EVALUATING AND ENHANCING THE STATUS OF SUSTAINABILITY IN ENGINEERING EDUCATION

Anders Rosén, Eva Liedholm Johnson, and Joakim Jaldén

KTH Royal Institute of Technology, Stockholm, Sweden

ABSTRACT

When the optional CDIO Standard for Sustainable Development was introduced in 2020, the CDIO community was encouraged "*to document the work and share their experiences, in particular reflecting on the usefulness of the new standards for future refinement and development*". This paper is a response to that call, providing insights in how this optional Standard has been used for evaluating and enhancing the status of sustainability in the *Civil Engineering and Urban Management* program and *Electrical Engineering* program at the KTH Royal Institute of Technology. Details are shared on how sustainability is integrated in the programs, and opportunities and barriers for enhancing the status of sustainability in the two programs, and in engineering education in general, are discussed. The paper concludes that the CDIO Standard for Sustainable Development provides a framework and terminology for dialogue and collaboration, within as well as between programs, that can be used for driving change, from an add-on approach, through integration approaches, towards transformative approaches to sustainability in engineering education.

KEYWORDS

Sustainability, Sustainable Development, Integration, Program Evaluation, Program Development, Standards 1-5, 8, 11, 12, Optional Standard for Sustainable Development

INTRODUCTION

Through recent revisions, the CDIO Standards and the CDIO Syllabus have been updated to better promote and guide the integration of sustainability and sustainable development in engineering programs (Malmqvist et al 2020a&b, 2022). Aspects of sustainability and sustainable development have been included in several of the updated twelve "core" CDIO standards. To further emphasize the role of sustainability and provide inspiration and guidance, one of the new "optional" CDIO standards, that have been introduced as part of the CDIO Standards 3.0, specifically addresses sustainable development. When this new optional CDIO Standard for Sustainable Development (hereafter for simplicity referred to as *the SD Standard*) was introduced, the CDIO community was encouraged "*to document the work and share their experiences, in particular reflecting on the usefulness of the new standards for future* *refinement and development*" (Malmqvist et al. 2020b). One response to that call was presented in Rosén et al. (2021), where the SD Standard was put to test in an institution-wide evaluation of a large number of programs at the KTH Royal Institute of Technology. A set of indicators were introduced to facilitate the application, and some modifications were proposed to the SD Standard rubrics. Based on the experiences from that application, KTH has now implemented the SD Standard in their new internal sustainability objectives for education (KTH 2021). The present paper is yet another response to that call. While Rosén et al. (2021) concerned the operationalization of the SD Standard and presented an overview evaluation of 15 programs, the present paper shares and analyzes details for two of those programs and, in addition, discusses opportunities and barriers to enhancing the status of sustainability in the two programs and in engineering education in general.

THE CDIO STANDARD FOR SUSTAINABLE DEVELOPMENT

The SD Standard has the same format as all CDIO Standards and is formulated in terms of: a *characterization*; a *description*; a *motivating rationale*; and *rubrics* for self-evaluation. For the convenience of the reader of this paper, the *description* and the *rubrics* with the slight modifications proposed in Rosén et al. (2021) are here reproduced in Box 1 and Box 2. As seen, the SD Standard, for example, emphasizes the importance of sustainability being progressed through the program with an early introduction and several following mutually supporting courses, to provide students opportunities to acquire and develop not only sustainability *knowledge*, but also sustainability *skills*, *attitudes*, and *key competencies*.

Box 1: The SD standard description (Malmqvist et al 2020b).

The program emphasizes environmental, social and economic sustainability in the adoption of the CDIO principles as the context for engineering education. Sustainability related knowledge, skills and attitudes, are explicitly addressed in program goals and learning outcomes. Aspects of sustainable development are integrated in several mutually supporting disciplinary courses and projects, possibly in combination with specific sustainability courses. Concepts of sustainability, potentials and limitations of science and technology and related roles and responsibilities of engineers, are established at an early stage of the education. Design-implement experiences provide students with opportunities to apply and contextualize sustainability knowledge, skills and attitudes, both in the development of new technology and in the reuse, redesign, recycling, retirement, etc., of existing technology. Physical and digital learning environments enable interdisciplinary and transdisciplinary collaborative learning and interaction with various external stakeholders. Sustainability learning experiences are integrated with the learning of disciplinary knowledge, personal and interpersonal skills, and product, process, system and service building skills. Active experiential and transformative learning activities develop students' key competences for sustainability. Enhancement of faculty competences for sustainability and related teaching competences is actively promoted. Approaches appropriate for assessing sustainability related learning outcomes are implemented. The integration of sustainable development is evaluated by students, faculty, industry, and societal stakeholders, and in relation to relevant UN and other frameworks.

