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The Educators' Perspective on Sustainability in the Study Programme: Electronic Systems Design and Innovation

Robin Berntsen Henriksen

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Norwegian University of Science and Technology
Department of Electronic Systems

Preface

This thesis concludes my two year international master's degree in Electronic Systems Design and Innovation, with Embedded Systems as my specialization profile. As my education has been generally very technically focused, this thesis, being about sustainability and the perspective of educators, has put me far out of my comfort zone. My learning curve has been steep, and almost everything introduced in this thesis has been completely new for me. Even so, the subject of sustainability is of ever growing importance in today's society, and I am very grateful to have gotten the opportunity to learn more about this complex issue. It has been an inspiring and educational journey.

I would like to express my deepest gratitude to my two supervisors, Associate Professor Torstein Bolstad & Associate Professor Elli Verhulst, who generously provided me with knowledge, expertise and guidance. Additionally, this thesis would not have been possible without the educators who participated in the interviews, and I would like to thank them for their patience and great insight. I am also grateful to my partner, Anna Sophie Nymoen Tveit, for inspiring and supporting me every day, and to my cat, Duplo, for all the entertainment and emotional support he has given me. Lastly, I'd like to thank everyone working for a more sustainable future.

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Abstract

Universities have become widely perceived as an important agent in advancing sustainable development, and research on sustainability in higher educational institutes has grown significantly since the sustainable development goals were presented by the United Nations in 2015. However, integrating sustainability in higher educational institutes is proving to be a difficult challenge. The educators are in the center of changing the curricula, and the goal of this thesis is to explore the educators' perspective on sustainability in higher electronic engineering education. This is further explored with the three research sub-questions; "How do educators perceive sustainability on the study programme Electronic Systems Design and Innovation?", "Which competencies and learning themes do educators see as the most important for the study programme, and how does the study programme perform on these today?" and "What are the barriers for integrating sustainability into the specific courses today?". These questions are primarily answered by interviewing educators on the study programme, and doing thematic analysis of the interviews. In addition, the study programme is being mapped by applying a toolkit supporting educators in integrating sustainability in higher education. The major findings are: That the educators agree that teaching students about sustainability today is important. The educators also perceive the four competencies; "system thinking", "critical thinking", "integrated problem-solving" and "creativity" to be well integrated on the study programme today, and they find these competencies to be essential for electrical engineers to master. When integrating sustainability, the main barrier identified by the educators was the difficulty of prioritizing it. This thesis identifies three key drivers that can help overcome this, and further motivate the educators. These are finding a common goal, developing a strategic plan and offering professional development opportunities. Future research should explore more in-depth questions based on the findings from this thesis, or as the sample size was low, it should also confirm that these findings are reasonable.

Contents

Acronyms

DES Department of Electronic Systems

ELSYS Electronic Systems Design and Innovation

HEI Higher Educational Institute

IPCC Intergovernmental Panel on Climate Chang

NSD Norwegian Centre for Research Data

NTNU Norwegian University for Science and Technology

RBA Responsible Business Alliance

SDG Sustainable Development Goals

UN United Nations

UNECE The United Nations Economic Commission for Europe

UNESCO United Nations Educational, Scientific and Cultural Organization

1 Introduction

Our world is getting warmer every day, and rapid climate change is a threat for humans, wildlife and ecological systems. Since 1981, the global average surface temperature has increased by 0.18°C on average each decade, and in 2020 it was 0.98° warmer than the 20th century average [1]. In figure 1, the average global surface temperature from the year 1880 to 2022 is shown, and it can easily be seen how the temperature has risen over the last century.

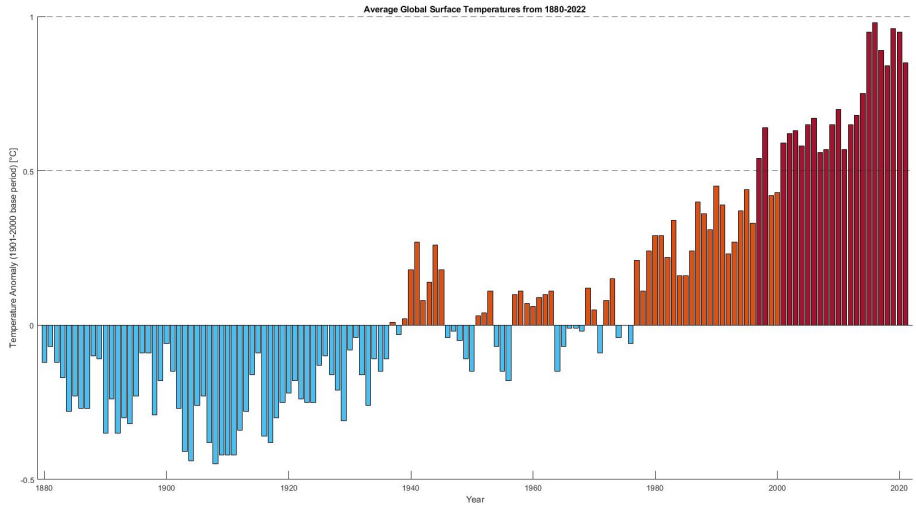


Figure 1: Average global surface temperatures ranging from the year 1880 to 2020. Data from National Oceanic and Atmospheric Administration [2].

On the 4th of April, 2022, the Secretary-General of the United Nations (UN) presented the latest climate report from the Intergovernmental Panel on Climate Chang (IPCC). He said that with our current energy policies, we are on a pathway to a global warming of 3°, which is twice the 1.5° goal set in the Paris agreement in 2015 [3]. This significantly increases the risks and impacts associated with the reasons for concern. Even today, we detect severe impact or risk to warm-water corals as a consequence of global warming. Moreover, if the temperature increases to 2°C, there will be severe and widespread risks of extreme weather events [4].

Going forward, reducing emissions of greenhouse gases is without a doubt important. However, sustainability is about more than stopping climate change. In 1987, the UN Brundtland commission defined sustainability as "meeting the needs of the present without compromising the ability of future generations to meet their own needs." [5], and the Sustainable Development Goals (SDG), presented in 2015 by the UN in the 2030 agenda, forms a framework for transitioning to a sustainable future [6]. The goals are shown in Figure 2, and they clearly state that sustainability is a broad term, including all parts of society. All goals are important in order to succeed in transitioning to a sustainable future, and hence goals like "no poverty", "clean water" and "responsible consumption and production" are just as important as "climate action".

Figure 2: Sustainable development goals by the UN [7].

There is a growing pressure and expectation for Higher Educational Institute (HEI)s to integrate sustainability. In "Goal 4 Quality Education", the UN explicitly mentioned universities in of one the sub-goals; "Goal 4.3 By 2030, ensure equal access for all women and men to affordable and quality technical, vocational and tertiary education, including university.". Additionally, in Norway, the "university and higher education law" (in Norwegian: "universitets- og høyskoleloven") was changed in 2021, adding that the purpose for HEIs is to contribute to environmentally, socially and economically sustainable development [8]. This is a clear sign that the Norwegian government expects HEIs to tackle the sustainability challenges that society faces today.

On corporate level, companies have also become more focused on sustainability. For example, when looking at Texas Instruments, a technology company with over 30 000 employees, they write a yearly corporate citizenship report [9], addressing everything from environmental sustainability to diversity and inclusion. For instance, this can be accomplished by setting concrete sustainability goals, launching on-demand courses on sexual orientation, etc. for employees, or by forming a Black Engineering Collective building leadership skills. Other companies are doing similar things as well; for instance Apple does a yearly Environmental Progress Report, and is committed to achieving carbon neutrality within 2030 [10]. Another good example is the Responsible Business Alliance (RBA), which is "the world's largest industry coalition dedicated to corporate social responsibility in global supply chains.". It includes more than 400 companies, with a combined revenue of over $7.7 trillion, directly employing more than 21.5 million people. The vision for the alliance is "A coalition of companies driving sustainable value for workers, the environment and business throughout the global supply chain." [11]. With companies focusing more on sustainability, the need for working professionals with sustainability knowledge and competency is increasing. Having this in mind, it is important for universities to integrate sustainability into the curriculum to ensure a sustainable future.

