Integrating sustainability competencies into electrical engineering courses

Sara Willhammar, *EIT, LTH*, and Max Collins, *IEA*, *LTH*

***Abstract*— Integrating sustainability into electrical engineering education is essential for preparing students to address complex technology and societal challenges, requiring the combination of disciplinary competencies with sustainability competencies such as, e.g., systems-thinking and critical thinking. In this work, we explore how sustainability content and competencies can be more effectively taught and assessed within two existing courses in electrical engineering at Lund University: Project in Embedded Systems, and Power Electronics: Interfacing Batteries and Photovoltaics in Power Grids. Both courses are assessed primarily through project work, providing a natural context for further integrating sustainability-oriented learning outcomes and more explicit development of sustainability competencies. Through interviews, we investigate current practices and challenges in embedding sustainability-related content, competencies and perspectives within our respective departments. We identify opportunities for constructive alignment between learning outcomes (LOs), teaching and learning activities (TLAs), and assessment strategies, targeting the development of sustainability competencies. Based on these insights, we propose revisions and additions to the course LOs, also aligned with the SOLO taxonomy. We further outline and suggest TLAs that can be incorporated into existing course and project structures to support co-creation, reflection, and peer learning. We discuss the generalizability of this approach to other courses in electrical engineering and related disciplines. Implementation in our courses is planned for 2026, followed by an evaluation of the outcomes through a student questionnaire.**

***Index Terms*— Co-creation, Constructive alignment, Electrical engineering education, Project-based learning, SOLO taxonomy, Sustainability competencies.**

I. Introduction

SUSTAINABILITY is increasingly recognized as important for engineers, responsible for the shaping of energy systems, digital infrastructures, and other emerging technologies. Electrical engineering graduates must be able to navigate complex trade-offs involving, e.g., performance, cost, ethics, resilience, and environmental impact. Preparing students for this reality requires deliberately integrating sustainability competencies into disciplinary teaching. This paper examines how sustainability can be meaningfully embedded into two electrical engineering courses at Lund University: Project in Embedded Systems (advanced course of 7,5 ECTS with approximately 70 students from the third-year Industrial Engineering and Management programme) and Power Electronics: Interfacing Batteries and Photovoltaics in Power Grids (advanced course of 7,5 ECTS enrolling approximately 40 fourth and fifth year students, primarily from the Electrical Engineering, Engineering Physics, and Environmental Engineering programmes). Both courses contain project-based elements, providing a natural foundation for developing systems-thinking and integration of interdisciplinary perspectives. Through semi-structured interviews with faculty staff, current practices and challenges in teaching sustainability in electrical engineering are identified. Based on these findings and using constructive alignment principles, revised learning outcomes (LOs), teaching and learning activities (TLAs), and assessment strategies grounded in sustainability competencies and the SOLO taxonomy are proposed for the aforementioned courses. Constructive alignment provides a structured approach to integrate sustainability into engineering courses and implies having aligned LOs, TLAs, and assessment methods [1], whereas the SOLO taxonomy supports the design of LOs with various cognitive complexity [2]. We adopt constructive alignment, as strongly integrated within the university, to ensure sustainability is embedded systematically rather than implicitly. Verbs related to the SOLO taxonomy guide the formulation of LOs in approaching evaluation, synthesis, and design. Our aim is to address and integrate the sustainability competencies [3], namely: systems-thinking, futures-thinking, strategic-thinking, values-thinking, interpersonal competence, intrapersonal competence, and integration competence. Given the project-based nature of both courses and to make the project relevant to the students, co-creation approaches are applicable [4]. Collaborative exploration, reflection, and peer learning could support students in addressing open-ended sustainability challenges.

II. Semi-structured interviews

We collected data through semi-structured interviews with two teachers from the Department of Electrical Engineering and Information Technology, Division of Communications Engineering, and two teachers from the Department of Biomedical Engineering, Division of Industrial Electrical Engineering and Automation. The interviews aimed to gather insights into current practices and challenges related to integrating sustainability into electrical engineering courses, both to identify existing successful examples and to understand obstacles that our proposals could address. Two guiding questions focused on current practices and challenges, with follow-up questions used to clarify and deepen responses: 1) in what ways do you integrate sustainability (content, competencies, perspectives) into your courses or teaching; and 2) what challenges do you see with integrating sustainability into your courses and teaching. Notes were taken during the interviews, and a thematic analysis was conducted to

identify recurring patterns, which then informed our suggestion of revising LOs, TLAs, and assessment methods to support structured and transferable integration of sustainability into other courses. The main findings from these interviews are summarized below.

