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Impact Of Teacher Training On Enhancing Sustainability Integration Into Engineering Education

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IMPACT OF TEACHER TRAINING ON ENHANCING SUSTAINABILITY INTEGRATION INTO ENGINEERING EDUCATION

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ABSTRACT

Engineering education institutions face a growing demand to provide graduates with adequate skills to respond to the sustainability crisis at hand. One approach to address this is to integrate sustainability as a cross-cutting theme into programmes and courses. At the same time competence development of academic staff is seen as an essential, yet underdeveloped prerequisite for a sustainability paradigm shift.

Aiming at enhancing sustainability integration into engineering education, this study investigates the impact of pedagogical training on the skills and motivations of teachers to embed sustainability into their teaching. A new pedagogical course (3

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ECTS) on sustainability in teaching was developed and executed at Aalto University four times during 2021-2022. The research data consists of course feedback, written reflection assignments, questionnaires to course participants, and a set of semi-structured interviews with teachers who had completed the training. In the analysis, we utilized an application of the four-level Kirkpatrick model of evaluating training impact. Preliminary results indicate that training is effective, especially when providing hands-on and customized support for teachers with different starting points for sustainability integration, and that both interdisciplinary and field-specific peer-support and learning are important elements of an impactful training. Apart from providing new knowledge on the impact of training on teacher capabilities, the study contributes to the development and improvement of pedagogical support for engineering educators to integrate sustainability into their teaching.

1 INTRODUCTION

1.1 Sustainability integration into engineering education

Sustainability is a hot topic on the agendas of universities and among others, engineering education faces a growing demand to provide graduates with adequate skills to respond to the sustainability crisis at hand. Both current and future engineering professionals will play a crucial role in driving the indispensable changes required to transform our path in sustainable directions. To answer this demand, education for sustainable development (ESD) is a key task for engineering education.

Apart from the common approach of offering sustainability-focused specialized courses for students, another approach to address this task is to *integrate sustainability* as a cross-cutting theme into programmes and courses (Kolmos et al. 2016). The key role of teachers in bringing change in academia (Barth 2013; Thomas 2015) is evident, but also a challenge, as teacher motivation and lack of sustainability-related competencies have been identified as hindrances to implementing ESD (Blanco-Portela et al. 2017). Competence development, through for example specific training of academic staff, is seen as beneficial or even as an essential prerequisite for a sustainability paradigm shift in higher education (Barth and Rieckman 2012). However, training of university teachers in teaching sustainability is found to be underemphasized and insufficient in higher education institutions (HEIs) (Holdsworth et al. 2008; Karvinen et al. 2016; Karvinen et al. 2017). At the same time, previous studies show that pedagogical training in general has a significant impact on the participants in developing as a teacher and in gaining pedagogical understanding, but due to a lack of affirming experiences, the transformative learning process often remains limited (Clavert and Nevgi 2012).

To reach the goal of enhancing ESD in engineering studies, we explore the impact of a pedagogical training course on individual teachers, particularly on their knowledge, skills, motivation for sustainability integration, and the actual implementation of the integration into their field-specific teaching.

1.2 Supporting teachers in sustainability integration

Aalto University's recent strategic goal is to strengthen sustainability throughout its operations. Regarding the development of education, competence development was identified as a key measure and thus, the university has developed teacher training to enhance and support the capabilities and motivation of the teachers to integrate sustainability into their teaching. The 3 ECTS pedagogical training course (“Sustainability in Teaching”, SiT) was designed in collaboration with sustainability specialists and pedagogical specialists of the university and has been executed twice a year since 2021. The course is open to all faculty at Aalto University, with a limit of 20 participants at each execution. Priority is given to professors and lecturers on the tenure track.