On a technological level, engineers possess a key role in creating a more sustainable world by improving and inventing new sustainable technology and solutions. An example of this is the improvement in technical performance of lithium-ion batteries and the decrease in prices of these, which is falling each year [12]. This gives, among other things, the possibility of cheaper electric vehicles with higher energy capacity, making it a more viable option. For example, in 2021, 65% of all new vehicles bought in Norway were electric [13]. Electrical vehicles can only help in reducing emissions if they are charged on renewable resources, as opposed to for instance fossil fuel. There has been enormous technological progress in solar and wind energy [14], leading the price of this type of energy to fall by 90% and 72%, respectively, since 2009 [15]. This means that in most major countries in the world, renewable energy is now cheaper than non-renewable energy, increasing the development and production of renewable energy every year.

The growing pressure from society and companies focusing more on sustainability leads to the need for professionals with sustainability competence and knowledge. This emphasizes the need for sustainable development in HEIs. However, integrating sustainability in HEIs has no clear path, and therefore it proves to be a challenging task. This challenge will be explored in Section 2.1, with Section 2.1.1 focusing on integration of sustainability in the curricula. Section 2.1.2 focuses on the important competencies and learning themes for sustainability, and Section 2.1.3 focuses on the drivers and barriers associated with integrating sustainability in the curricula. The Educators are in the center of changing curricula, and thus their perspective on sustainability is important. Section 2.2 explores this further by looking at the previous research, as well as expressing the goals of exploring the educators perspective. The end of the Section 2.2.1 gives background on the need for having a toolkit supporting educators in integrating sustainability, as well as presenting a toolkit that does this. In Section 2.3 the study programme, as well as the toolkit applied to map and integrate sustainability on the study programme is presented.

This thesis explores the research question "What is the educators' perspective on sustainability in higher electronic engineering education?". However, as this is a difficult question to thoroughly answer on its own, the thesis attempts to answer three more specific research sub-questions related to individual study programmes, with the goal of contributing to the more general question. The three sub-questions follow:

1. How do educators perceive sustainability on Electronic Systems Design and Innovation?
2. Which competencies and learning themes do educators see as the most important for the study programme, and how does the study programme perform on these today?
3. What are the barriers for integrating sustainability into the specific courses today?

The methods applied for answering these research questions are primarily semi-structured interviews of the educators, with thematic analysis applied to the transcriptions of the interviews, and secondarily are the results from the mapping of the study programme. All the methods are presented in Section 3. The results are in Section 4, which presents the results of the thematic analysis, as well as the results of mapping sustainability in the study programme. The results are then discussed and seen in context with the background, as well as the more general research question in Section 5. Lastly is the conclusion of the thesis in Section 6.

2 Background

2.1 Sustainability in Higher Education

HEIs need to address Earth's future challenges, as it is the younger generation that is tomorrow's professionals and social leaders [16]. Doing so is key for reaching the SDGs and transitioning to a sustainable future, because education among other things builds human capital, directly targeting SDGs 4 (Education), 5 (Equality) and 10 (Reduced Inequalities) [17].

Research on integrating sustainability in higher education has grown significantly since 2016, and integration of SDGs in universities is becoming a field of study under exploration, with expectation of an increase in intellectual production in the coming years [18]. Universities have at the same time become widely perceived "... as important agents in advancing more sustainable practices in different cultures and context" (P. 298, Riccaboni & Trovarelli, 2015 [19]), and are now making more systematic changes towards sustainability, like re-orienting their education [20]. Efforts on integrating sustainability by HEIs can come from various sources, i.e. curricula, research, outreach and campus operations [21][22], and to achieve significant change, hard work, strategic planning and patience is required [23]. There is no common path for integrating sustainability in HEIs, but there are some common characteristics, like establishing a network of expertise within the HEIs [24]. One of the most pressing challenges for institutionalisation of sustainability in HEIs is the human factor [25], as well as the role of the stakeholders. This indicates the need to keep making the community more involved and aware of the changing process to achieve institutionalisation [26].

2.1.1 Sustainability in Curricula

Integrating sustainability into the curricula creates sustainable literate graduates that help transitioning society to a sustainable future. Not only can they use their knowledge and competency to innovate new sustainable solutions, they can also use it to teach current professionals about sustainability. A recent book by Lozano et al. (2021) gives great insight into how sustainability is incorporated in curricula, and the competencies being developed by looking at case studies from 15 HEIs [27].

Sustainability can be integrated in the curricula with a horizontal or vertical approach [28][29]. The vertical approach adds one or more sustainability focused courses to the curricula, while the horizontal approach can be achieved in three different ways. The first one being adding sustainability as a specialization profile or major, the second one being intertwining sustainability as a concept in pre-existing disciplinary-courses and the third one being covering some sustainability in already existing courses. In engineering programmes, the vertical approach may be insufficient to integrate by itself. This is because sustainability would then be taught in isolation from the other courses, which would lead to the engineers having trouble integrating the sustainability knowledge into their designs and solutions [30]. Researchers often prefer the horizontal or a combined approach for integration, because it better supports a holistic, systematic and interdisciplinary approach [30][31]. However, others state that neither of the approaches are preferred, as there are strengths and weaknesses in both [32].

Name	Level	Description
Denial	None	No sustainability education
Bolt-on	Low	Education about sustainability
Build-in	Medium	Education for sustainability
Redesign	High	Education as sustainability

Table 1: Concept for defining the level of implementation of sustainability in the curricula, by Sterling and Thomas [33].

An established concept for defining four levels of sustainability in the curricula is shown in Table 1, ranging from denial (none) to redesign (high), with redesign permeating into the whole institution beyond education, affecting everything up to university leadership. A cluster analysis of 131 case studies identified six clusters for curriculum implementation that can be linked up to the four levels [34]. These six clusters, as well as the four levels work to develop an understanding of how sustainability is integrated on different HEIs and smaller departments or study programmes.

1. Cluster one is named "collaborative paradigm change" (redesign), and has strong support from all internal and external stakeholders, has a clear vision for sustainability, implements sustainability in not only the curriculum, but also in research, outreach and campus operations, as well as excellent collaboration, leading to paradigm change.
2. Cluster two is named "bottom-up, evolving institutional change" (redesign/build-in), and starts with value driven bottom-up initiations, with leadership support coming at the later stages of implementation. Collaboration and knowledge exchange through communication are key for being able to achieve this level of integration.
3. Cluster three is named "top-down, mandated institutional change" (build-in/redesign), and is initiated and executed by presidential leadership, which develops a strategic plan, but lacks motivation from the bottom leading to mostly build-in levels of implementation.
4. Cluster four is named "externally driven initiatives" (build-in and bolt-on), which is characterized by strong external support and weak internal support and planning.
5. Cluster five is named "limited initiatives" (build-in and bolt-on), and suffers from lack of collaboration and weak coordination across faculties leading to isolated initiatives.
6. Cluster six is named "limited institutional change" (bolt-on), and consists of bottom-up activities by a few sustainability champions that struggle to achieve significant change due to lack of support.

Box 1: The six clusters identified by Weiss, Barth & Wehrden in 2021 when analyzing 131 international case studies [35]

2.1.2 Competencies and Learning Themes

Competencies are something that cannot be taught directly by a teacher, but has to be developed by the learner, as the quote from United Nations Educational, Scientific and Cultural Organization (UNESCO) in Box 2 describes.

> "Competencies describe the specific attributes individuals need for action and self-organization in various complex contexts and situations. They include cognitive, affective, volitional and motivational elements; hence they are an interplay of knowledge, capacities and skills, motives and affective dispositions. Competencies cannot be taught, but have to be developed by the learners themselves. They are acquired during action, on the basis of experience and reflection."

Box 2: Description of competencies by UNESCO on page 10 from the book "Education for sustainable development goals: learning objectives" [36].

Integrating competencies in higher educational programmes is seen as key to achieve sustainability for HEIs [37], and there are considerable efforts made for defining competencies needed for sustainability [38][39]. There is also research on creating agreed upon reference frameworks for key competencies, including learning objectives for the competencies [40][41].

