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Changing the world one engineer at a time – unmaking the traditional engineering education when introducing sustainability subjects

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Abstract

Purpose – The information technology (IT) sector has been seen as central to society's transformation to a more just and sustainable society, which underlines teachers' responsibility to foster engineers who can contribute specifically to such ends. This study aims to report an effort to significantly update an existing engineering programme in IT with this ambition and to analyse the effects and challenges associated with the transformation.

Design/methodology/approach – This study is based on a combination of action-oriented research based on implementing key changes to the curriculum; empirical investigations including surveys and interviews with students and teachers, and analysis of these; and a science and technology studies-inspired analysis.

Findings – Respondents were generally positive towards adding topics relating to sustainability. However, in the unmaking of traditional engineering subjects, changes created a conflict between core versus soft subjects in which the core subjects tended to gain the upper hand. This conflict can be turned into productive discussions by focusing on what kinds of engineers the authors' educate and how students can be introduced to societal problems as an integrated part of their education.

Practical implications – This study can be helpful for educators in the engineering domain to support them in their efforts to transition from a (narrow) focus on traditional disciplines to one where the bettering of society is at the core.

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Originality/value – This study provides a novel approach to the transformation of engineering education through a theoretical analysis seldom used in studies of higher education on a novel case study.

Keywords Sustainability, Information technology, Science and technology studies, Software engineering education, Unmaking education

Paper type Research paper

1. Introduction

As our global societal predicaments unfold, and graduates need to be prepared to face an increasingly volatile world, it has become clear that higher education needs change (UNESCO, 2017). Exactly how to provide an education that enables "a profound transformation of how we think and act" (UNESCO, 2017, p. 7) is a source of contention though, both within higher education in general, and engineering education, in particular (Mulder, 2017). There are frameworks for reorienting education around key competencies for sustainability (Wiek *et al.*, 2011; UNESCO, 2017), or around emancipation instead of detailed curricula and metrics (Biesta, 2009; Osberg and Biesta, 2020). In engineering education, there have been calls to steer towards trans-disciplinary, challenge-based approaches, and to make sustainability orientation "creative, effective, and acceptable" (Ashford, 2004), but at the same time, many approach sustainability education in engineering through more incremental change, focusing on techniques for life-cycle assessments and minimization of harm through material and energy use (Mulder, 2017).

Computing education is positioned squarely in the middle of several such tensions. For instance, politicians and policymakers tend to place high hopes in digitalization to solve pressing social problems (Golding, 2007). The information technology (IT) sector is seen as key to both economic growth (Katz and Koutroumpis, 2013), but along with that, the unsustainable growth of the use of critical materials and energy (Court and Sorrell, 2020). Also, computing is seen as the key for social change through online participation and communication in democratic processes (European Commission, 2021), but because social platforms are owned by advertising-funded US companies, the toxicity and outsized influence of those platforms have caused concern for both research (Vosoughi *et al.*, 2018) and in the public debate.

Computing education is still motivated and underpinned by notions that the most vital abilities are to learn how to build new, advanced applications using powerful techniques such as machine learning (Pollock *et al.*, 2019). The adoption of a mature and self-critical attitude towards the role of technology in society is not seen as an equally central competence in graduate profiles (ibid). The question is, rather, how engineering education may balance the desire from students and employers for specific, in-depth, computing competencies, while opening new vistas for our students so that they become willing and able to practice engineering in a much wider and more complex setting.

There are several challenges for those who seek to restructure and widen the scope of engineering degree programmes, including institutional barriers (Leifler and Dahlin, 2020), professional identities and different perceptions of sustainability (Pollock *et al.*, 2019). A previous case study in Sweden has shown that there is a gap between the needed competences related to economic issues, sustainable business management, social topics, green technologies and the education provided to engineers (Hanning *et al.*, 2012). Even when degree programmes do change, such changes are not necessarily long-lived or far-reaching, depending on how those changes are understood among students and staff in relation to their professional identities and perceptions of valuable learning experiences. For instance, in the survey by Thürer *et al.* (2018) on sustainability integration in engineering education, they found a lack of studies on the values and norms of teachers and students and the outcomes of changes to a degree programme.