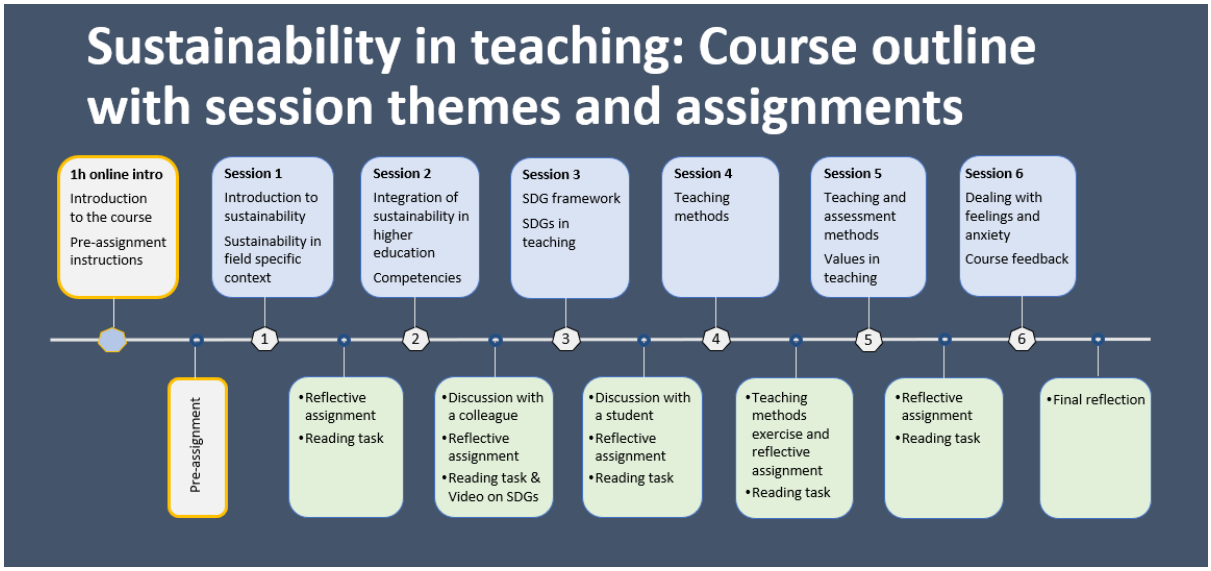

Fig 1. Outline of the SiT-course.

The course consists of an introductory session about practicalities, followed by six bi-weekly sessions (á 3 lessons) covering various aspects of sustainability integration, sustainability competencies, teaching and assessment methods of sustainability-specific competencies, and contents (Figure 1). Additionally, the course addresses the role of values and emotions in ESD. The structure of the course has remained the same since the beginning, but based on feedback some teaching and learning activities have been developed further with an aim to better support teachers with different professional and career stage determined starting points for their teaching.
The sessions are accompanied with advance readings of the newest relevant literature, and the participants are requested to have discussions about sustainability in their field both with department/programme peer teachers, and students. They also familiarize themselves with diverse online learning materials. Between the sessions, the participants work on reflecting and applying the learnings of the session to an actual course they want to develop during the SiT. The aim is that the participants would identify possible ways of embedding sustainability into their teaching and create a feasible plan during the training on how to implement sustainability integration into the course they are teaching, including the design of concrete learning activities.

2 METHODOLOGY

2.1 Analytical framework

In our study, the impact of the pedagogical training is approached through an analytical framework, building on a firmly established model initially developed by Don Kirkpatrick in the 1950s (Kirkpatrick and Kirkpatrick 2005). It's a method of evaluating training impact and although it has predominantly been designed for and used in the corporate world, it has also been applied in higher education (Cahapay 2021).
The framework captures training effectiveness on four levels, namely:
1) reaction: satisfaction of participants towards the training;

2) learning: measures knowledge, skills, motivation acquired by training participants, and confidence to perform the expected change;

3) behaviour: ascertains changes in behaviours as a consequence of the training, measured by the level of activity following the training; and

4) impact: institutional outcomes that indicate the effectiveness of training.