UNESCO presented eight key competencies based on the work from the leading researchers in 2017. The competencies are "system thinking", "anticipatory", "normative", "strategic", "collaboration", "critical thinking", "self-awareness" and "integrated problem-solving" [36]. The key competencies form a basis, and are seen as crucial for sustainability. They are multi-functional and can be applied to multiple scenarios. For example with "normative" competency when building wind turbine parks, the local community and wildlife are affected. Though on the other hand, an increase in renewable energy production is good for sustainability. When doing these assessments "normative" competency is important in order to make good choices, but the competency is also important in other scenarios. For example when ordering electrical products from the other side of the world, it is important to reflect on the working conditions of the people producing these products, and what materials these products use.

Fields of action are essential for facilitating sustainable development, and the 17 SDGs, which are accepted by all countries in the UN, are great examples of such fields. In 2005, a list of 19 key themes for sustainability were presented by The United Nations Economic Commission for Europe (UNECE). The list implies that with such diverse themes, a holistic approach is required to address them. The themes include among other things "human rights", "cultural diversity", "economy", "production and consumption patterns" and "biological and landscape diversity" [42]. More recently, in 2018, Rieckmann proposed selected key themes for education for sustainable development, "climate change", "biodiversity", "sustainable production and consumption", "global justice", "disaster risk reduction" and "poverty reduction". Rieckmann then presented learning objectives and the relevance to sustainable development for the theme, before connecting them to the 17 SDGs [43]. Utilizing these learning themes is a good start, but ultimately they should be adapted to the context in which they are needed. Trying to include all the SDGs when adapting learning themes can be considered important, as the SDGs are accepted as necessary by the majority of the world, in order to achieve a sustainable future.

2.1.3 Barriers and Drivers

Creating sustainable literate graduates and integrating sustainability into the curricula are challenging processes, with a number of drivers and barriers having been identified when doing so. A frequency analysis from Weiss et al. (2021) in Table 2 shows the top 10 drivers and barriers they identified after analyzing 133 studies. Note here that "vision", "interdisciplinary competence", "internal priority setting" and "interdisciplinary space" are represented both in barriers and drivers, which makes them more significant than the others. Another thing to notice is that many of these barriers and drivers build on each other. For example "vision", "strategic plan" and "leadership", as it is often "leadership" that creates "vision" and a "strategic plan", or "communication" and "coordination", as the former is most likely needed to succeed in the latter.

Key barriers	%	**Key drivers**	%
Interdisciplinary competence	29	Coordination	47
Vision	29	Internal priority setting	46
Resources	29	Window of opportunity	45
Organizational structure	22	Strategic plan	41
Incentives	14	Interdisciplinary space	41
Crowded curriculum	14	Government	40
Internal priority setting	13	Sustainability champions	38
Leadership	10	Communication	38
Interdisciplinary space	9	Leadership	34
Collaboration	9	Vision	33

Table 2: Most common barriers and drivers, identified by Weiss, Barth, Wiek and Wehrden in 2021 by a frequency-analysis of 133 studies [44].

There are several ways to increase the likelihood of more comprehensive integration of sustainability in the curricula [44]. The changes in the curricula are influenced by the overall strategies in the HEIs [45], and better integrating sustainability in the other sources, i.e. research, outreach and campus operations of the HEIs can increase this likelihood [46]. More leadership support increases the chances of integration, as processes of integrating sustainability often find their limits through lack of leadership support [47]. This is also reflected by the drivers and barriers presented in Table 2, with leadership being mentioned as both. Early adopters are important for organizational change [48], and sustainability champions within HEIs can work as important enablers [49], as well as play a vital role in integrating sustainability [50]. Incentives to integrate sustainability, as well as development programs or development opportunities for the educators, also increase the chances of more comprehensive integration in the curricula [21][51]. More active involvement from internal and external stakeholders also increases the likelihood of integration of sustainability in the curricula [24] [52]. Taking all this into consideration, it is apparent that achieving comprehensive integration of sustainability in the curricula most likely requires sustainability to be integrated within the whole organization.

2.2 Educators' Perspective on Sustainability

The Educators are in the center of changing the curricula, and HEIs are being considered major drivers for sustainability. The importance of incorporating sustainability in the curricula is evident, and the need to assess in what way the curricula addressees sustainable development is growing. Assessing the curricula can be helpful for giving the HEIs a starting point in developing strategic and holistic plans in the future, as they will get a better understanding of how, where and if the institute is tackling sustainability issues [53]. Internal and external stakeholders in HEIs agree that teaching sustainability is a necessity, but have different visions as to what the optimal way to achieve integration is [54]. The educators play an important role in promoting and integrating sustainability in HEIs, and understanding the educators' perspectives and challenges within the specific context and institutions is essential in order to ensure progress [55][56].

The educators in four Swedish engineering programmes struggled with the concept of social sustainability, proclaiming the need for offering professional development opportunities to the educators [57]. By exploring the educators' perspective on Electronic Systems Design and Innovation (ELSYS), similar challenges can be identified for the study programme. There seems to be a limited amount of research on the in-depth perspective of educators on sustainability in HEIs today. However, one example comes from a university in Spain, which analyzed the level of integration of sustainability by doing three semi-structured interviews [58]. The study found among other things that the educators find critical, creative and reflection thinking, as well as incorporating sustainability in curricula to be important aspects for integration of sustainability. Another example is from Qatar, which pointed out the lack of professional development opportunities, and that few educators were aware of the SDGs and their connection to education [59]. This study was aimed at preparatory level of education (age 13-15), but it highlights similar problems to other studies.

There are four goals that this thesis aims to explore when looking at the educators' perspective on sustainability:

- Find out if the educators think integrating sustainability in the study programme is important, and if it is something that should be prioritized. If the educators don't think it is, understand why, so it will be possible to better motivate and inspire them.
- Understand the barriers for integrating sustainability in their courses, so that the educators can receive the support needed to achieve more comprehensive integration.
- The educators' perspective can work as a starting point when developing a common goal and strategic plan for the study programme. For example by understanding what competencies the educators perceive as the most important for the study programme in regards to sustainability.
- The process of interviewing the educators raises awareness around sustainability, and informs the educators about existing competencies and learning themes that can be integrated for sustainable development. It may also motivate and inspire the educators to make changes to their courses in the near future, and start discussions with other educators in the department.

2.2.1 Toolkit to Support Educators in Integrating Sustainability

Integrating sustainability in the curricula is a complex issue, with a number of drivers and barriers to overcome, and a great amount of competencies and learning themes to include. To develop these competencies and learning themes, a combination of pedagogical approaches is needed [60], in such a way that the students can take advantage of different learning processes [61]. There are existing frameworks to support educators developing their courses to provide more complete, holistic and systematic sustainability education [62][63], and tools for assessing sustainability in curricula [27][29][64]. UNESCO also provides a roadmap for education for sustainable development [65]. To help motivate and inspire educators to integrate sustainability in the curricula, a hands-on toolkit can be applied. Ceulemans & De Prins provides a teacher's manual and method to support educators in integrating sustainability [28]. However, the hands-on toolkit "Ecodesign in Higher Education" is preferred as a starting point for ELSYS, because the author of this toolkit is involved in integrating sustainability in the study programme, providing knowledge, insight and experience. The toolkit will now be presented.

Toolkit: Ecodesign in Higher Education
The EHE-kit has an available website that provides concrete guidance for educators free for anyone to use [66]. The concept and materialisation of the EHE-kit is briefly explained based on the scientific article written about the toolkit [67], to give some context to the adapted toolkit applied to ELSYS that is presented later.

From the article: "The goal of the EHE-kit is to offer a hands-on toolkit to teaching staff in engineering education that supports the integration of ecodesign in the curriculum of the educational programme." The toolkit aims to do this by informing, motivating and inspiring the educators, which also raises awareness and connects individuals that have an interest for ecodesign and sustainability. In addition, it focuses on activating teaching methods, supporting social learning and developing competence for the educators. The kit supports both the horizontal and the vertical approach, and a combined bottom-up/top-down approach.

The materialisation of the kit consists of three parts:

1. The guide mentioned earlier, including background information and process guidelines. Link to the English version: https://ecodesign.vlaanderen-circulair.be/en/tools/ehe-kit
2. Cards on three different subjects containing concise information to support ease of use. The cards are linked together when they are relevant to each other, making it possible to use the EHE-kit in multiple ways. The three subjects are:
    - Learning content cards describing relevant themes within ecodesign.
    - Teaching method cards with the aim of offering different methods to teach certain competencies.
    - Examples from practice cards that give practical examples from educators of how to integrate ecodesign into engineering education.
3. Worksheets that are templates for work sessions. The EHE-kit includes a matrix-worksheet and an example-card template.

