point scale to track coverage from [28] to develop the mapping tool as presented in Fig. 1. The 4-point scale consists of *1. Not at all (covered), 2. Somewhat (covered), 3. Mostly (covered), and 4. Thoroughly (covered)* [28] and is represented by different colors in the mapping tool.

This mapping tool is primarily intended to be used by course coordinators to assess and track their own process in integrating SOs into their courses.

Prerequisites:

1. Have a defined list of SOs for the department.
2. Deliver an introductory course for teaching staff on these objectives.

Steps:

1. Take a study program.
2. List all the courses
3. Ask course coordinators to check which SOs are already covered by the course using a 4-point scale.
4. Ask course coordinators to check which SOs could be covered in their courses.
5. Review the coverage of the SOs.
6. Ask course coordinators to include the SOs in the courses.
7. Monitor for SOs not covered and make department-wide reflections on ways to integrate these too.

A similar process could be used to evaluate the coverage of sustainability goals for the research output of the department.

Sustainability Objective	DT1001	DT1002	IT2003	TDT4001	TDT5001	TDT5002		Somewhat coverage in:	Significant coverage in:
1.Ethical responsibility, towards present and future generations								66,66666667	0
2. Contemporary issues								33,33333333	16,66666667
3. Human service provisioning conforming to the carrying capacity of								0	33,33333333
4. Social responsibility as a future professional, and as a citizen.								0	33,33333333
5. The impact that human activities have on the Planet, regarding sustainable and unsustainable resources appropriation.								16,66666667	50
6. Global trends that impact the life quality of present and future								16,66666667	0
7. The triple bottom line (TBL) and other sustainable development (SD) dimensions that influence their own knowledge discipline.								16,66666667	16,66666667
8. Assessment criteria or sets of principles or available tools related to sustainability in their own discipline.								0	0
9. The impact of the ICT solutions or actions in a triple bottom line								16,66666667	50
10. Life cycle analysis using the appropriate SD dimensions constraints in the design of processes, products and components.								0	16,66666667
11. Connectedness and implications for designed services as related to the sustainable development (SD) dimensions' constraints.								16,66666667	0
12. Actions to foster sustainability in professional and personal life.								16,66666667	0

Fig. 1 An illustration of the expected outcome of the self-reporting tool tracking the coverage of SOs in IDI study programs (derived from [26], [28], [32]). Data points in the figure don't represent actual data. Educators would be asked to report on the coverage of the courses they teach.

5.1 Threats to validity

Given the growing number of publications addressing sustainability in higher education, a thorough systematic literature review would certainly improve understanding of the niche to which this article belongs. Although the literature review for this study was extensive, no formal method was used to obtain a complete overview of the field.

The interviews did not aim to fully capture the department's workforce. Although we reached participants in a variety of ways, it is likely that self-selection influenced participation, as individuals with an interest in sustainability were more likely to participate. While the conclusions and suggestions of this work aim to provide a broad line of improvements, it may be difficult to generalize the solutions for every computer science department, especially those from different educational systems. Although the results enhance the existing body of knowledge, the research findings should be used as part of a tailored strategy for a department seeking to improve sustainability based on its own strengths and weaknesses.

6 Conclusion and Future Work

This study explored strategies for integrating sustainability into teaching practices at the Computer Science Department (IDI) at NTNU. Through a literature review, we collected best practices and strategies. Interviews and focus group discussions with IDI staff revealed current practices and opinions regarding the integration of sustainability into their courses. This bottom-up approach enabled the development of a strategy that meets the needs and requirements of IDI staff.

The results show that the topic of sustainability is already being addressed in several courses, usually stemming from the course coordinators' own motivations. To achieve a department-wide, coherent integration of sustainability into classroom practice, faculty need sufficient support, resources, and a framework that can serve as a starting point. Such a framework should focus on the sustainability competencies required of students and the sustainability learning objectives associated with those competencies.

Future research will continue to follow the path of integration chosen by IDI and examine how sustainability learning goals are developed and applied to individual courses.

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References

[1] B. Penzenstadler *et al.*, 'Everything is INTERRELATED: Teaching Software Engineering for Sustainability', in *2018 IEEE/ACM 40th International Conference on Software Engineering: Software Engineering Education and Training (ICSE-SEET)*, May 2018, pp. 153–162.

[2] Brundtland, Gro Harlem, 'Report of the World Commission on Environment and Development: Our Common Future', 1987. [Online]. Available: https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf

[3] United Nations, 'Sustainability', United Nations. Accessed: Feb. 21, 2023. [Online]. Available: https://www.un.org/en/academic-impact/sustainability

[4] L. M. Hilty and B. Aebischer, 'ICT for Sustainability: An Emerging Research Field', in *ICT Innovations for Sustainability*, L. M. Hilty and B. Aebischer, Eds., in Advances in Intelligent Systems and Computing. Cham: Springer International Publishing, 2015, pp. 3–36. doi: 10.1007/978-3-319-09228-7_1.