Box 2: The slightly modified SD Standard rubrics proposed in Rosén et al (2021).

1) Minor sustainable development learning experiences are implemented in at least one course and needs and opportunities for extended integration of sustainable development have been identified. 2) At least two sustainable development learning experiences, where at least one is substantial, are implemented and there is a plan for extended integration of sustainable development. 3) There are explicit program goals and intended learning outcomes considering knowledge as well as skills related to environmental, social, and economic aspects of sustainability, and students learning towards these goals and outcomes are supported by at least four sustainable development learning experiences, where at least two are substantial, including an introduction early in the program. 4) The integration of sustainable development is pervasive, well adapted to the program context, promoting progression of knowledge, skills, attitudes, and key competencies for sustainability, and there is documented evidence that students have achieved the related intended learning outcomes. 5) The SD Standard is fully implemented.

BRIEF OVERVIEW OF THE TWO CASE PROGRAMS

The two KTH programs studied in this paper are *Electrical Engineering* ('EE') and *Civil Engineering and Urban Management* ('CE'). They are both 3+2-year bachelor+master programs, but quite different in structure and sustainability integration, making them interesting to compare. In this study, we are mainly focusing on the first three years, i.e., the bachelor parts of the programs.

The EE program

The EE program aims to provide students abilities to work with and develop new products within the broad area of electrical engineering, including sub-areas such as electric power engineering, information and communications technology, and machine learning. The program underwent a major revision in 2013, to re-introduce a progression of engineering skills to supplement what had become an increasingly academic education (Björn et al 2023). A previously introduced project course (EH1010) in the first year was here complemented by yet another project course (EN1020) in the second year, and by reworking the third-year bachelor thesis project (EF112X). In addition, a program integrating course (EH1110) spanning over the first three years was added, and some subject-specific courses in electrical engineering were moved to the first year to increase program cohesion. To a considerable extent, the reworked program structure was guided by the CDIO principles. In the first year, students take introductory courses in analog and digital electronics and programming in parallel with the introductory math courses. The first-year project course integrates this knowledge and introduces the students to project management in a project where they are building a robot that includes physical and software components. In the second year, students take courses in electrophysical and signals and systems, and the second-year project course requires integration of this knowledge, now with significantly more challenging technical requirements. The bachelor thesis projects in the third year are based on proposals from all faculty involved in the program and span the full set of sub-areas of electrical engineering.

The CE program

The CE program aims to provide students with prerequisites and the abilities to participate in and manage work on how buildings, infrastructure, and cities should be designed, built, and administered. The first two years mainly contains compulsory courses in mathematics and natural science subjects and civil engineering and urban management fundamentals. In year 3, students are given the opportunity to prepare for continuing studies in one of five MSc programs by creating a distinct profile toward one of five specific specializations: civil and architectural engineering, construction project management, ground and water engineering, town and traffic planning, geographical IT and real estate economics, and real estate law. The professional profile of the program is highlighted early during the first term through the course AI1527 Introduction to the Planning and Building Process, which also provides an extensive introduction to sustainability as discussed further below. Several of the other courses also contain practical and realistic exercises, seminars, laboratory work, field exercises, and project assignments, to support the students in developing engineering skills. Thus, the program provides both breadth and depth, meaning that the students get a holistic view and learn to put things in context and deal with complex issues. However, in contrast to the EE program, the program does not contain any large projects except from the bachelor thesis project.

SUSTAINABILITY IN THE TWO PROGRAMS

As mentioned, the SD Standard has earlier been operationalized and applied in an institution-wide program evaluation at the KTH Royal Institute of Technology (Rosén et al 2021, Hermansson & Rosén 2021). Starting with a pilot with ten programs, the SD Standard *rubrics* were elaborated and slightly modified to better capture essential differences in how sustainability is being integrated in programs. The modified rubrics were then used in the institution-wide evaluation. To facilitate evaluation in relation to the rubric levels, a set of indicators (i-v) were introduced which are here reproduced in Table 1. The sustainability status in the EE and CE programs were, as seen in the table, rated to correspond to SD Standard rubric levels 1 and 3 respectively. The rational for these ratings will here be discussed in relation to the indicators i-v.