2.3 Integration of Sustainability in Electronic Systems Design and Innovation

2.3.1 Programme: Electronic Systems Design and Innovation

Electronic Systems Design and Innovation is the study programme that is being analyzed in this thesis. The study programme is under the Department of Electronic Systems (DES) in Norwegian University for Science and Technology (NTNU), and is a five year master's degree within technology. Additionally, a two year international master aimed at bachelor students exists, which is very closely related to the five year master. This study focuses on the five year master, and this thesis is written with that in mind.

Pilot Project
In 2021, the study programme started a pilot project under "Fremtidens Teknologistudier (FTS)" or in English "The Future's Technology Studies". FTS developed recommendations for technology studies in NTNU for 2025 and forwards. The FTS project has ended, but the pilot project in the study programme is continuing, and is called "Verktøykasse for integrasjon av bærekraft i siv.ing.-studiene" or in English "Toolkit for sustainability integration in civil engineering degrees". The goal of the pilot project is to map and integrate sustainability in the study programme, by applying an adapted version of the EHE-kit. If the project is considered a success, the adapted toolkit will be made available for other study programmes to use. This thesis is a part of this pilot project, and aims to continue mapping the study programme, while exploring the educators' perspective in order to gain better insight in to how to integrate sustainability further in the study programme.

Structure of Programme
Students in NTNU need 30 points each semester, with most ELSYS courses giving 7.5 points, meaning that each student normally takes four courses each semester. In the first three years of the programme, all students take the same courses with one exception in the third year. After three years, the students can choose between six different specialization profiles; "Acoustics", "Analog Circuit Design and Radio Systems", "Design of Digital Circuits", "Embedded Systems", "Nano Electronics and Photonics" and "Signal Processing and Communications". The profiles have some obligatory courses, but give students the flexibility to choose between several elective courses from the department. Common for all students is "Experts in Teamwork (EiT) in the spring semester in the fourth year, which puts together students from different study programmes that work together on the same project. Additionally, on the autumn semester in the fifth year, all students take a specialization project, normally with two specialization courses worth 3.75 points on the side, before finishing their degree after a master's thesis worth 30 points. All obligatory or choose between courses for the study programme are shown in Appendix A. Elective courses for each profile are not shown, but all elective courses for the study programme are included, with the last table including the four courses that are never obligatory or choose between.

2.3.2 Toolkit for Integrating Sustainability in Civil Engineering Studies

The toolkit in the pilot project is based on the EHE-kit presented in section 2.2.1, and is adapted to the current time and the NTNU context by a project team consisting of two educators and three students; Associate Professors Elli Verhulst and Torstein Bolstad, and students Julie Romslo, Selma Tofte Thiis and Solveig Reppen. The main differences from the original EHE-kit are the competencies, which are a completely new addition, as well as the worksheets that are adapted in such a way that the courses can be mapped for each competency and learning theme. The learning themes are based on the EHE-kit, but also adapted for the context of ELSYS. The procedure of filling out the worksheets is explained below, before the background for these competencies and learning themes are chosen is explained.

More information about the toolkit can be found here (in Norwegian):
https://www.ntnu.no/fremtidensteknologistudier/piloter/baerekraft-i-siv.ing.-studiene

Worksheets
To map sustainability, a competency worksheet and a learning theme worksheet are used. These are filled out by an educator with good knowledge of the course being surveyed. Cards explaining the different topics on the worksheets are available to inform and assist the educators when filling out the worksheets. There are in addition keywords for the different topics on the worksheets, for example on the competency worksheet, the topic "system thinking" has the keywords "the bigger picture", "understand relationships" and "influence on the system". The educators go through the worksheets and answers whether the topic is already integrated or can be integrated by setting a check mark in a designated place, with an additional place for notes to shortly explain the reasoning behind each check mark. They are allowed to mark both "already integrated" and "can be integrated" for the same topic, and if the topic is/can be partly integrated the educators are allowed to put brackets around the check mark. If one educator has two similar courses, then both can be filled out at the same time if the educator sees it fit to do so.

Competencies
There are nine chosen key competencies included in this toolkit to map sustainability. Eight of these are from the key competencies presented earlier by UNESCO.

The eight key competencies from UNESCO were adopted and expanded by a working group initiated by the principals of five universities in Bergen during a SDG conference in 2019. The report was presented by the group at the SDG conference in 2020. In the expanded version, a "creativity" competency is added, and the "collaboration" competency is changed to "transdisciplinary collaboration" competency, with extra focus on co-creation for problem solving [68]. See Table 3 for the nine competencies, including keywords briefly explaining each competency. The competency worksheet can be found in Appendix B, with the associated competency cards in Appendix D.

Abbreviation	Competency	Keywords
SST	System Thinking	See the bigger picture Understand relationships Influence on the system
ANT	Anticipatory	Future scenarios Foresee possible problems Future effects
NRM	Normative	Norms and values Trade-offs Conflicts of interests
STR	Strategic	Long-term planning Develop goals Collective actions
TDC	Transdisciplinary Collaboration	Cooperation Respect different fields Deal with conflicts
CRT	Critical Thinking	Analyze problems Questioning Reflection on pros and cons
CRE	Creativity	Think outside the box Innovation Complex problem solving
SAN	Self-Awareness	Your impact Your Contribution Evaluate actions
IPS	Integrated Problem-Solving	Complex problems Combining competencies

Table 3: The nine key competencies.

Learning Themes

There are also nine learning themes chosen for mapping sustainability. These learning themes are adapted for the study programme by the project team mentioned earlier, and are based on the EHE-kit, SDGs and the experience within the team. Each learning theme is linked up with multiple SDGs, and together they cover all 17 SDGs. The learning theme cards also shows which SDGs the learning theme supports. The nine learning themes are presented in Table 4, with keywords briefly explaining what they are about. The learning theme worksheet can be found in Appendix C, with the associated learning theme cards in Appendix E.

Abbreviation	Learning Theme	Keywords
CCE	Circular Economy	Use of raw materials, Environmental accounting Design, production and distribution, Reuse, recycling and waste, Consumption
SUE	Sustainable Use of Energy Sources	Renewable energy Energy efficiency in production Energy saving innovation
RUM	Reasonable Use of Materials and Resources	Dangerous and rare materials Using less materials Conflict-creating use of resources
LHE	Limitations of Harmful Emissions	In the air, on land and in the ocean During production During consumption
GWC	Good Working Conditions	The technologist's responsibility for reflection Fair wages, End poverty Focus on the worker's health
CBW	Consequences for Biodiversity and Wildlife	Animals on land and in the ocean Habitat disturbance Loss of nature
CHU	Consequences for Humanity	Local and global societies, Health impact Individual impact, Consumption patterns Society and communication
EUD	Equality and Universal Design	Anti-racist technology Gender neutral technology, Inclusive innovation Disability adaption
IMI	Impact on Infrastructure	Organizational, physical and digital infrastructure Aids in health and education, Digital interaction Innovative cities and industries

Table 4: The nine learning themes.

3 Methodology

In this section, the methodology for this thesis is presented. The general research question "What is the educators' perspective on sustainability in higher electronic engineering education?" worked as a baseline for choosing the research methods. To understand the perspective of the educators, a qualitative approach is required, because it is necessary to understand how the educators think about and perceive sustainability in the study programme [69][70]. The qualitative approach does not limit the data in the same way as a quantitative approach would, and it allows the data to be more detailed. One-on-one in-depth semi-structured interviews are conducted with the educators as participants (Section 3.1.1). The advantage of this is the open-ended nature allowing opportunities for new ideas to emerge, and for the educators to give meaningful insight when answering the questions. In addition, it gives the opportunity for the interviewer to observe the educators and ask follow-up questions. The interviews are transcribed (Section 3.1.3) and later analyzed using a thematic analysis approach (Section 3.1.4) to identify and interpret patterns and themes. From the findings of the thematic analysis, the research sub-questions were developed and adapted using an inductive-deductive approach. This is because the expectations to the findings were uncertain, and the flexibility of this approach allows the most important data to be included in the result.