Against this background, our study aims to explore the view of sustainability in software engineering education, as perceived by students, teachers and the programme board in a Swedish degree programme in software engineering. The research questions guiding this study were:

RQ1. How is sustainability in IT education understood by students and teachers?

RQ2. What challenges does the change towards the inclusion of sustainability subjects in an IT education bring?

RQ3. What aspects of the change process contributed positively to the integration of sustainability subjects?

The study was done in the context of a five-year engineering programme with a focus on IT at Linköping University. Previous studies have shown that sustainability has a low integration in curriculums in higher education in Europe (such as in fields as media and communication, Karmasin and Voci, 2021). In this study, a case is presented where sustainability has been integrated in a computing degree programme and how this integration process has been perceived by teachers and students is explored. This is done in a novel way through a science and technology studies (STS) analysis. Combining STS and engineering education perspectives provides an innovative way to think reflexively about the power and politics intertwined in engineering and how this can be included in engineering education (Pritchard and Baillie, 2006). Now more than ever, engineering training needs to make sense of and respond to the pressures facing the field of education, such as increasing inequities, a growing focus on standardization, the erosion of institutions and the increasing trust in numbers (Gorur *et al.*, 2019). In relation to this, STS allows educational researchers to "trace, disentangle and subsequently show how relationality is one of the prime characteristics of each and every educational practice" (Decuypere, 2019, p. 136). This relational sensibility means that the study focuses on the practices, interactions and relations between teachers, curriculums and students in the entanglement of engineering and sustainability. STS can thus provide an inclusive and novel analysis of heterogeneous networks of actors and make visible how these relations shape higher education (Tummons, 2021; Salomão Filho and Kamp, 2019).

2. Background

2.1 Description of the degree programme

In accordance with the European Bologna process, the Swedish engineering degrees are either three years (first cycle) or five years (first and second cycles) in length. The five-year engineering degrees at Linköping University are organized and administered as a single five-year programme rather than as two separate programmes (bachelor and master). Historically, these engineering programmes are rooted in a tradition where mathematics and physics were seen as the core subjects which everyone with such a degree was expected to master.

The programme in IT (IT programme) was started in 1995 as a response to what had already then been identified as a necessary area of improvement for future IT engineers, giving a more holistic system perspective. The programme was at the time pioneering in engineering education in Sweden through the introduction of problem-based learning (PBL) in all basic courses as well as the introduction of subjects such as ethics and psychology. See

Hmelo-Silver (2004) for a longer discussion on this educational method. In our implementation of PBL, each semester has a person responsible for coordinating among teachers how students are to conduct their PBL related to all courses. Students take on weekly problems closely related to their courses in programming, mathematics, physics as well as gender issues and sustainability. Addressing the problem is done in groups of – seven to eight students who design their own learning goals and problem statements. It is resolved with a joint discussion a week after startup when everyone has had a chance to learn about the subject on their own. The unique curriculum was successful and much appreciated by industry and alumni, but also hard to maintain in a system where most courses are taught according to a more traditional template. At the time of the most recent update of the programme, its profile had largely reverted to one like other engineering programmes at the university.

2.2 Motivation for change

In contemporary critiques towards engineering degree programmes, studies have pointed to a socialization process in engineering education that causes disengagement in social problems (Cech, 2014), and the inadequacy of traditional engineering methods for problem-solving in addressing wicked, real-world problems (Lönngren, 2019). Considering this, within the CDIO community, there have been recent changes to the standards that define engineering education (Malmqvist *et al.*, 2020). These changes have not been implemented in all of engineering education, however, and much of engineering education is still strongly rooted in disciplinary traditions of mathematics and technical subjects.