Table 1: Evaluation outcomes for the two programs. (Reproduced from Rosén et al. 2021 where the EE program was labelled ‘E’, the CE program was labelled ‘B’, and ‘SD’ is used as an abbreviation for Sustainable Development).

Indicator / Program	EE	CE
i) Program objectives (0-3)	1	2
ii) Introduction to SD at an early stage of the program (0-2)	1	2
iii) Number of compulsory courses with *minor* SD learning experiences	1	4
iv) Number of compulsory courses with *substantial* SD learning experiences that are developing students' *knowledge* for SD	0	1
v) Number of compulsory courses with *substantial* SD learning experiences that are developing students' *knowledge* & *skills* for SD	0	1
SD standard rubric level (0-5)	1	3

Program Objectives (indicator i)

The Swedish Higher Education Ordinance stipulates overarching learning objectives for all Swedish university degrees. For the Master of Science in Engineering degree, which the CE and EE programs lead to, there are twelve such national overarching goals. Three of these are related to sustainability and are here reproduced in Box 3. As seen, the first captures the very essence of engineering *skills*, whereas the second and third can be seen as concerning *attitudes*. Hence, neither sustainability *knowledge* nor *key competencies for sustainability* are explicitly considered in these goals, which hereby can be seen as somewhat weaker than the SD Standard (Box 1 & 2). In line with these observations, the first indicator (i) in Table 1 indicates that sustainability-related program objectives are either: missing (i=0); some (i=1); in line with the Swedish Higher Education Ordinance in Box 3 (i=2); or more extensive/ambitious (i=3).

Box 3: Sustainability-related degree requirements for the Master of Science in Engineering degree (*civilingenjörsexamen*), as stipulated in the Swedish Higher Education Ordinance.

- Ability to design and develop products, processes and systems with consideration of human prerequisites and needs and the society's goals for economically, socially and ecologically sustainable development.
- Ability to formulate judgements considering relevant scientific, societal and ethical aspects, and demonstrate an awareness of ethical aspects of research and development work.
- Insight into the possibilities and limitations of technology, its role in society and the responsibility of humans for its use, including social, economic as well as environmental and work environment aspects.

The EE program

The subset of the EE program objectives that could be related to sustainability are here reproduced in Box 4. As seen, there are no explicit considerations of sustainability or sustainable development. However, the first three objectives concern *environment*, *society*, economy (*business*), and related responsibilities and impacts, and the fourth concerns *systems perspectives*, *holistic viewpoint*, and *lifecycle*. Sustainability can hence be seen as implicitly considered by these objectives; however, this relies on how these objectives are enacted in the program and what meaning is given to *insight*, *consideration*, *understanding*, and *respect* in the students' learning and assessment. As seen in Table 1, the EE program objectives were in Rosén et al. (2021) rated as i=1, i.e., weaker than the Swedish national goals. While it is the view of the program director that the program does indeed fulfill these national requirements, it is also clear that the entirety of the learning objectives is not accurately reflected in the program objectives, so the rating is deserved. In particular, the program objectives do not reflect the "*ability to design and develop products, processes, and systems with consideration of human prerequisites and needs and the society's goals for economically, socially and ecologically sustainable development*", which need to be rectified in upcoming revisions of the program objectives. This objective is to quite some extent already addressed by the progression of project courses. How to enact it more deeply with regards to sustainability, is elaborated in following sections.

Box 4: The subset of the EE program objectives that can be seen as related to sustainability.

- Exhibit the insight that problem-solving takes its point of departure in needs and functionality, with consideration to business conditions, environment, and society.
- Exhibit insight into the possibilities and limitations of technology, its role in society, and the responsibility of humanity for how it is used nationally and internationally.
- Exhibit an understanding of and respect for the significance of how electrical engineering affects people, society in general, and the environment with respect to limited natural resources.
- Be able to analyse electrical engineering problems through a systems perspective, with a holistic viewpoint of technical systems and their life cycles, from the idea and needs to specifications, development, manufacturing, operation and decommissioning processes.