A combination of qualitative and quantitative research is utilized for the mapping of sustainability in the study programme (Section 3.2), and for understanding the most important competencies and learning themes. However, the primary focus is on the qualitative methods. The quantitative research approach gives the opportunity to present numerical or binary data using tables and graphs. This gives the possibility to visualize the data in a manner that is easy for the reader to understand, and gives the qualitative data a starting point that can be further explored. The qualitative data supports the quantitative data in order to better understand the result.

Figure 3 visualizes how the mentioned research methods contribute to the research sub-questions, with those questions being repeated below. In the following sections, the research methods will be explained in more detail, including choice of method, data gathering and data analysis.

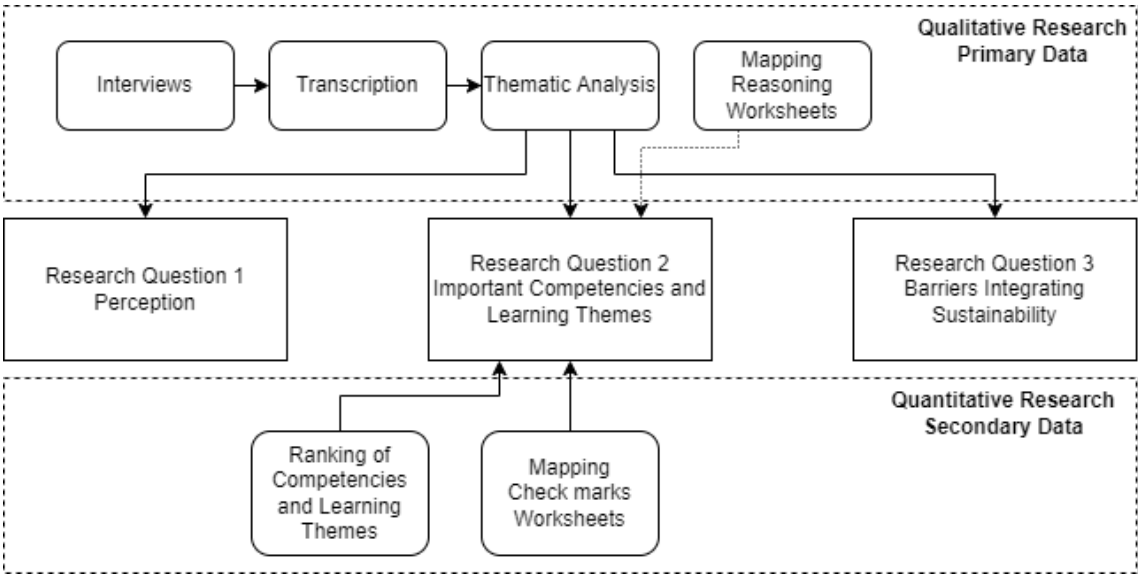


Figure 3: Overview of research methods, and how they contribute to the research questions.

Research Sub-Questions:

1. How do educators perceive sustainability on Electronic Systems Design and Innovation?
2. Which competencies and learning themes do educators see as the most important for the study programme, and how does the study programme perform on these today?
3. What are the barriers for integrating sustainability into the specific courses today?

3.1 Interviews with Educators

3.1.1 Structure of Interview

The interview is divided into two parts as shown in Figure 4. The interview can be carried out in Norwegian or English. Part one is, as the figure shows, about filling out the worksheets for the educators' individual courses. The reason this takes about 30 minutes is that the goal is to have the educator explain their thought processes behind their choices when filling out the worksheets. This gives insight into how the educators understand the competencies and learning themes, and what their criteria is for counting a competency or learning theme as integrated. Part two of the interview, as the figure shows, focuses on questions to the educators in order to understand their

perspective and perception on sustainability in the study programme today. The questions and the process of creating them are presented in Section 3.1.2. This part also takes up towards 30 minutes, with five minutes estimated for each main question, with the exception of the two last questions. The participants will have the opportunity to only participate in part one of the interview. The reason for this is to lower the threshold to partake, and that it is expected that fewer participants are required for part two.

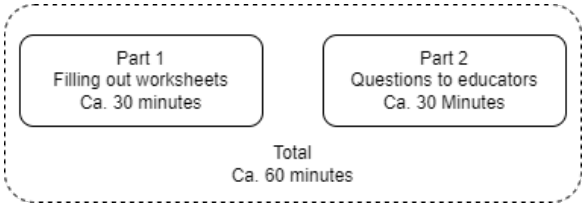


Figure 4: Structure of the interview.

The interview is recorded with permission from the participant, but this is completely voluntarily. To ensure that the participant knows this, it is emphasized in the invitation sent to the participant in advance of the interview. An approved application to the Norwegian Centre for Research Data (NSD) is necessary to be allowed to record interviews. This was obtained before starting the interview process, and the participants receive a consent form before the beginning of the interview, in order to make sure that their privacy and rights are secured.

The interview style is semi-structured, making it possible to ask follow-up or additional questions, or skip questions that may already have been discussed previously in the interview [71]. A semi-structured style encourages the educators to answer the questions in-depth and with meaningful insight, and promotes the possibility for discussions around interesting topics. Even though the interviews are semi-structured, they still follow the interview guide in chronological order, with the exception being that the first and second question may be switched around, see Box 3 for reference. Following the order makes it easier to categorize and analyze the transcription afterwards, and it helps the author carry out the interviews in an organized way. The educators may struggle to get started at the beginning of the interview, and this is the reason for exchanging the order of competencies and learning themes between interviews. By doing this and observing the educators, it may be possible to find out if the educators find answering one of them harder compared to the other.

3.1.2 Interview Questions

The interview questions are developed based on the general research question "What is the educators' perspective on sustainability in higher electronic engineering education?". Figure 5 shows the questions distributed into three categories.

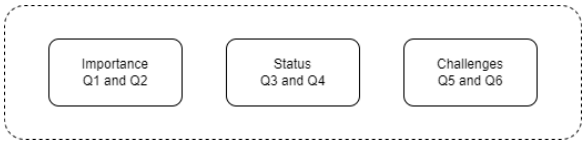


Figure 5: Questions distributed in categories. Qx meaning the number questions in Box 3.

The first category "Importance" focuses on what the educators perceive as the most and least important competencies and learning themes for the study programme, as well as which competencies and learning themes are already well integrated today, or should be better integrated. It is important to understand what the most important competencies and learning themes are for the study programme. This is because it might not be feasible to develop all competencies and learning themes equally, and the educators in the study programme can give great insight into this.

The second category "Status" focuses on how well the educators think sustainability is integrated in the study programme today, as well as what they think is the best way to further integrate sustainability into the study programme. Again, as with the previous category, the educators can give great insight here. The educators have knowledge about the study programme, and their perception can help understand how well sustainability is integrated today. The educators also are in the center when changing the curricula, and they can give important perspectives on how to best integrate sustainability further into the study programme.

The third category "Challenges" focuses on the challenges of integrating sustainability into the educators' specific courses, as well as what they know is being done towards sustainability in their respective fields. Understanding the drivers and barriers that the educators experience when integrating sustainability into their courses is important in order to help motivate and aid them into further integrating it more comprehensively. The question asking if the educators know what is being done in their respective fields is added to understand if they follow the development on sustainability, and if sustainability is something that engages them.

The interview guide can be found in Box 3. However, it should be specified that the educators are told that the questions are about the study programme, and not their specific course(s), with the exception of question six, which is course specific.

Part 1 ca. 30 minutes
Filling out worksheets

Part 2 ca. 30 minutes
Questions - semi-structured

1. Place the three most important competency cards foremost. Then place the three least important competency cards last.
   (a) Which competencies do you have the impression are already well integrated today?
   (b) Which competencies do you think should be better integrated?
2. Place the three most important learning theme cards foremost. Then place the three least important learning theme cards last.
   (a) Which learning themes do you have the impression are already well integrated today?
   (b) Which learning themes do you think should be better integrated?
3. Do you have an opinion on how well sustainability is integrated in the study programme today?
4. How important do you think it is to teach students about sustainability in the study programme?
   (a) What do you think is the best way to integrate sustainability in the study programme?
      i. Why?
   (b) How important do you think cooperation between courses and educators is?
5. Do you know what is being done in terms of sustainability within the field of your course?
   (a) What are today's sustainability challenges?
      i. Which barriers must be broken?
      ii. Long term challenges
6. What are the biggest challenges with integrating sustainability into your course?
   (a) Do you feel that you have sufficient knowledge about sustainability in order to integrate it?
      i. Is it difficult to know how to integrate sustainability?
   (b) Is it difficult to find space for sustainability in your course?
      i. Does sustainability fit badly into the course?
7. Can I contact you again if I have additional questions to you at a later point in time?
8. Do you want to add anything before we wrap this up?