Still, the general momentum of change in engineering education points to new roles of engineers in society where responsibility and sustainability are included in a modern understanding of this profession. This change is not only seen in educational literature but also present in the everyday life of education planners. A pressure to change was also connected to the fact that the education was attracting fewer students than desired, which created a window of opportunity for change. The teachers saw a way to attract more prospective students, and especially, to appeal to women, by adding a focus on sustainability. Thus, a rethinking of the programme started during 2015 with the first changes being implemented in 2018. Part of this was an evaluation of the programme which included the students, and several of the students saw gender issues as important – they wanted to be able to show future employers that they had taken a course concerning gender.

2.3 Changes made to the degree programme

Once the decision to implement changes to the programme had been taken, the path to a new curriculum had to be staked out. As a comparatively small programme (around 40 students per year) in a university that accepts over 1,400 engineering students in various subfields every year, it is very difficult to take a clean-slate approach to programme design. Courses are given by several departments, often combining students from different programmes in the same course. Because of the constraints, this puts on the curriculum, a few key subjects considered to be most important to strengthen in the programme were prioritized.

The formal decisions regarding the curriculum are taken by a board of education, based on prepared material from a programme planning group (PPG). In the PPG (which is composed of teachers, students and other personnel that are involved in the programme), the following areas were prioritized to be included or strengthened in the new curriculum: legal aspects, ethics, gender and diversity, leadership, sustainability, cybersecurity and programming skills. In the end, five new courses relating to these subjects were developed and included in the curriculum.

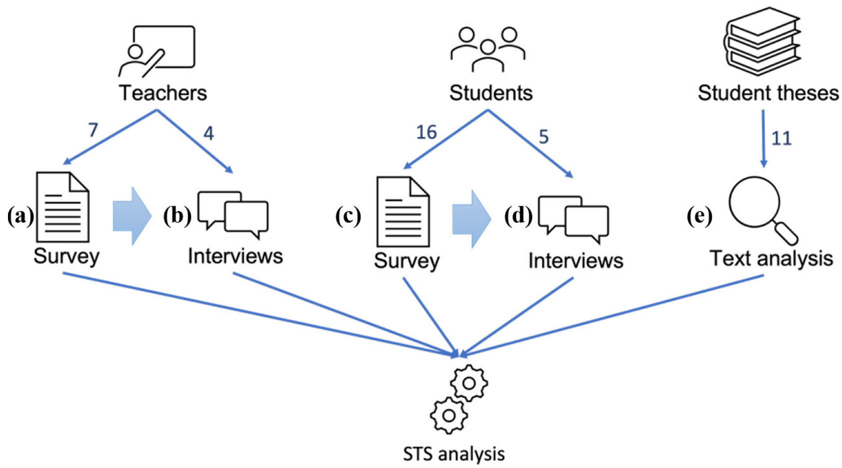
3. Methodological framework

In terms of research design, the study can be understood as a case study (Myers, 2013), where the case is that of the described changes in the engineering programme in IT. The study was made with a constructivist approach (Law, 2004; Bruun Jensen, 2007; Jerak-Zuiderent, 2019), in which researchers are understood as actors in the situation which they also study. In, for instance, ethnography, this is nothing new (Davies, 1999), and it is also common in STS. This paper is then an example of the co-production of the researchers and the researchers' objects/people of study, and the knowledge that emerges through their interaction engages this contingency of knowledge production (York, 2018). So, the authors were thoroughly entangled in the study in several ways; some of the authors initiated the process of change in the programme, in their roles as members of the programme board, and some were in charge of the new courses (in gender and technology, IT and sustainability and ethics) which were part of this change.

Furthermore, the authors designed the study and decided how to collect empirical material, conducted this collection of materials and analysed it, while some of the authors were also responding to the survey aimed at the teachers in the programme. The authors were included as survey respondents in the paper because they are actors in the process of reconfiguring the programme, and their voices matter too. Overall, this means that the researchers were part of and entangled in the empirical material, as well as in the collection and analysis of it.