The CE program

The subset of the CE program objectives that can be seen as related to sustainability are here reproduced in Box 5. This program has used the national goals as basis for formulating the program objectives. Hereby, the first two objectives in Box 5 closely resembles the first and third national goals in Box 3, but further specified with regards to civil engineering. The second national goal (Box 3) is however not considered, but since a third *knowledge* related program objective has been added, the third in Box 5, the program objectives were in Rosén et al. (2021) rated as i=2.

Box 5: The subset of the CE program objectives that can be seen as related to sustainability.

- Demonstrate the ability to develop products, processes and systems within the technological area of Civil Engineering and Urban Management, taking into account the conditions and needs of human beings and society's goals for economic, social and ecological sustainable development.
- Demonstrate insight into the opportunities and limitations of urban management, its role in society and the responsibility of human beings for how it is used, including ethical, social, financial as well as environmental and work environment aspects.
- Demonstrate understanding of the significance of technology applications for sustainable urban development as well as how the planning, construction and administrative procedure, the built environment and physical infrastructure can be developed.

Introduction to sustainability at an early stage in the program (indicator ii)

The SD Standard emphasize that the *concepts of sustainability, potentials and limitations of science and technology and related roles and responsibilities of engineers*, should be *established at an early stage of the education* (Box 1). The second indicator (ii) in Table 1, indicates whether an introduction to sustainability at an early stage of the program is: missing (ii=0); exists (ii=1); or is extensive/ambitious (ii=2).

The EE program

In this program the students get a brief introduction to sustainability in the course EH1110 Global Impact of Electrical Engineering. This 7.5 ECTS credits course was included in the program as a program-integrating course extending through the first three years. The course includes lectures, writing of individual essays on treated topics, and discussion seminars in smaller mixed groups of 10 to 15 students moderated by a faculty member. The course broadly covers the applicability and impact of electrical engineering on society, including sustainability. Two of the ILOs address sustainability: "*review critically and reflect on the role of the electrical engineer in a sustainable society*" and "*analyze and form an opinion on the possibilities and limitations of electrical engineering and its role in society and the responsibility of people for its use, including social and economic aspects*". Hence, the focus is on sustainability *knowledge* and *attitudes*. Although not explicitly mentioned by the ILOs, environmental sustainability is frequently addressed in lectures and seminars. Assessment is through the essays and by requiring students to take an active role in the seminars. Since the moderation of the seminars and the grading of the written assignments are distributed across 30 or so faculty members, there is a challenge to maintain a uniform quality and some seminar groups might place less emphasis on sustainability.

The CE program

In this program the students get a rather thorough introduction to sustainability in the 13.5 ECTS credit course AI1527 Introduction to the Planning and Building Process, that is running over the whole first semester. It introduces and provides a basis for the whole program, for example dealing with infrastructure and planning, natural resources, sustainable infrastructure, real estate development, and building and civil engineering structures. Covered applications are linked to various aspects of sustainability. The ILOs provide a broad integrated account for various technical aspects of civil engineering and in addition to that: perspectives on human needs; historical and future perspectives on society and urban development; natural preconditions such as soil, water and ecosystem; political, legal, and administrative aspects; economic, social and ecological aspects of sustainability, including ethical, gender and equality aspects, and possible conflicting dilemmas between them; and the professional role of engineers and how they can influence the development in society. Most of the ILOs concerns sustainability *knowledge* but some are also concerning sustainability related *attitudes*. Teachers from several different departments, representing social sciences, natural sciences, and purely technical disciplines, are involved in the course.

Minor and Substantial SD Learning Experiences (indicators iii-v)

The indicators iii-v in Table 1, are simply counts of courses in the program with sustainability related ILOs and corresponding activities and assessment. Only courses that all students in the program take are considered. The evaluation hence indicates the base-line status of sustainability in the program, while some students might reach further through elective courses. These indicators make distinctions between *minor* (iii) and *substantial* (iv-v) sustainability learning experiences. What can be considered as minor and substantial is of course not absolute, but some guiding ideas are elaborated in Box 6. In accordance with the slightly modified rubrics proposed in Rosén et al (2021), distinctions are also made between courses that only concern sustainability *knowledge* (iv) and courses that also provide students opportunities to develop sustainability *skills* (v). It should be noted in Box 1 and Box 2, that the SD Standard in addition to *knowledge* and *skills* also considers sustainability *attitudes* and *key competencies*, these are however not considered by the indicators iii-v but clearly in rubric level 4. Some guiding ideas on how to interpret sustainability knowledge, skills, attitudes, and key competencies, are provided in Box 6.