Box 3: Interview guide. Norwegian version in Appendix F.

3.1.3 Transcription Style

All recorded interviews are transcribed and anonymized, making it possible to conduct detailed analysis of the interviews. Transcriptions are written in either English (US) or Norwegian (Bokmål) depending on what language the interview is held in. The transcription style is intelligent verbatim, with the goal being to provide an easy to read transcript that captures the participant's voice and intended meaning [72]. Filler words, non-standard words, repeating words or sentences or general noise are removed, unless they appear relevant. However, pauses, long run-on sentences and irrelevant or off-topic sentences are included, as judging this is subjective. This helps ensure that no information is lost in the transcription process.

Additionally, bold text with title and time stamp is added whenever the transcription moves to a new topic. Topics can be the different competencies and learning themes from the worksheets, or the different questions from Box 3. If for example it's desired to know what multiple educators say about the learning theme "consequences for humanity", it will be easy to find the bold title in the transcription, read what the educator says about the topic and then, if necessary, check the recording using the time stamp. This organizes the transcriptions in such a way that they are easy to navigate, and analyzing them will be more effective than otherwise, as the example conveys.

The transcription style presented above fits this thesis well, because it stays true to the intended meaning of the educator, but also produces transcriptions that are easy to analyze.

3.1.4 Thematic Analysis

Thematic analysis is the chosen method for analyzing the transcriptions. This is a good approach when attempting to understand the perspective and perception of the educators, and to identify and interpret patterns and themes. When attempting to understand the data, a latent approach is used, because the assumptions and subtext underlying the data is important in order to better understand the educators in the context of this thesis [73].

The approach for thematic analysis in this thesis is based on the step-by-step guide from Braun & Clarke [74][75]. The adapted step-by-step guide applied is presented in Box 4, including a short description for each step. However, it should be specified that this is a recursive and not a linear process. After the first draft of the results is written, an iterative process (step six to eight) of going through the transcriptions, themes, codes and results is executed in order to make sure that the understanding of the educators is as thorough as possible.

1. Familiarization - Transcribing the data, reading and rereading the transcription and taking notes of central ideas and important observations. An example of an early observation is that "system thinking" is essential for most courses, according to the educators.

2. Initial Naming of Codes - Inductive approach. Picking out all relevant quotes and color-coding them with a very low threshold for making new codes. Everything is organized into one single, large document, with the possibility for one quote to have multiple codes. Relevant quotes that are hard to put a code on are placed at the bottom of the document.

3. Develop Research Questions - Develop the research sub-questions according to the initial findings in the previous step.

4. Generating Themes - Combination of deductive and inductive approach. Grouping the codes that fit together into themes, and discarding codes that rarely appear or don't fit in at all. Each theme gets its own document with an initial naming. A single quote can be included into multiple themes.

5. Reviewing Research Questions - Reviewing the research questions with the initial themes formed.

6. Reviewing Themes - Deductive approach. Splitting up and/or combining codes and themes. Reviewing the relevancy of quotes in context with the transcription. Removing and/or adding quotes when going through the transcriptions again. An example of reducing codes were for the theme "Integration of Sustainability in Specific Courses" when combining two codes concerning barriers into one code about barriers.

7. Defining and Naming Themes - Refining the themes and codes, and better understand the meaning of each theme. Redefining the names to be more descriptive of the theme and code. For example, the name of one code was changed from "Attitude" to "Attitude towards sustainability".

8. Writing Results - Presenting the findings of the thematic analysis. Express the meaning of each theme and put it into context.

Box 4: Step by step process of the thematic analysis.

3.2 Mapping of Sustainability in the Study Programme

Sustainability is a large term that can be hard to define, and it needs a wide variety of knowledge and competencies. A simple and effective method for mapping the competencies and knowledge integrated in the courses is important in order to motivate the educators to voluntarily participate. This, combined with the need for a tool supporting educators in integrating sustainability in their courses, makes the adapted toolkit presented in Section 2.3.2 a good fit for this study programme.

The toolkit limits the number of competencies and learning themes to a manageable amount, and utilizes easy-to-use worksheets for the educators to fill out. Combining this with keywords on the worksheet, as well as supporting cards, contributes to lowering the threshold for participation in the mapping of the study programme. The supporting cards help the educators to quickly relate to and understand each competency and learning theme in the worksheet, in such a way that they can fill out the worksheets effectively and accurately.

This was mentioned in Section 2.3.2, but is repeated again here. The competency worksheet can be found in Appendix B, with the associated competency cards in Appendix D. And the learning theme worksheet can be found in Appendix C, with the associated learning theme cards in Appendix E.

3.2.1 Selection of Courses and Data Gathering

The goal is to offer all courses belonging to the DES in Appendix A the possibility to fill out the worksheets. Educators responsible for the courses are sent an e-mail with information about the project, including an invitation to participate. If there is no reply within a few days, a follow-up e-mail or an office visit is attempted in order to reach the educator.

The educators can participate and fill out the worksheets in three different ways: Over an interview being recorded, and later transcribed; over an interview that is *not* being recorded, but with notes taken during the interview; by self-reporting and filling out the worksheets in their own time, and then delivering it via e-mail. However, the invitation encourages an interview if possible for the educator, and reasons that this is to get a better understanding of their thoughts and reasoning behind each check mark on the worksheet, as this can significantly differ from person to person. Additionally, when interviewing, the reasoning for why they are not checking something as "already integrated" or "can be integrated" is explored. The possibility of having a dialogue, including follow-up questions, is also possible when filling out the worksheets over an interview. The educators are encouraged to ask for more information about the project, or clarification about the worksheets over e-mail. A positive side-effect of doing interviews is that it contributes more to creating awareness around sustainability, compared to the case where the educators fill out the worksheets themselves. The reason being that they get to talk through the process during an interview, and thus reflect more around each topic, which also helps them remember the whole process better.

3.2.2 Data Analysis of Worksheets

The check marks from the worksheets are manually counted and written into a table including all competencies, learning themes and mapped courses. The table is then split in two, with one half for the competencies and one for the learning themes. These two halves are presented in Section 4.3. In addition are two bar charts, the first one representing the competencies, and the second one representing the learning theme. These two charts are made in MATLAB, presenting the total percentage of "already integrated" and "can be integrated" for each competency and learning theme. The brackets around the check marks are not taken into consideration in the bar charts, and are counted as standard check marks.

3.3 Ranking System of Competencies and Learning Themes

A ranking system for Question 1 and Question 2 from Box 3 is created in order to be able to give an indicator of the most and least important competencies and learning themes. Points are given to each competency and learning theme from the ranking that the educators gives in the interview. However, this method does not paint a full picture of the most and least important competencies, as the reasoning from the educators is not included. Nevertheless, the reasoning from the transcriptions will be analyzed and presented together with the ranking in Section 4.2.2. The goal of the ranking system st to give a quick overview of what the educators picked out as the most and least important competencies and learning themes, while the reasoning gives additional meaning to the rankings. Table 5 shows the way points are given in the ranking system.

Importance	**Points**
Most important	3
Second most important	2
Third most important	1
Third least important	-1
Second least important	-2
Least important	-3

Table 5: Ranking system with points scored according to the importance given by the educators of the competencies or learning themes. If two or more of these are given equal importance, the mean value of these is calculated.

4 Results

In this section, the results of this thesis are presented. Section 4.1 shows how many educators participated in the interviews, as well as how many of the educators received an invite. Section 4.2 presents the four themes from the thematic analysis, using the approach presented in Section 3.1.4. The second theme (Important Competencies and Learning Themes for the Study Programme, Section 4.2.2) includes the ranking of the most and least important competencies and learning themes. The ranking in this section applies the method presented in Section 3.3. Section 4.3 presents the mapping of sustainability on the study programme, and applies the method in Section 3.2.1.