3.1 Empirical material

The empirical material in the paper consists of (a) one survey of teachers involved in the new curriculum, (b) short interviews with senior lecturers involved in the curriculum revision, (c) one survey of students who have taken the new curriculum, (d) interviews with some of these students and (e) bachelor theses written by these students. Figure 1 shows an overview of the methodological approach with the five data collection steps. The steps are further explained below:



Note: The numbers show the number of participants/items included in the collection

Figure 1.
Overview of the methodological approach

(1) The survey aimed at the involved teachers consisted of eight open-ended questions concerning the Higher Education Degree Ordnance for Swedish engineers and difficulties to make changes in a study programme. Seven teachers in the programme responded to the survey, three of whom were part of the programme board and some of whom were not. From this survey, four teachers with responsibility for coordinating courses within a semester was contacted.

(2) Interviews were made with four senior lecturers in mathematics, physics and computer science. The interviews lasted for about 20–40 min each and were conducted via Zoom. These lecturers were all involved in the changes of the curriculum. The questions concerned their views on sustainability generally, and their experiences of the changes made in the programme.

(3) The survey aimed at students had seven open-ended questions and asked whether they would be willing to be contacted for an online interview with further questions. Sixteen students answered the survey and five were willing to be (and were subsequently) interviewed.

(4) Students were interviewed during approximately 20 min each. In these interviews, the questions concerned what they thought about the courses and what they think being an engineer means.

(5) At the end of their third year, the students write a bachelor thesis as part of a semester oriented towards information security. The thesis projects are performed in pairs and the resulting reports are usually around 25–30 pages in length. The report template has a heading in the discussion chapter called "The work in a wider context". So, it is reasonable to expect that they would bring up issues relating to how their work relates to a larger societal discussion around their chosen topics. We analysed 11 reports written by 22 students from the IT programme. If present, we read the section on the work in a wider context and also did textual (case-insensitive) searches for the terms "privacy", "sustainab*", "ethic*", "gender" and "societ*" in the entire document.

3.2 Analysis of the empirical material

The survey answers and interview material were thematically coded and categorized. This coding and the anonymized answers were then shared with the group and discussed, drawing on the various authors' experiences in the classroom, in course planning and against other academic work about teaching ethics, sustainability and diversity.

Analytically, we aim to extend the focus on "making" in engineering education. Educational practices are always in the making and thus, when something new is introduced or made, something else is being re- or unmade (Decuypere, 2019). This is of interest as educational studies often focus on the processual nature of phenomena as they are unfolding and therefore tend to neglect the, sometimes problematic, unmaking of the more established educational system. The making/unmaking problematic underscores the power relations involved in such a process of reconfiguration. For instance, introducing (making of) new and untraditional subjects at the expense of existing and more traditional subjects in an engineering programme must be argued for and motivated by arguments which are credible in this specific context. It necessarily involves a negotiation between actors which are differently situated in relation to established practices and structures, in a process in which some subjects are at the same time unmade. There is a risk that the actors with a close relation to these are moved to a somewhat more peripheral position, which will be shown in our result section.

4. Results

4.1 Different understandings of sustainability in engineering education

One issue that arose during the work to integrate sustainability throughout the programme was to define the borders of sustainability. In computing education, the level of integration of sustainability issues can be characterized as "immature" (Pollock *et al.*, 2019), with mostly calls to action being presented but few clear definitions, guiding principles or assessments of interventions. Pollock *et al.* (2019) also describe how the integration of sustainability is often done "in the abstract", without specific learning activities, outcomes or assessments within courses. The definitions of what amounts to equitable and sustainable computing are often mismatched to societal definitions, and value conflicts tend to be ignored in research on issues of "Green IT" (Knowles, 2014).

The teachers in our study discussed sustainability in the context of using engineering techniques for the right purpose, or building reliable, adaptable and durable IT systems. One of the interviewed teachers argued that sustainability concerns the construction of systems which are adaptable and changeable:

> [. . .] [we should be] sustainable in our social engagement [. . .] and [. . .] in a changing world [. . .] [we should make systems] which people want to use and which are adaptable [. . .] we have to think about who belongs to different categories and how we treat people. (interview with teacher)