Current practices: The interviews showed that sustainability is incorporated in courses, but largely implicitly or, e.g., by focusing specifically on technical aspects such as efficiency and energy consumption, or smaller initiatives like reusing components from year to year in project work. Some mentioned more explicit efforts, such as including ethics workshops or discussions on social responsibility. Overall, sustainability is often treated as a background theme rather than something explicit. It tends to be linked to environmental performance rather than broader sustainability perspectives. The interviewed teachers expressed an awareness of its importance and a willingness to do more, but noted that, currently, integration depends largely on individual efforts rather than a coordinated departmental or program-level approach.

Current challenges: The main challenges identified were related to uncertainty about how to meaningfully integrate sustainability into technically demanding courses. Time limitations and already dense course designs were seen as barriers to introducing new material without sacrificing already existing content. Some teachers also expressed uncertainty about "what sustainability in teaching" actually entails - whether it only focuses on content (e.g., renewable energy, efficiency) or on (and if that case, how) developing competencies such as systems thinking, ethical reasoning, and long-term perspectives. Lack of coordinated support and shared understanding across courses and programmes further complicates integration.

III. Suggestions

In this section, we give suggestions for TLAs that address the challenges and main themes highlighted in the interviews. Through these, we want to 1) broaden the perspectives of what sustainability in electrical engineering courses can mean beyond the topic of, e.g., energy, and 2) describe concrete examples that can be integrated into courses without removing existing content and with not too big adjustments. We give suggestions for modifications to three types of commonly used TLAs: exercises, project, and seminars.

Exercises: Exercises including interdisciplinary perspectives, trade-offs and that encourage reflection could be integrated. It could be interdisciplinary discussions during lectures, adding a question on trade-offs to existing exercise sessions, or as smaller individual reflective hand-in tasks.

Projects: Many electrical engineering courses include a project component. Without having to drastically exchange existing projects, a re-framing and minor adjustments of the project description to begin with a sustainability motivation could be possible. Moreover, with awareness of the sustainability competencies, teachers might realize that their projects already relate to, e.g., systems-thinking and integration competencies, and can then make this more explicit. To make the project even more relevant and meaningful to students, one can also allow for co-creation of the process and/or content [4].

Seminars: These, here called seminars, could be implemented in many ways: during lectures, as part of existing seminars/project presentations, or by adding extra sessions. The idea is that one, preferably early, during the course discusses sustainability in the specific context to create awareness and start thought processes (initial seminar), and then, preferably towards the end when they have the whole picture of the course, they are to discuss their gained disciplinary knowledge while including sustainability perspectives (final seminar).

In Table 1 we outline how we propose to revise the LOs in our courses to integrate the sustainability competencies. Table 2 links these LOs to our suggested TLAs. Finally, in Table 3, we describe our approach to implement the TLAs in our respective courses.

IV. Conclusion

It is important for engineering students to develop sustainability competencies and to address this in courses and teaching. To get insights to current practices and challenges, we have conducted semi-structured interviews with teachers in electrical engineering. Our interviews only included four teachers and since sustainability integration is much up to individuals, more teachers should be interviewed to get a broader and more representative view. Our intention has been to find examples that could be generally applied to other other electrical engineering courses, and potentially also other areas, and as future work, we could ask the same teachers if our suggestion would be relevant for them or what could make them more relevant and actionable. The findings about limited current practices and that mentioned challenges were quite expected and calls for spreading more awareness of what sustainability in teaching means and examples of what a teacher can do to integrate it into courses in a meaningful way without compromising on existing content. Aiming to make a contribution in this regard, we have proposed TLAs that potentially could be generally applicable and give two examples of how LOs, TLAs, and assessments can be constructed and/or revised to integrate sustainability competencies into electrical engineering courses. We plan to implement our suggestion into two of our courses during spring 2026 and evaluate the outcome.