Box 6: Guiding ideas of how to interpret terms in the SD standard rubric levels in Box 2.

• A *minor* sustainable development (SD) learning experience can typically be a small SD related module, and related ILOs and assessment, integrated in a core engineering course or in a program introductory course, corresponding to <1 ECTS credit.
• A *substantial* SD learning experience can for example be a course that is more or less completely dedicated to SD, or an extensive integration of SD in a core engineering course in terms of several ILOs and related learning activities and assessment, corresponding to several ECTS credits.
• Rubric level 3 (Box 2) requires substantial SD learning experiences that, in addition to developing students' SD *knowledge*, also develop students' SD *skills*, which typically can be abilities: to contextualize, operationalize, and apply SD knowledge in engineering work; to evaluate environmental, social and economic consequences; and to take action for sustainable development based on such evaluations for example in decision making and engineering design.
• Rubric level 4 (Box 2) further requires development of students' sustainability attitudes and key competencies. *Attitudes* are typically related to assumptions, norms, values and worldviews (e.g. Sterling 2011). *Key competencies for sustainability*, such as systems-thinking, critical-thinking, and abilities to communicate and collaborate across disciplinary and cultural borders, are clusters of individual dispositions comprising knowledge, skills, motives, and attitudes, that within the Education for Sustainable Development (ESD) domain are considered necessary for coping with the increasingly diverse and interconnected world and for taking action on sustainability and transformation (e.g., Wiek et al 2016, UNESCO 2017, Malmqvist et al 2022).

The EE program

In the SD Standard application in the institution-wide program evaluation in Rosén et al (2021), the only sustainability learning experience identified in the EE program, was the program-integrating course (EH1110) described in the previous subsection. As indicated in Table 1, the program was hereby observed to have only one *minor* (iii=1) and no *substantial* (iv=v=0) sustainability related learning experiences and was rated to only reach the SD Standard rubric level 1. There were however some sustainability related activities going on in the bachelor thesis course that were not considered in the evaluation, and in some other courses that had not yet been formalized in terms of ILOs and assessment and could therefore not be identified in the evaluation. These 'unnoticed' activities, and how they are being formalized and enhanced, will be described in the following section.

The CE program

As indicated in Table 1, the CE program was in Rosén et al (2021), found to have four *minor* (iii=4) and two *substantial* sustainability learning experiences, one mainly concerning sustainability *knowledge* and *attitudes* (iv=1) and the other also providing students opportunities to develop sustainability *skills* (v=1).

The substantial learning experience that concerns sustainability *knowledge* and *attitudes* is the program introductory course (AI1527), that was described in the previous section. The other substantial sustainability learning experience is the course AL1301 Natural Resources Theory. It has several ILOs that concern *knowledge* and *skills* related to *environmental science and methodologies*, as well as general and environmental aspects of sustainability, for example: "*perform calculations of materials and energy flow both within the anthropogenic and natural systems*"; "*use scientific criteria to evaluate ecological status at soil and water resources in relation to their use in society*"; "*apply basic thermodynamic principles and carry out simple energy calculations regarding renewable energy resources*"; "*draw independent conclusions about possible results following implementation of Swedish environmental objectives and the global sustainability goals*".

Among the minor sustainability learning experiences is the course AH1030 Urban Development and Transport System. Dealing with the importance of coordinating planning and traffic systems, dwellings, and green areas, in order to ensure long-term sustainable civil engineering, it supports students in developing *knowledge* as well as *skills* related to environmental, social, and economic sustainability. Another minor sustainability learning experience is the course AI1802 Project Management and BIM in the Built Environment. It considers *knowledge* related to general aspects of sustainability through the ILO: "*describe how project management and BIM can contribute to a more sustainable built environment*". Yet another course is AI1525 Legal Framework of the Built Environment, which has the overall objective that "*the student after finishing the course should know the basics of the system of law that regulates and has impact on sustainable development in the built environment"*. The fourth minor sustainability learning experience is the course AI1128 Economics of the Built Environment that concerns *knowledge* related to economic aspects of sustainability through the ILO: "*explain how economic policy instruments may be used to achieve a sustainable society*". Finally, the bachelor thesis project course, that was not included in the evaluation in Table 1, includes an ILO that concerns understanding of the meaning of a sustainable development within the subject area.