Sustainability was seen to be related to the IT programme in a clear way, and several teachers indicated a "systems" view, which not only concerns narrow technical systems but wider and more inclusive systems consisting also of users, the future and a changing world. Another argued that sustainability is already the basis of engineering subjects such as optimization. Through optimization, one can make long-term predictions based on calculations, rather than guessing. This will counteract unsustainable, short-term thinking, according to that teacher. However, there is flexibility in the understanding of the borders of sustainability depending on the context. One of the teachers interviewed said that it is "hard to find room for both physics and sustainability". In this statement, the two are made incompatible and discussed as different things. The same teacher said a little while later that sustainability concerns "the idea that we must pay for everything we consume [. . .] there has to be a perspective of a circular flow". In this statement, physics and sustainability are, contrary to the previous statement, related to each other through a focus on circularity and reuse of resources.

Other teachers spoke about sustainability as something "outside" the engineering education that needed to be better integrated. The difficulties in separating the sustainability from engineering subjects on one hand, and the argument that it is important to integrate sustainability in engineering subjects on the other hand might seem a bit contradictory. It is therefore not surprising when teachers find it difficult to navigate in defining sustainability for IT engineers:

> Don't ask me that question! How difficult! I have a very vague picture about what sustainability is, it is such a large concept. [. . .] But it is important to include in the education. (interview with teacher)

Even though it is difficult to define, this teacher considers it important to include in engineering education. This is also evident in the survey, where all respondents agreed that contributing to sustainable development is an important aspect when it comes to educational goals for engineering education. When asked whether sustainability is important for IT engineers, one interview respondent replied: "It is not possible to say no to that question". Statements like these could be a sign of a narrow discursive framework, where there is no room to argue against sustainability. Sustainability is now incorporated in documents ranging from government directives to course syllabus and strongly interwoven in the social fabric of society and education. This leaves little room for critical voices against sustainability, caters for the making of a new engineering education – and, consequently, also an "unmaking" process of the traditional engineering education. However, the vagueness of the concept of sustainability opens for discussions as seen in interviews where some versions of sustainability which was related to a broader understanding of sustainability as solving problems were easier to accept for some teachers. This view is also present in the survey where one respondent replied that sustainability is appropriate in the educational goals, but only in some forms: "Yes, if one interprets the goals as being about contributing to a sustainable development and not only know about societal problems". There are thus competing understandings of sustainability in education being enacted, which in turn create tension as they have consequences for how the engineering programmes should, or should not, change.

4.2 Challenging the traditional engineering education

Some teachers thought that the traditional engineering subjects (such as mathematics, mechanics, optimization and computer science) are the heart of the engineering education, and that the changes towards including sustainability had drawbacks as it detracts from what they consider to be the core problem-solving practice of engineering:

> I think it has gone a little too far, a little too much "soft" subjects. These are important things, but I personally believe that optimization is perfect. Some other courses focus on problems but offer no solutions. (interview with teacher)

Soft subjects in Science, Technology, Engineering and Mathematics are often defined in relation to leaderships skills, teamwork, ethical issues, creative and critical thinking (Cukierman and Palmieri, 2014). The soft subjects are harder to describe as they cover a broader scope, are characterized by different epistemological traditions and are most often defined in relation to other subjects, which is why they tend to be called "non-engineering" subjects in engineering education (Litzinger *et al.*, 2011). The divide between "soft" subjects and those which are often called "real" engineering (or core) subjects is not neutral. Soft subjects, even though their name suggests them as harmless, are threatening the core subjects. Some of the teachers were ambivalent to the changes pertaining to gender issues and ethics, and still saw themselves primarily as representatives of their more technical disciplines, trying to promote that which they felt best able to: "I fight for my view of what's best, which is to provide engineers with tools to solve problems". This statement is tied to an understanding of problems as solvable with quantifiable measures or technological solutions and disconnected from social concerns or disagreements. Such an understanding is at odds with sustainability challenges where environmental concerns, economic development and social issues often are intertwined. The requirements to be able to implement sustainability throughout engineering education thus also have to involve remaking of a specific kind of problems which engineers are expected to be able to solve.