As we applied the model to the learning for sustainability integration at HEIs, the operationalization of the four levels required some adjustments. In our analysis, the reactions (level 1) are quantitively measured through instant feedback as grades and feedback given for the training by the participants. The learning (level 2) is a qualitative measure, based on the participants' self-evaluation. We are particularly interested in what elements of the training supported the learning of the participants. The behavioural change (level 3) can be observed numerically through the number of teachers who have actually made changes in their teaching in order to integrate sustainability, and how many students have been exposed to it. To have a deeper insight into different types of changes made, a complementary, qualitative approach is useful. The impact (level 4) has been identified as the most difficult to reach. Since higher education follows the temporalities of curriculum cycles, for example, course and programme renewal and consecutive student learning, the analysis of institutional outcomes would require more long-term observation and more versatile methods of study. Thus, we concentrated our analysis mainly on levels 1-3, leaving level 4 as a task for future research.

2.2 Material and methods

Our study material consists of data derived from the three/four first executions of the SiT-course in 2021 and 2022 (Table 1). A total of 75 persons have participated in the courses. As study subjects, we invited course participants who completed the course and are still employed at Aalto University (Table 1). We used data triangulation to allow for the temporally distinct levels of analysis of the applied Kirkpatrick model and the qualitatively different information needs of the analysis (see also Cahapay 2021). Thus, our research material for the study consists of retroactive material, i.e. existing register data (anonymous course feedback, course assignments) and material collected only later specifically for the study purpose (survey, interview). Since tracing the impact of the course requires time between training and actual changes in teaching, the data collection for material other than retroactive material was targeted only at the completers of the three first executions of the SiT, altogether 41 participants.

Table 1. Summary of study material. As the course feedback is anonymous, we have no demographic information on those respondents. Note: Apart from teachers in the engineering field, the SiT-course has been offered to teachers in Business, and Arts and Design. However, only two of the respondents do not represent engineering fields.

		Professor (track)	Lecturer/ Univ. teacher	Other (postdoc)	N	% of invited
Anonymous retroactive study material (participants in 4 course executions)					75	
	Course feedback	N/A	N/A	N/A	38	51%
Retroactive study material (invited, from 3 course executions)					41	
	Pre-course questionnaire	4	5	3	12	29%
	Course assignments	4	5	3	12	29%
Collected material (invited, from 3 course executions)					41	
	Post-course survey	4	5	3	12	29%
	Semi-structured interview	1	3	3	7	17 %

After data collection, the interview recordings were transcribed and all the data was pseudonymized. For Finnish native speakers, the interview was conducted in Finnish. Where necessary, quotes have been translated into English by the authors. As the course was offered to teachers in engineering, arts and design, and business, we refer to individual respondents accordingly with E= Engineering, A = Arts and design, B = Business, and a running number.
As part of the analysis, the anonymous course feedback and post-pedagogical course sustainability integration activities carried out by the teachers were quantitatively described. For the qualitative analysis, the material was manually coded as inductive coding in Atlas.ti, however, reflecting themes and patterns that were interpreted as relevant regarding the Kirkpatrick model levels of impact (Thomas 2006). At this stage of our study, we relied on single coding. In the following sections, we present selected key results categorized according to the Kirkpatrick levels of analysis.

3 RESULTS AND DISCUSSION

3.1 Reaction to training (Level 1)

In general, the course received very good post-course feedback from the participants (Figures 2 and 3). On a scale of 1-5 (1 the lowest and 5 the highest), the course was graded with a total average of 3,97. Regarding the question about whether the course met the expectations of the participants, 92 % answered that the course either met or exceeded their expectations. When asked, whether they would recommend the course to their colleagues, only one respondent would not recommend the course, while 84 % of the course participants would recommend the course (N = 38). 13 % answered “I do not know“.