OPPORTUNITIES AND BARRIERS TO ENHANCING THE STATUS OF SUSTAINABILITY

This section describes how the status of sustainability has been enhanced in the two programs, as a reaction to and with guidance from the SD Standard application, and related opportunities and barriers are discussed.

The EE program

As described, the sustainability status in the EE program was rated as low in the institution-wide evaluation. However, there were some sustainability related activities in the program that were not identified in the evaluation. For example, the bachelor thesis course, has one sustainability-related ILO that considers the student's ability to "*show awareness of social and ethical aspects including economic, social and ecologically sustainable development*". It is addressed in a workshop where the students collaborate on writing thesis introductions that should discuss sustainability aspects of their projects. Minor SD learning experiences have also been introduced in the mandatory course EI1110 Electrical Circuit Analysis, and in the conditionally elective course IL2204 Semiconductor Devices for Integrated Circuits. Further, some aspects of social sustainability, such as ethics, diversity, and inclusion, are addressed in the first-year project course in connection to the challenges of working in project groups and when discussing the project outcomes. The second-year project course has the largest potential to integrate environmental sustainability skills, but this has not yet been realized. This said, the new ILO, "*make a design and build a product where choices are made considering sustainability*", was introduced in 2022, following the discussion that was a direct consequence of the institution-wide application of the SD Standard. Work is now going on to formalize and further enhance these sustainability related goals and activities, and to ensure progression of knowledge as well as skills related to social and environmental sustainability and ethics through the sequence of the three project courses (EH1010, EH1020, EF112X). After such development, the program could have three minor (iii=3) and two substantial (iv=1 & v=1) sustainability related learning experiences. This would make the program corresponding to the SD Standard rubric level 3, and thereby complying with KTH's new sustainability objectives for education (KTH 2021).

As may have been noticed by the reader, this paper has focused on only a handful of courses out of the 22 mandatory and 13 conditionally elective courses that constitute the first three years of the EE program. This points toward one of the most significant barriers to enhancing the status of sustainability in the program. Electrical engineering is a well-established subject internationally and this program has a very long history, starting with the introduction of electrical engineering as a subject at KTH in 1901. This carries strong expectations of what the curriculum should contain. As the bachelor+master is now organized, there are requirements on the first three years to cover a broad range of electrical engineering theory to qualify the students for nine different master programs in sub-disciplines spanning from machine learning to electrical power engineering. This leaves limited room for more comprehensive sustainability integration. Further, research in electrical engineering at KTH is strong, with a QS ranking by subject in the range of 16 to 25 worldwide, which is the highest of all subject areas at KTH. This goes hand in hand with a strong-minded faculty sometimes protective of their respective sub-topics. The question of reducing any electrical engineering sub-topic to allow more extensive sustainability integration is still sensitive. Similar resistance was evident when the project courses where introduced.

The CE program

For the CE program, the outcome from the SD Standard application in the institution-wide evaluation, became a positive injection to continue the work on further enhancing the status of sustainability that has been going on more or less systematically since 2013. Even though the program is already corresponding to the SD Standard rubric level 3, and thereby comply with KTH's new sustainability objectives for education (KTH 2021), the program management is determined to continue leading the way. A new deeper evaluation has been initiated, through close dialogue and collaboration between the director of the CE program (second author of this paper), directors of two of the connecting master programs, and an engaged expert from the KTH Department of Learning (first author of this paper). This has included several meetings and workshops with teachers and program advisory boards that also include students. Progressing the program beyond rubric level 3 would for example require enhanced opportunities for transformative learning and development of students' key competencies for sustainability. One possibility that is considered could be to redesign the existing program introductory course (AI1527), by including a larger project where the students should work with real world wicked problems related to sustainable urban or rural development. Such learning could be further progressed by establishing yet another challenge-driven project course in year two or three. However, similarly as for the EE program, such more extensive modifications would most probably meet resistance by faculty members who are concerned about maintaining 'their own' sub-topics and courses in the curriculum.