The survey furthermore shows that the teachers argued that change is a difficult process, or at least time consuming, within an existing educational programme. In the survey, we saw that some teachers argued that there was a lack of insights in the programme as a whole, and that this had as consequence removed some subjects which were perceived as central for IT. All interests and desires could not be fully taken into account as the unmaking required that some were doomed to be replaced. The process not only has an effect on curriculums and teaching outcomes, but also triggered emotional responses and larger questions about the engineers' role in society, and the roles of teachers who felt left out of the process when their courses became less central to the revised curriculum. Our results confirmed Hoover and Harder's (2005) reflection that a process of change reorienting education towards sustainability, that relies on networks of engaged actors without explicitly making sure all are onboard, risks excluding those who feel they have less to contribute.

There is a tension between the amount of time spent on natural science and technology-focused subjects on the one hand and sustainability subjects on the other hand, and this tension is present in both interviews and the survey. When asked whether the goal in the Swedish Higher Education Degree Ordnance which is focus on a "broad knowledge in the chosen field of technology, including knowledge in mathematics and science, as well as significantly in-depth knowledge in certain parts of the field" was fulfilled in the IT programme, the teachers differed in their answers. Some said that 50% of the education should focus on these subjects, others answered more reflectively on what they would like to see more of, whereas one teacher argued that the students now lacked enough knowledge in fundamental natural science subjects. When we, on the other hand, asked how much of the education should focus on the goal to "demonstrate the ability to develop and design products, processes and systems with regards to human conditions and needs and society's goals for economically, socially and ecologically sustainable development" and if the focus today is enough, other views were presented. One teacher argued:

> I think that the students should be continuously (as in every term and at every turn) reminded that they are going to be building societal infrastructures, not "digital" or "computer" infrastructures, and that these infrastructures need to be accessible and usable to many different groups in society, not just the ones that are identified as potential customers and thereby paying for their (future) labour.

There is, for some teachers, a strong view that the programme's purpose is to act for sustainable development rather than to just focus on providing the students with technical competences.

The Swedish Higher Education Degree Ordnance requires engineering education to train students to take decisions with social, ecological and economic considerations. At the same time, these documents also state that engineering education relies on traditional engineering subjects. This has led to a controversy where the same documents can be used to argue for, and against, change:

> The IT-students need electro physics; it is important as the science base for technology. According to the Swedish Higher Education Degree Ordnance, the student should know the boundaries of technology, and this is where electro physics is important. This has not been present in the discussion. We are cutting off a leg which is important for the engineering profession. (interview with teacher)

This issue could be discussed in different ways depending on what parts of the Swedish Higher Education Degree Ordnance that are put in focus and on what is at stake for different actors. The focus on profession adds a dimension to the issue as it stresses the risk of missing fundamental knowledge for the engineering profession. The argument relies on the already existing web of knowledge where electrophysics is one of the strong pillars. The respondent is advocating for his subject by siding with the existing knowledge framework which traditionally has been a solid base. This reasoning is a response to the unmaking processes which are understood as undermining the engineering profession. Responses in line with this reasoning also occur in the survey sent to teachers, where one teacher argued that the students do not learn a solid base in natural science. This could be contrasted with other views from teachers, arguing that all activities should be subordinated to students understanding and working for the transformation of society.

This re-organisation of education requires large efforts and some teachers argue that there is a need to rethink how we work with educational development to more easily incorporate the topics that are relevant for the future engineers:

> Sometimes one would like to turn everything upside down, throw everything up in the air and do it all over again [. . .]. (interview with teacher)

Rethinking the whole programme would unmake the established curriculum and divisions between subjects, allowing for a more open-ended process. However, this process has its drawbacks as years of work in building the programme would be lost.