[5] Y. Cai, 'Integrating sustainability into undergraduate computing education', in *Proceedings of the 41st ACM technical symposium on Computer science education*, in SIGCSE

'10. New York, NY, USA: Association for Computing Machinery, Mar. 2010, pp. 524–528. doi: 10.1145/1734263.1734439.

[6] Kunnskapsdepartementet, 'Kunnskap og FNs bærekraftsmål', Regjeringen.no. Accessed: Aug. 25, 2023. [Online]. Available: https://www.regjeringen.no/no/tema/utdanning/innsikt/internasjonalt-kunnskapssamarbeid/utdanning-og-nye-barekraftsmal/id2398973/

[7] Kunnskapsdepartementet, 'Meld. St. 4 (2018–2019)', Regjeringen.no. Accessed: Aug. 25, 2023. [Online]. Available: https://www.regjeringen.no/no/dokumenter/meld.-st.-4-20182019/id2614131/

[8] 'Sustainability at IE - NTNU'. Accessed: Aug. 25, 2023. [Online]. Available: https://www.ntnu.edu/ie/sustainability

[9] B. Krogstie and J. Krogstie, 'Introducing sustainability in IT education: The case of a course in user-centred design', in *2020 IEEE Frontiers in Education Conference (FIE)*, Oct. 2020, pp. 1–5. doi: 10.1109/FIE44824.2020.9274173.

[10] H. Burden and F. Sprei, 'Teaching sustainable development through entrepreneurial experiences', *International Journal of Sustainability in Higher Education*, vol. 22, no. 1, pp. 142–156, Jan. 2020, doi: 10.1108/IJSHE-09-2019-0273.

[11] P. A. Müller, T. Bäumer, J. Silberer, and S. Zimmermann, 'Using research methods courses to teach students about sustainable development – a three-phase model for a transformative learning experience', *International Journal of Sustainability in Higher Education*, vol. 21, no. 3, pp. 427–439, Jan. 2020, doi: 10.1108/IJSHE-08-2019-0252.

[12] D. H. Fisher, Z. Bian, and S. Chen, 'Incorporating Sustainability into Computing Education', *IEEE Intell. Syst.*, vol. 31, no. 5, pp. 93–96, Sep. 2016, doi: 10.1109/MIS.2016.76.

[13] S. A. Robila, 'A Sustainability Component for a First-Year Course for Information Technology Students', in *2012 IEEE 12th International Conference on Advanced Learning Technologies*, Jul. 2012, pp. 90–94. doi: 10.1109/ICALT.2012.56.

[14] M. Rogers, T. Pfaff, J. Hamilton, and A. Erkan, 'Using sustainability themes and multidisciplinary approaches to enhance STEM education', *International Journal of Sustainability in Higher Education*, vol. 16, no. 4, pp. 523–536, Jan. 2015, doi: 10.1108/IJSHE-02-2013-0018.

[15] T. Worthington, 'A Green computing professional education course online: Designing and delivering a course in ICT sustainability using Internet and eBooks', in *2012 7th International Conference on Computer Science & Education (ICCSE)*, Melbourne, Australia: IEEE, Jul. 2012, pp. 263–266. doi: 10.1109/ICCSE.2012.6295070.

[16] A. Desai, 'Hands on project experience in a core class focused on sustainability', in *2015 IEEE Frontiers in Education Conference (FIE)*, Camino Real El Paso, El Paso, TX, USA: IEEE, Oct. 2015, pp. 1–4. doi: 10.1109/FIE.2015.7344320.

[17] P. Hector and C. Kohtala, 'Experimenting with sustainability education: the case of a student-driven campus initiative in Finland', *Local Environment*, pp. 1–16, Feb. 2021, doi: 10.1080/13549839.2021.1891033.

[18] M. Hamilton, 'Learning and Teaching Computing Sustainability', in *Proceedings of the 2015 ACM Conference on Innovation and Technology in Computer Science Education*, Vilnius Lithuania: ACM, Jun. 2015, pp. 338–338. doi: 10.1145/2729094.2754850.

[19] L. Morell, M. Trucco, C. Bash, and C. Patel, ‘An engineering curriculum track for IT for sustainability’, in *2012 Frontiers in Education Conference Proceedings*, Seattle, WA, USA: IEEE, Oct. 2012, pp. 1–6. doi: 10.1109/FIE.2012.6462324.

[20] M. V. Palacin-Silva, A. Seffah, and J. Porras, ‘Infusing sustainability into software engineering education: Lessons learned from capstone projects’, *Journal of Cleaner Production*, vol. 172, pp. 4338–4347, Jan. 2018, doi: 10.1016/j.jclepro.2017.06.078.