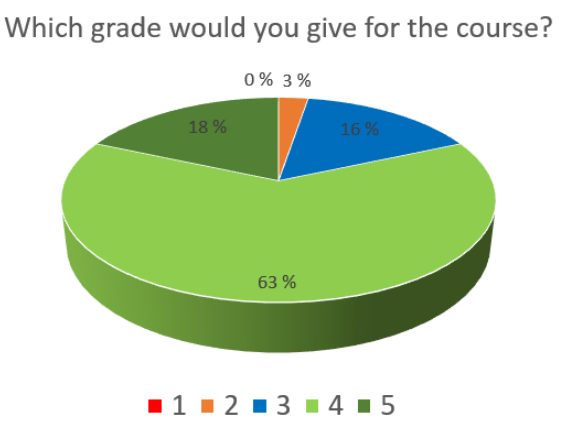

Fig. 2. Participant assessment of the course quality. Scale 1-5 with 1= fair, 5= praiseworthy, N= 38.

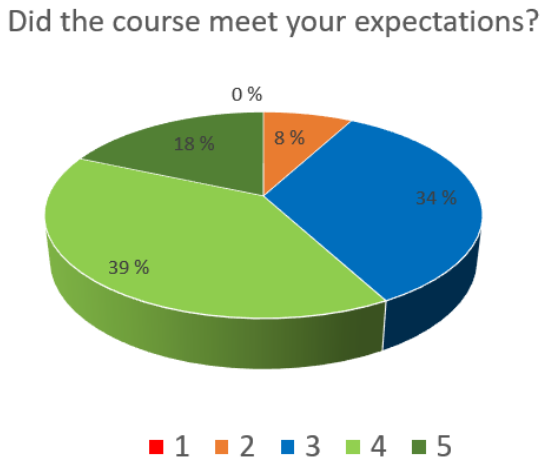

Fig. 3. Participant assessment of course concerning their expectations. Scale 1-5 with 3= the course met my expectations, 5= the course exceeded my expectations, I was surprised, N=38.

3.2 Learning (Level 2)

In terms of participant learning, our main finding was that the course did contribute to their learning. Particularly the collegial discussions supported the learning in a positive way. The learning was pronounced regarding new perspectives and complexity of sustainability, and sustainability competencies as a way to approach integration into teaching. Additionally, the training boosted the confidence of the teachers to actually start integrating sustainability into their teaching.

While the participants mostly had basic knowledge about sustainability, the concept of students acquiring specific sustainability competencies was an *"eye-opener"* (E8) for several participants. As highlighted by one participant: "*Once we started to discuss about teaching methods and sustainability competencies, the learning process really started within me: it is only then when I started to appreciate the true complexity of sustainability in teaching, which means that earlier I have had rather superficial – or one-sided – understanding about it"* (E8). As a part of the learning, the course helped the teachers to challenge their accustomed ways of approaching sustainability. Finding new connections in their subject field seemed to require the nudge to look at their subject from new angles: "*I just realized when I started revising the lecture that it is very easy to link observations […] to sustainability themes, I just need to put "different glasses" on*" (E4). For the teachers in the various fields of engineering, the connections to environmental aspects of sustainability were familiar to a larger extent, but major learning happened regarding the social dimension of sustainability. As one participant stated that "*The course improved my understanding on the importance of social sustainability. Social structures can render our efforts futile and most people do not realize this*" (E9).

Turning their learnings into actual modifications in the teaching through, for example, addressing new sustainability content or exploring new ways of teaching, seemed to require many teachers to step out of their comfort zone. Having been reluctant to do so earlier, several teachers stated after the course that they felt more confident in taking the first steps toward sustainability integration. "*Now, I feel I […] am more ready to discuss about it [sustainability]"* (E8). This included acknowledging that sustainability integration is a process and that it can be advanced piecemeal in small steps. This was an important insight for many. Readiness to start sustainability integration does not mean that one has to be a full specialist, but requires the courage to take the first steps on a journey that will continue: "*I gained confidence to do it, even if I am not in any way specialised on the subject*" (A2).