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TABLE 1: REVISED LOS IN THE COURSE PLANS, ADDRESSING SUSTAINABILITY COMPETENCIES

	Sustainability competency	SOLO taxonomy	New or revised LO
EITP45: Project in embedded systems			
1	Systems-thinking	Multi-structural to relational	Describe embedded systems and analyze their technological, business and sustainability-related trade-offs.
2	Futures-thinking	Extended abstract	Hypothesize on the future use of embedded systems and envision their long-term impact.
3	Strategic-thinking	Relational	Construct requirements and make design decisions balancing technology, business and sustainability.
4	Values-thinking	Extended abstract	Reflect on trade-offs due to engineering design choices in embedded systems by applying sustainability principles.
5	Interpersonal competence	Relational	Collaborate in teams to successfully drive an interdisciplinary project forward in an effective way.
6	Intrapersonal competence	Extended abstract	Reflect on the experience and responsibility of engineering development work of embedded system.
7	Integration competence	Relational	Design, develop and realise an embedded system as a functioning prototype that promotes sustainability.
EIEN90: Power electronics: interfacing batteries and photocoltaics in power grids			
8	Systems-thinking	Relational	Identify, analyze and propose relevant power converters and associated control, taking into consideration impact on grid performance, energy efficiency, and environmental impact across system lifecycle.
9	Futures-thinking	Extended abstract	Evaluate emerging converter technologies in relation to development of sustainable and resilient energy systems.
10	Strategic-thinking	Relational	Formulate design decisions balancing technical performance, cost, and sustainability objectives under real-world constraints.
11	Values-thinking	Relational	Reflect on ethical, social, and environmental trade-offs impacted by engineering design decisions and deployment.
12	Interpersonal competence	Relational	Collaborate in interdisciplinary teams to design, evaluate, and communicate sustainable power electronics solutions.
13	Intrapersonal competence	Multi-structural to relational	Demonstrate responsibility in learning by reflecting on challenges and sustainability-related decision making.
14	Integration competence	Extended abstract	Synthesize technical, environmental, and societal dimensions to propose power electronics solutions supporting long-term sustainability goals.

TABLE 2: SUGGESTION OF TLAS ADDRESSING THE LOS, WHICH CAN BE USED IN BOTH COURSES

	LOs	TLAs	Assessment
a	1, 4, 6, 8, 11, 13	Exercises addressing interdisciplinarity, trade-offs, and reflections	Hand-ins, exam questions, participation in discussions
b	1, 3, 5, 6, 7, 8, 10, 12, 13, 14	Co-creation project with sustainability motivation	Completed project
c	1, 2, 4, 6, 8, 9, 11, 13	Initial seminar and final discussion seminar	Active participation in seminars (or as a part of project presentations)

TABLE 3: IMPLEMENTATION EXAMPLES OF THE SUGGESTED TLAS IN THE TWO COURSES

	Proposed implementation in EITP45	Proposed implementation in EIEN90
a	Students and teachers from two different disciplines, together explore interdisciplinary trade-offs. Exercises during lecture breaks encourages the students to "see the world" through the three lenses. In an individual reflection task in the end they are to reflect on trade-offs.	Students work in small interdisciplinary groups on open exercises analyzing a realistic power-electronics case, identifying technical and environmental trade-offs. In a short report, they discuss how design choices influence performance, sustainability, and societal values.
b	Students work in groups on a technical project that includes that the students are to implement a prototype of an embedded system that can contribute to sustainability. They can be creative with their prototypes and iterates it throughout the course, making intentional design choices in each step.	Students collaborate in teams on a co-creation project addressing a power-electronics problem with a clear sustainability motivation. Through iteration, they integrate technical analysis with environmental and societal considerations to show how collaborative design supports both performance and sustainability goals.
c	An initial seminar takes place in the beginning of the project, discussing sustainability in the context of embedded systems and the impact these systems could have for a sustainable future. Another seminar is held in the end of the project where the students present and reflect on design choices they made and the inherent sustainability trade-offs.	The project begins with an initial seminar on strategic challenges and sustainability in grid-connected power electronics, where students discuss and set project goals. The course concludes with a final seminar where teams present and reflect on their design choices, strategies, and sustainability outcomes in relation to broader system and societal contexts