[21] A. Klimova, E. Rondeau, K. Andersson, J. Porras, A. Rybin, and A. Zaslavsky, ‘An international Master’s program in green ICT as a contribution to sustainable development’, *Journal of Cleaner Production*, vol. 135, pp. 223–239, Nov. 2016, doi: 10.1016/j.jclepro.2016.06.032.

[22] J. Porras, A. Seffah, E. Rondeau, K. Andersson, and A. Klimova, ‘PERCCOM: A Master Program in Pervasive Computing and COMmunications for Sustainable Development’, in *2016 IEEE 29th International Conference on Software Engineering Education and Training (CSEET)*, Dallas, TX, USA: IEEE, Apr. 2016, pp. 204–212. doi: 10.1109/CSEET.2016.39.

[23] M. Albert and M. Uhlig, ‘Education for sustainable development at Chemnitz University of Technology’, *International Journal of Sustainability in Higher Education*, vol. ahead-of-print, no. ahead-of-print, Jan. 2021, doi: 10.1108/IJSHE-02-2021-0078.

[24] J. Membrillo-Hernández, V. Lara-Prieto, and P. Caratozzolo, ‘Sustainability: A Public Policy, a Concept, or a Competence? Efforts on the Implementation of Sustainability as a Transversal Competence throughout Higher Education Programs’, *Sustainability*, vol. 13, no. 24, p. 13989, Dec. 2021, doi: 10.3390/su132413989.

[25] O. Leifler and J.-E. Dahlin, ‘Curriculum integration of sustainability in engineering education – a national study of programme director perspectives’, *International Journal of Sustainability in Higher Education*, vol. 21, no. 5, pp. 877–894, Jan. 2020, doi: 10.1108/IJSHE-09-2019-0286.

[26] D. Argento, D. Einarson, L. Mårtensson, C. Persson, K. Wendin, and A. Westergren, ‘Integrating sustainability in higher education: a Swedish case’, *International Journal of Sustainability in Higher Education*, vol. 21, no. 6, pp. 1131–1150, Jan. 2020, doi: 10.1108/IJSHE-10-2019-0292.

[27] J. Webster and R. T. Watson, ‘Analyzing the Past to Prepare for the Future: Writing a Literature Review’, *MIS Quarterly*, vol. 26, no. 2, pp. xiii–xxiii, 2002.

[28] S. Mann, L. Muller, J. Davis, C. Roda, and A. Young, ‘Computing and sustainability: evaluating resources for educators’, *SIGCSE Bull.*, vol. 41, no. 4, pp. 144–155, Jan. 2010, doi: 10.1145/1709424.1709459.

[29] O. Cico, M. L. Jaccheri, and A. Nguyen Duc, *Incorporating societal topics in software engineering education: A case study of a customer-driven course*. Bibsys Open Journal Systems, 2020. Accessed: Mar. 08, 2022. [Online]. Available: https://ntnuopen.ntnu.no/ntnu-xmlui/handle/11250/2727295

[30] L. M. Hilty and P. Huber, ‘Motivating students on ICT-related study programs to engage with the subject of sustainable development’, *International Journal of Sustainability in Higher Education*, vol. 19, no. 3, pp. 642–656, Jan. 2017, doi: 10.1108/IJSHE-02-2017-0027.

[31] J. Marcus, N. C. Coops, S. Ellis, and J. Robinson, ‘Embedding sustainability learning pathways across the university’, *Current Opinion in Environmental Sustainability*, vol. 16, pp. 7–13, Oct. 2015, doi: 10.1016/j.cosust.2015.07.012.

[32] M. Svanström, F. J. Lozano-García, and D. Rowe, ‘Learning outcomes for sustainable development in higher education’, *International Journal of Sustainability in Higher Education*, vol. 9, no. 3, pp. 339–351, Jan. 2008, doi: 10.1108/14676370810885925.

[33] J. Holmberg, U. Lundqvist, M. Svanström, and M. Arehag, ‘The university and transformation towards sustainability: The strategy used at Chalmers University of Technology’, *International Journal of Sustainability in Higher Education*, vol. 13, no. 3, pp. 219–231, Jan. 2012, doi: 10.1108/14676371211242544.

[34] B. Penzenstadler and A. Fleischmann, ‘Teach sustainability in software engineering?’, in *2011 24th IEEE-CS Conference on Software Engineering Education and Training (CSEE T)*, May 2011, pp. 454–458. doi: 10.1109/CSEET.2011.5876124.

[35] A. Di Giulio and R. Defila, ‘Enabling university educators to equip students with inter- and transdisciplinary competencies’, *International Journal of Sustainability in Higher Education*, vol. 18, no. 5, pp. 630–647, Jan. 2017, doi: 10.1108/IJSHE-02-2016-0030.

[36] ‘Education for Sustainable Development Goals: learning objectives - UNESCO Digital Library’. Accessed: Apr. 05, 2022. [Online]. Available: https://unesdoc.unesco.org/ark:/48223/pf0000247444