Discussion

As indicated in Table 2, the SD Standard rubric levels can be mapped to the different response levels, or strategies, to sustainability in education that are outlined and discussed by Sterling (2004) and Kolmos et al (2016). Based on this it can be argued that the EE program has earlier applied an add-on strategy but is now, as a reaction to the SD Standard application in the institution-wide evaluation, working towards an integration strategy. The CE program has already established an integration strategy but is now considering some re-building, and possibly more extensive transformations, to enable progression beyond SD Standard rubric level 3.

Table 2: The SD Standard rubric levels mapped to the different response levels/strategies to sustainability in education according to Sterling (2004) and Kolmos et al (2016).

Response levels/strategies (Sterling 2004, Kolmos et al 2016)		**SD Standard rubric levels**
Denial or Rejection	no change	0
Add-on	weak, education about sustainability	1-2
Integration	strong, education for sustainability	3-4
Re-building or Transformation	very strong, sustainable education	4-5

Electrical engineering and civil engineering share similarities in being old and well-established academic disciplines and professions. With this comes the burdens of strong traditions and expectations from society, industry, and senior faculty, for example on what the curricula should contain. Further, there might be economic and career incentives that make faculty protective of their sub-disciplines, competence areas, and courses. Such factors can create significant barriers to change, in particularly against more extensive integration of sustainability since this will not only require interdisciplinary perspectives and new teaching and learning approaches, but it could also question the techno-centered and reductionistic foundations of traditional engineering science and education. One explanation for the difference in sustainability status between the CE and EE programs, is that civil engineering as a discipline incorporates technology as well as societal, social, economic, and ecological, perspectives, while electrical engineering is more techno centered. Another significant factor is the presence of individual enthusiasts or groups among faculty, who have interest, competence, and courage, to drive change. For example, within the environment surrounding the CE program at KTH there are several such individuals and research groups that drive change with regards to sustainability. Similarly, the establishment of the project courses in the EE program was driven by individuals and a research group engaged in project management at the electrical engineering department. This highlights the potential for mutual learning in collaborations across disciplines and between programs, where for example, in the case of this paper, the EE program could benefit from finding inspiration and support from the CE program in enhancing the status of sustainability, while the CE program could find inspiration and support from the EE program in developing project courses. This also highlights the importance of concerned and competent leadership and top-down support, on the program level, as well as on the department and the university levels.

CONCLUDING REMARKS

The paper has shared deeper insights from application of the SD Standard and discussed related opportunities and barriers. The study is limited in only concerning two programs in the same national and university contexts. However, since the two studied programs are quite different in disciplines, structures, and levels of and approaches to sustainability integration, the study is contributing with specific as well as general perspectives that could be valuable also beyond the studied context. The study confirms the conclusions from Rosén et al (2021), that the SD standard is useful, not only for guiding and evaluating program development towards full implementation of the SD Standard, but also for evaluating and enhancing the status of sustainability in basically any engineering program, independently of status and conditions. The SD standard provides a framework and terminology for dialogue and collaboration, within as well as between programs, that can be used for driving change from an add-on approach, through integration approaches, toward more extensive transformations.

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BIOGRAPHICAL INFORMATION

Anders Rosén is an Associate Professor in Engineering Education at the KTH Royal Institute of Technology with special focus on sustainability education, challenge-driven education, and educational transformations. Deputy Director of the KTH Global Development Hub. PhD in Naval Architecture and background as teacher, program director, and researcher, at the KTH Centre for Naval Architecture.

Eva Liedholm Johnson is an Associate Professor in Real Estate Planning at the KTH Royal Institute of Technology with special focus on land-related rights. She has been the program director for the Civil engineering and Urban Management Program since 2012 until the end of 2022.

Joakim Jaldén is a Professor in Signal Processing at the KTH Royal Institute of Technology with a focus on signal processing and machine learning theory and methods with applications in wireless communications and the life sciences. He has been the program director for the Electrical Engineering program at KTH since 2016.

Corresponding author

Anders Rosén
KTH Royal Institute of Technology
SE10044 Stockholm, Sweden
+46702580210
aro@kth.se