4.3 A need for new ways of measuring learning outcomes

Another aspect in the unmaking of the traditional engineering education is what the learning outcomes look like and how we measure them. For some subjects, such as gender and equality courses, one interviewee wanted explicit proof that the new course "changed" something:

> Everything must be useful. The course in gender is good, but do we know if it actually changes anything? Can we see that in bachelor theses? I do not think we do. The challenge is to add elements, but it is difficult to measure whether it will have an impact. (interview with teacher)

The educational system measures learning outcomes in different ways, and bachelor theses are by some understood as an important control point in what the student have learned the first three years. In line with the teacher in the quote above, we were curious about how the changes in the IT programme had affected the bachelor theses. Thus, we were also interested to see whether the students would bring up subjects related to sustainability, diversity or other societal aspects without us specifically asking about it. The bachelor thesis is written as part of a course on information security and sustainability issues are not specifically addressed in the course. There is, however, a section where the students are asked to relate their thesis subject to a broader societal perspective.

None of the theses we analysed brought up sustainability directly, which seems to indicate that the students do not consider this topic to be relevant in the context of information security. As expected, privacy was much more prevalent with nine reports including some mention of this concept (some only briefly, others quite frequently). Ethical and societal issues were discussed in eight reports each, though typically with rather brief statements. Finally, the word gender was included in three of the reports.

The inclusion of sustainability in the curriculum preceding the bachelor thesis project can have caused some students to actively reflect on these matters when given the chance to do so. Still, it is also clear that most of the students perceive sustainability as relatively peripheral to their problem and therefore treated it briefly (or not at all) in the report. This illustrates that merely adding courses is not in itself sufficient to change the way students and teachers think about what counts as important engineering topics in relation to these kinds of reports.

The change in courses might not have had a large impact on the bachelor thesis, but in some respects that might not be a problem, or even preferable. Some subjects introduced in the curriculum are, rather, meant to affect their professional lives after their formal education is finished. Measuring understandings of and insights into different social issues and others' perspectives can be hard to fit into the traditional matrix of examination. Also, changes concerning the types of natural science presented as a "basis" are not subjected to the same type of scrutiny in having visible effects on students' ability to conduct thesis projects. In fact, overall degree programme quality is primarily assessed through teachers' self-assessment of how course learning goals align with items in a common syllabus for engineering degree programmes. Some researchers argue that this traditional framework for measuring learning relates to the neoliberal culture of western societies, where evidence-based policy and focus on efficiency and productivity create an apolitical rationality of science (Gorur *et al.*, 2019) that hides underlying political motivations. The strong movement towards standardizations of teaching quality has been criticized for providing a too narrow version of teaching standards and reducing teaching practice to a specific kind of practice. Instead, teachers should acknowledge the networks of heterogeneous actors (such as students, teachers as well as material and technical actors) to give a greater multiplicity and dimension to teaching practices (Mulcahy, 2011). Focusing on how different standards enable specific teaching practices we can hold difference in tension, rather than seeking to reconcile them. The tensions allow for critical discussions on the role of teachers in relation to sustainability. Re-thinking education with different forms of sustainability might also mean rethinking the way we evaluate educational outcomes. The STS approach to education urge teachers to re-invent responsibility not only for the engineering education outcomes, but also for our understanding of knowledge as not all subjects can be fit into the current administrative framework.

4.4 Becoming the new IT engineers – students' experiences

The teachers' views on the inclusion of sustainability in the IT programme's curriculum showed important insights to the organisation of knowledge and its consequences. We were also interested in understanding the students' perceptions of an IT engineer and their expectations of their education. We interviewed the first cohort of students who took the new curriculum, after they had just finished their undergraduate part and were about to start the master element of the degree.

One of the questions we asked the students was what they thought is the most important ability/skill for an engineer to have. Their answers included the ability to do advanced math and technical competence, but much more frequently they brought up the ability to solve problems, the ability to learn independently, collaborate in a team and the ability to think about how their technological solutions would be affecting society. As one student wrote, "[. . .] to understand technology in one's area of specialization, but also to be able to analyse and reflect upon technology's impact on society and individuals and vice versa". This answer was, perhaps, a direct nod to our particular interests as their teachers and reflects the entangled knowledge construction we are engaged in. It also showed that the conflicts of interest behind the scenes, where teachers felt the need to fight for their subjects, are invisible to the students. The unmaking of the engineering education is not controversial for them and there is no apparent divide between "core" and "soft" subjects for students.