4.1 Participation

There were in total six completed interviews, two of which were held during the specialization project written prior to this thesis. In total three educators answered part two of the interview, containing the questions presented in Box 3. Table 6 shows an overview of all interviews completed. Two of the educators answered for two courses simultaneously, as indicated in the table. Three additional interviews were planned, but were never carried out. This was due to a combination of sickness and busy schedules for the teaching staff in the scheduled interview period.

In total 19 educators were contacted via e-mail, with follow-up e-mails if there were no answers within a couple of days. Office visits were also attempted, but with limited luck, as some educators still worked from home due to the covid situation, and others being generally busy and hard to catch at the right time. Educators for all courses have either been contacted at least once, or have filled out at least one of the worksheets previously, with the exception of the specialization courses in the fifth year. However, most of these are covered when contacting educators about other courses, because educators responsible for the specialization courses are normally responsible for other courses in the study programme as well.

Educator	Course(s)	Worksheets	Questions	Recorded	Transcribed
1	2	X		X	X
2	1	X		X	X
3	1	X	X	X	X
4	2	X	X	X	X
5	1	X	X	X	X
6	1	X			

Table 6: Overview of educator interviews. The first two interviews were carried out during the previous project, and the last four interviews during this thesis.

4.2 Thematic Analysis of Interviews

Four themes emerged when doing thematic analysis of the five transcribed interviews, consisting of just over 29 000 words. Most of the data comes from Educator 3, Educator 4 and Educator 5, as these are the ones that answered the questions in part two of the interview. Each theme has a number of different codes, ranging from two to four, as shown in the overview of the themes in Figure 6. The figure also links the themes to the research question they primarily answer to, with the exception of the fourth theme named "Vision on Sustainability". This theme is not directly related to the three research sub-questions, but has been considered important to include, because it assist in answering the more general research question "What is the educators' perspective on sustainability in higher electronic engineering education?".

The first theme, "Perception on Sustainability Today", looks at the educators' perspective on sustainability in the study programme today. This is achieved by attempting to understand how well they think sustainability is integrated today, how important they think it is to teach sustainability to their students, and by looking at the strengths and weaknesses of the study programme related to sustainability. The second theme, "Important Competencies and Learning Themes", explores which competencies and learning themes the educators think are the most important for the study programme. This is achieved by looking at their rankings of the competencies and learning themes, and by looking at their justifications for each ranking. The third theme, "Integrating Sustainability in Specific Courses", explores the educators' opinions on the most optimal ways of integrating sustainability into their individual courses, and the accompanying challenges of doing this. The last theme, "Vision on Sustainability", attempts to understand the optimal ways of integrating sustainability into the study programme (not specific courses). It also explores the educators' vision for the future regarding sustainability in the study programme.

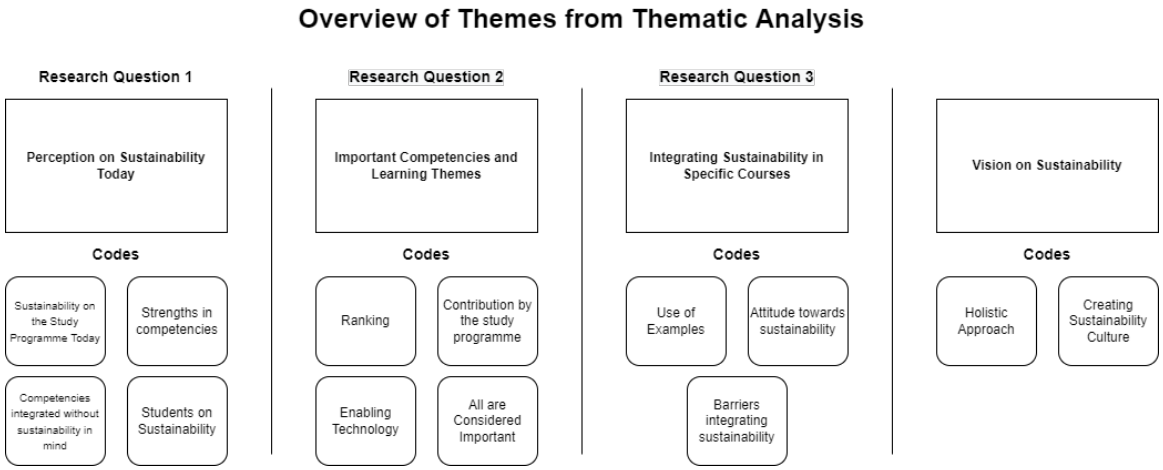


Figure 6: Overview of the themes found by the thematic analysis, with the belonging codes to each theme, and which research questions they try to answer.

4.2.1 Perception on Sustainability Today

This theme primarily attempts to answer the research question "How do educators perceive sustainability on Electronic Systems Design and Innovation?", and attempts to understand the educators' perspective based on the four codes; "Sustainability in the study programme today", "Strength in competencies", "Competencies integrated without sustainability in mind" and "Students on sustainability".

The general opinion of the educators is that it is difficult to judge the level of sustainability integrated as of today. This is mainly because they lack a complete overview of the whole study programme. When Educator 3 was asked about how sustainability is integrated today, they said that the business economics side of things is probably better integrated than sustainability today, before continuing to answer according to Box 5.

> "... but remember that in universities it takes a long time to change the culture, so in my opinion we have already come far in the process, ... So we can acknowledge that there's a large potential for improvement, and also that there are forces at the department that are currently working towards this improvement."

Box 5: Educator 3 on how sustainability is integrated in the study programme today. Norwegian version in Box 35.

When talking with Educator 5 about the same question, they said that there is a focus on sustainability today, and that processes of integrating sustainability in the study programme are currently in progress. They then summarized the question according to Box 6.

> "... But it's being worked on [integrating sustainability], it is. And in my opinion, I don't think we're lagging behind. To clarify, there are probably study programmes in NTNU and elsewhere in Norway that are in front of us, but I also think that we are in front of many others, so we are relatively on track with it."

Box 6: Educator 5 on how sustainability is integrated in the study programme today. Norwegian version in Box 36.

An example from Educator 5 gives reason to believe that there are ongoing processes of integrating sustainability. The Educator mentioned a self initiated project for integrating the SDGs in one of their courses. This involves requiring the students in that specific course to relate to how their projects contribute to the SDGs.

In general it seems that the educators acknowledge that the study programme is working towards integrating sustainability, and they agreed that it is important to teach the students about sustainability. As already mentioned, the educators expressed difficulties with determining how well sustainability is currently integrated in the study programme. However, when doing the thematic analysis, it was noticed that they have some thoughts about how well some of the key competencies are integrated today.

The educators think that the study programme performs well on the four competencies "system thinking", "critical thinking", "integrated problem-solving" and "creativity". The reasoning being that they are necessary competencies for electrical engineers, and that they are in a way "typical engineering competencies". One example of this is when Educator 3 was filling out the worksheet for "system thinking" competency, and reasoned like in Box 7.

> "... So, system thinking is unavoidable in order to understand an electronic system..."

Box 7: Educator 3 reasoning when filling out worksheet for "system thinking" competency. Norwegian version in Box 37.

When Educator 5 ranked the three most important competencies, they reasoned in Box 8 as to why they think "creativity" competency is important. The educator also talked about how they aim to design projects and assignments to be open-ended and have multiple solutions. This develops a "creativity" competency, and can be argued to also develop "critical thinking".

> "And NTNU has, what is it, "Constructive, Creative, Critical and" one more thing. Yes, at least creative is one of NTNU's four words. And that is maybe a strength that Norwegian engineers have, compared to many others. That when you come out from here [graduate], you [students] have a basic attitude in which you can come up with lots of clever things. ..."

Box 8: Educator 5 reasoning when ranking three most important competencies. Norwegian version in Box 44.

Educator 1 came to the following realization when reasoning whether or not "integrated problem-solving" competency was integrated into their course, see Box 9. This competency combines all the other competencies, thus requiring prowess in the other competencies to master it. Whether the educators actually consider this or not, has not been directly answered.

> "... So what I'm thinking is that they learn how to become engineers, and engineers learn how to solve complex problems. ..."