We attempted to trace in more detail, what supported the learning and confidence-building of the course participants. Our respondents saw collegial peer support through both spontaneous and facilitated discussions as a very important factor in their journey to integrate sustainability. This was evident in several ways and in the analysis, we found three categories in how collegial discussions supported their learning:

a) Sharing of insights: It was widely acknowledged that there exists already a lot of competence and insights within Aalto University, but siloed ways of working prevent this from being usefully deployed for the learning and benefit of all. Apart from seeing sharing as useful in general, it was seen also indispensable for creating a more holistic and systems-level approach, which was considered essential to sustainability education: "*I believe we have many teaching practices in place that are suitable also for educating sustainability. Therefore, I believe sharing best practices will be a must, but also sufficient for providing the necessary toolbox to teachers*." (E1)

b) Widening of perspectives: As a multidisciplinary HEI, Aalto University can provide fruitful ways of broadening one's thinking through encounters with perspectives from other engineering areas, or even disciplines from within Arts and Design, or Business. Facilitated discussions in mixed background groups during the course nudged the participants to think differently than accustomed: "*I liked the most the small group discussions [..] they gave me food for thought and challenged my own thinking.*" (anon. feedback)

c) Encouraging a sense of community: Academic specialists in their specific field often feel that when discussing and integrating sustainability in their teaching, they leave their comfort zone and are insecure about their expertise. Here, peer discussion can act as encouragement and reassure that getting hands dirty with sustainability integration is a joint pursuit and challenge. As highlighted by one participant: "*Most important thing I have learned or seen in this course is definitely that I am not alone with the problems and that there are others to whom I can connect also for help*." (E3)

Our key takeaway is that it is crucial to enable and nourish this kind of collegial support. It requires sufficient time and the creation of an encouraging atmosphere during the training. Even though spontaneous informal discussions could be possible in the academic community, it seems that the time constraints of everyday academic work, and the lack of encounters (especially since the pandemic has increased remote work) are the main hindrances. Thus, allocating sufficient time during the course for these designated discussions is crucial for its success.

3.3 Behavioral change (Level 3)

In our survey and the interviews we asked the course participants whether they had made changes in their teaching to integrate sustainability and if yes, what kind of changes, and how many students have these changes affected.
According to our respondents, since completing the course, altogether an estimated 675 students have been exposed to new sustainability-related teaching. Of these, 461 students were in the field of engineering. As the development of teaching and teacher competencies is a process that evolves over time, it is likely that more changes still will be implemented in the future, since they were still in a preparatory phase. Three respondents reported that they already had a feasible plan, on how to change their forthcoming teaching to integrate sustainability.[2] One participant had made a plan, but due to changes in teaching responsibilities, another teacher actually implemented the changes. As for the implementation, a special mention was the structure of the SiT-course that was considered helpful to the participants in supporting their ability to design and implement changes in their teaching:
"The step by step -structure of the course led me to act and include sustainability into my course. [...] The course helped me to prepare myself and to figure out e.g. which kind of course material I could collect regarding my own field and sustainability, and how to present the assignment subject to the students." (A2)
The analysis gives us more insight on the different strategies and "depth" of sustainability integration, adopted by the teachers. Here, it is important to keep in mind the differences in the situation of the teacher within their specific programme and

[2] In regard to these numbers, it is important to note that our data can be biazed. The small N might indicate that those teachers who had actually made changes were more prone to participate in the study.

position, and hence, their differing “leeway” in implementing changes, or at times, even (re-)creating courses. We identified the following different strategies with increasing depth of integration:

A) Building awareness of and enabling encounters with sustainability: Here, no new content is included, but during classes, the teacher is being more explicit and makes students more aware of already existing sustainability connections and issues. One key was emphasizing and explication of sustainability relevance of the course content, which remained the same: *“Highlighting certain existing elements in my teaching, instead of assuming that students can see the connection.”* (E1)
Another way of increasing awareness was setting sustainability as the context of exercises, such as calculations: “*In the exercises the implementation of the topical subject with sustainability is most simple. Now I could imagine me developing nice calculation examples […] including mass -and energy balances with solubility and liquid/vapour -data or other physics to point out the sustainability issues.*” (E7)