The students' views on why they wanted to become IT engineers and what responsibilities the profession came with, provided a broad and varied picture of the future IT engineer. Curiosity, making things and enjoying the process of solving problems and overcoming challenges were quite common answers. The relatively high status and good pay of engineering jobs also came up. But some students said they were motivated by the desire to make new products or services which would help people. And, inspiringly, one of the students wrote that they were motivated by, "a desire to improve and contribute positively to my surroundings through my future professional work".

In the interviews, students were, among other things, asked whether and how their imaginaries of what an engineer is had changed from before they started studying to now, after taking the three-year bachelor part of the degree. Several of the students mentioned that they were inspired to become engineers because they have parents or relatives who were engineers – but that after their education, they have started to think of their futures of engineers as slightly different from how they perceived their relatives' careers. Now they were thinking of their future careers of entailing both practical and social aspects. They also see their future roles as problem-solvers. Some of them see their future involving being managers, but managers who were competent with the technology their teams were developing or maintaining. Their view of the engineering role has a broader scope beyond technological competences and the problems they strive to solve range from developing products to working towards a fairer society. This may indicate that they are already imagining integrating technology and sustainability in their future work life. Whether the change and willingness to integrate is due to their education is not possible to know from our study but we can argue that they do not find the unmaking of the traditional engineering education as problematic. Rather, our students have embraced the focus on social issues and sustainability as a natural part of their future.

5. Discussion

The making of a new engineering education, and as a desired effect, a sustainable engineer, is not only about making new, but also about unmaking. The traditional engineering education cannot be combined with the sustainable development agenda, as it takes up space and time from other, often more traditional engineering, subjects. The unmaking of the traditional engineering education therefore introduces conflicts as subjects that previously were seen as central to becoming an engineer now are enacted as obsolete, which leads to some teachers feeling the need to "fight for their subjects" in relation to the so-called soft skills.

We argue that these controversies can be used to create generative critique, a critique that is capable of producing new possible futures (Verran, 2001), through slowing down and paying due attention to the disconcertment the changes bring (Jerak-Zuiderent, 2015). Disconcertment is described as a disruption that is experienced when our taken-for-granted assumptions are contradicted (Verran, 2001) and allowing people to express their experiences of disconcertment could make room for alternatives to what is hegemonic (Smolka *et al.*, 2021). Instead of accepting the divide between "soft" and "core" subjects, we aim to open for new ways to discuss the future of the engineering education by internalizing a broader approach to problem-solving which includes sustainability. The controversy could instead be one of what kind of engineers we want to provide for society and how to find ways to encourage students to think about their future professional responsibilities throughout the engineering programme and not just in specific courses. Allowing the controversies in the unmaking of the engineering education will take time and acknowledging the difficulties it brings will create space for building (new) common ground for teachers. Considering that the divide between subjects is not as evident for students, we can expect them to be prepared to learn to deal with complex problems where different dimensions of sustainability are involved. Decuypere (2019) urges us to not "tame the complexity" and rather to teach students to handle present and potential futures that are difficult to anticipate. In this way, we are opening up for interdisciplinary discussions about the role of engineering education and how organizing for sustainable futures is needed to enhance students' capacities to respond to our increasingly complex world and help them become, in the words of Haraway (2016), "response-able".

6. Conclusions

The engineering education is in a re-making process, adjusting to a growing interest in including sustainability and responsibility into the engineering profession. Our study has provided insights into this process as it is occurring in an IT-education in Linköping, Sweden, which has adjusted its curriculum to further include sustainability. As this paper has shown, there is a need to change how we are doing education as the ways we measure and standardize learning outcomes are poorly fitted for some sustainability subjects such as gender studies, where learning outcomes might appear too fluffy and "woke" in comparison to other measurable learning outcomes applicable to engineering topics. We furthermore argue that students need to be better at dealing with complex and interdisciplinary problems in relation to sustainability which demands new ways of incorporating a larger variety of disciplines. The work needed to fully integrate sustainability in higher education also comes with new opportunities to develop far-reaching interdisciplinary collaborations and learning opportunities within both education and research.

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