B) Learning activities to explore sustainability connections: Here, the course core content was connected to one or several aspects of sustainability, utilizing frameworks, such as the UN Sustainable Development Goals (SDGs). The course would typically include an introduction to sustainability as new content and the students be given learning activities that would direct them to discuss and explore how the topic at hand is connected to sustainability. As an example: *“I added sustainability and SDG:s as a theme into an independent assignment of […] course”.* (A2)

C) Field-specific teaching with sustainability focus: At this level, the course would revolve around field-specific sustainability connections and engages students to work with these issues in a major coursework or project, typically including teamwork. This type of integration requires a major reallocation of workload during the course in question and means re-structuring many components of the course, including introducing the selected perspectives and facilitating a major learning activity. As an example: “*I added [..] one lecture with sustainability topics (included: the domains, key-performance indicators in relation to social, economical and environmental sustainability of [course topic], feedback loops, normative decisions) and then a larger project work in which students need to create a [board] game.*” (E8)

The processual character of teaching development was evident from our data. One teacher reported minor changes of type B in their first execution of the course but planned to shift into a deeper integration (type C) in the next execution of the course. To its largest extent, one respondent in engineering had a plan (and green light from the department) to create a new course with field-specific sustainability fully integrated as the main focus of the course, and after piloting, even to be developed further into a MOOC.
Our key observation on this behavioural change of teachers into actually implementing sustainability integration is that the teachers need to find their own way of doing it. As many teachers felt operating in an area beyond their comfort zone and core expertise, they needed to figure out which ways of teaching would fit their purpose and styles best. This connects again to the learning through sharing - as one participant pointed out, learning from peers about different alternative ways to approach sustainability integration will help them find the suitable ones for their specific needs and styles. Whatever type of integration the teacher finds suitable for their respective course, it must be a fit, not “*artificial*” (E8).

3.4 Organizational impact (Level 4)

We identify preliminary signs in the data that the pedagogical course might also support the changes at the organizational level (Kirkpatrick model level 4). The interviewees spoke about discussions they had had regarding founding a new course in the curriculum and about agreeing together with the programme teaching team on how sustainability integration would be furthered in the future. However, in-depth insight into the long-term impact of the training would require further analysis of the organization-level changes. On the other hand, as Cahapay (2021) has pointed out, factors influencing that level are myriad, and discerning whether the long-term impact is due to the training, or a result of external factors, is hardly possible.

4 SUMMARY

In summary, our analysis indicates that the SiT-course seems to be an effective tool to support integration of sustainability into engineering education as a cross-cutting and cross-disciplinary theme. Based on teacher self-evaluation, significant learning has happened at least in some areas of sustainability integration. According to our findings, combining knowledge about sustainability and sustainability education with learning activities focusing on one's own teaching context, and supporting both individual and collective reflection across disciplines have made this course an effective measure to support sustainability integration.

A training course may work as a platform for networking, sharing, and learning with peers, thus providing a way to overcome the time constraints hindering sustainability integration (Karvinen et al. 2017). In addition, the course may result in a more comprehensive and deep approach to sustainability in teaching, help teachers in finding meaningful connections between their subject and sustainability, lower the threshold of individual teachers to start integrating sustainability, and could even work as a means to achieve institution-level changes for sustainability.

While not addressed in our study as such, we believe that a training like the SiT-course could be transferrable to other HEIs of engineering, as well. The course has been showcased at various seminars and discussion events in the European context, especially within the UNITE-network, and it has raised interest, inquiries and appraisal as a concrete measure to advance capabilities for sustainability. Reflecting the unique combination of educational fields at Aalto University (engineering, science, arts, business), the course is designed to support teachers from various fields and thus, making transfer more easy. However, customization to best serve each institutions specific needs is necessary. For continuous learning and development, we encourage sharing of experiences in teacher training for sustainability integration within the HEIs.

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