Box 9: Educator 1 reasoning when filling out worksheet for "integrated problem-solving" competency. Norwegian version in Box 39.

The educators pointed out that the competencies are not necessarily integrated with sustainability in mind. Instead, they are integrated because they are imperative for electrical engineers to master. One example of this is when Educator 3 reasoned for how well the "system thinking", "creativity" and "integrated problem-solving" competencies are integrated in the study programme today. See Box 10.

> "... Even though we teach the students these things, we don't necessarily focus on sustainability, but more on general competency. But we can surely implement thinking about it, and apply it regarding sustainability areas."

Box 10: Educator 3 reasoning when asked about which competencies the study programme are performing well in. Norwegian version in Box 40.

It can also be noticed that when the educators read the competency cards specifically mentioning sustainability, they often specified it in the same way as Educator 5 did when filling out the worksheet for "integrated problem-solving". See Box 11.

> "Yes, in that sense, if linked to sustainability challenges like it says here, then we don't do that, but more on engineer competency. And then there is the project assignment where you get experience in it as well."

Box 11: Educator 5 reasoning when filling out the worksheet for "integrated problem-solving" competency. Norwegian version in Box 41.

This means that the four competencies in question do not directly relate to sustainability in the study programme today. However, discussion with the educators lead to the belief that it should be possible to use the competencies in a sustainability context, provided that they are already mastered. This though, also requires a sufficient knowledge of sustainability.

The educators seem to have the impression that students are familiar with the sustainability term and that generally, they are engaged in sustainability. Following is one example from Educator 5 when asked about how important they think it is to teach students about sustainability. See Box 12.

> "... well, most of our students are very good both when it comes to general knowledge and they are able to see what's important. So what we should try to do is exemplify as good as possible, to be able to concretize it in the specific course and in the study programme. That, so that one, when you get to the other end actually can take what you learned about circular economy or energy effective electronics, and apply it then, for a better world."

Box 12: Educator 5 when asked about the importance of teaching students about sustainability. Norwegian version in Box 42.

When filling out the worksheet for "reasonable use of materials and resources", Educator 4 mentioned that the students are engaged in regards to what happens to the waste products for the project in their course. The educator then answered according to Box 13 when asked about what they think is the best way to integrate sustainability in the study programme.

> "Well, I don't think it [sustainability] is a new term for today's students. Or, it won't be implemented anything that's very new, so the task will be to remind [the students] of sustainability in every course. That one has focus, what should I say, that one includes it in the mindset. So that it kind of comes in with, becomes part of the core reflex [i.e. it happens automatically] to think about such things when one later enters the working life and contributes to society. ... "

Box 13: Educator 4 when asked about the best way to integrate sustainability in the study programme. Norwegian version in Box 43.

To sum up the theme, the educators think it is hard to assess how well sustainability is integrated today in the study programme. Four different strengths in competencies were identified by doing the thematic analysis, but these four competencies are not integrated with sustainability in mind. They are integrated because they are essential competencies for electrical engineers to master. The educators also have the impression that the students are engaged in sustainability, and that this is something that should be benefited from when trying to integrate sustainability in the study programme.

4.2.2 Important Competencies and Learning Themes for the Study Programme

This theme primarily attempts to answer the research question "Which competencies and learning themes do educators see as the most important for the study programme, and how does the study programme perform on these today?". To answer this question, both results from rankings and thematic analysis is utilized. The rankings scope out the educators' view on the competencies and learning themes, which were found during part two of the interview. During analysis, the three codes found for these themes were; "Contribution by the study programme", "Enabling Technology" and "All are considered important".

The educators' rankings of the competencies and learning themes are shown in Table 7, and were found by the use of the method from Section 3.3. For the most important competencies, there is a three way tie having five points; "system thinking", "creativity" and "integrated problem-solving". All three educators listed "integrated problem-solving" as one of the most important competencies. The competency ranked as the least important is "self-awareness", with a significantly lower score (-7) compared to the second and third least important competency, "normative" (-4) and "strategic" (-3). "Self-awareness" is listed as one of the least important competencies by all educators. An interesting observation is that "transdisciplinary collaboration" was ranked as one of the most important competencies by one educator, and one of the least important by another. This also applies to "strategic", but with two of the educators ranking it as one of the least important instead of one. "Critical thinking" was never mentioned by any of the three educators as either the least or most important.

For learning themes, "sustainable use of energy sources" is ranked as number one with six points, and it is the only learning theme listed as one of the most important by all educators. The second and third most important learning themes are "impact on infrastructure" (5) and "reasonable use of materials and resources" (4), with "circular economy" (2) as the fourth. "Limitations of harmful emissions" was never mentioned as either the most or least important learning themes by any of the educators. The two least important learning themes are "good working conditions" (-7.5) and "equality and universal design" (-6). Both are ranked as one of the least important competencies by all educators. "Consequences for biodiversity and wildlife" (-2) and "consequences for humanity" (-1.5) are ranked as the third and fourth least important competency. Again, an interesting observation is that "consequences for biodiversity and wildlife" is considered one of the most important learning themes by one educator, but one of the least important learning themes by the two others.

Competency	**Points**	**Learning Theme**	**Points**
System Thinking Competency	5	Sustainable Use of Energy Sources	6
Creativity Competency	5	Impact on Infrastructure	5
Integrated Problem-Solving Competency	5	Reasonable Use of Materials and Resources	4
Transdisciplinary Collaboration Competency	0	Circular Economy	2
Critical Thinking Competency	0	Limitations of Harmful Emissions	0
Anticipatory Competency	-1	Consequences for Humanity	-1.5
Strategic Competency	-3	Consequences for Biodiversity and Wildlife	-2
Normative Competency	-4	Equality and Universal Design	-6
Self-Awareness Competency	-7	Good Working Conditions	-7.5

Table 7: Ranking of competencies and learning themes. Individual rankings in Appendix G.

Generally, the educators found it difficult to rank the competencies and learning themes, and often spent a bit of time in advance of ranking them. When the educators reasoned for their rankings, they tried to look at where it is most natural for the study programme to contribute to the industry and society. An example of this follows in Box 14, showing Educator 3 reasoning for why they chose the competencies that they did when ranking. They also used a similar line of reasoning when ranking the learning themes later.

> "... So I would say that those three [competencies] are the most important, the three areas where our study programme can have a significant contribution. ... that's not because these are not important, but I think we have a lesser potential to have an important contribution to them."

Box 14: Educator 3 reasoning when ranking competencies. Norwegian version in Box 44.

When Educator 5 was struggling to rank the learning themes, they limited themselves to only look at the courses from the department, before reasoning like the quote in Box 15 shows. They also used the same reasoning when ranking the competencies later. It is important to notice the slight difference in the meaning of Educator 5 and Educator 3 when they highlight that everything is important. Educator 3 looks at where they think the study programme can contribute the most. Thus, they think that integrating and focusing on those will be the most beneficial, and then letting other study programmes or fields focus on the other competencies or learning themes. However,

Educator 5 thinks the students should learn all the competencies and learning themes during the course of the study, but not necessarily by the courses given by the DES, but instead by courses given to the study programme from the other departments.

> "... that these [learning themes] are not what's the main priority as learning objectives in our courses. Nevertheless, it's important that our students get these [learning themes] in courses, during the study years, but not necessarily in the courses we are offering. And if we then, the other way around, say "ok, which of these [learning themes] will naturally become affected by the courses we offer"."

Box 15: Educator 5 reasoning when ranking learning themes. Norwegian version in Box 45.

An explanation justifying why the study programme can contribute the most to society can be found by looking at the enabling technology that electrical engineers help create. An example of this can be seen in Box 16. Here, Educator 5 reasoned for why "sustainable use of energy sources" is important for the study programme. The same reasoning was used when ranking "impact on infrastructure", before struggling to pick out the third learning theme.

> "... But it's also that enabling technology that we evoke, which makes many other society sectors able to ensure sustainable use of energy resources. ..."

Box 16: Educator 5 reasoning when ranking learning themes. Norwegian version in Box 46.

Educator 3 also mentioned enabling technology when asked about what is being done for sustainability in the field for their specific course. See quote in Box 17. This shows that the educators think of enabling technology as important for electrical engineers to be able to contribute with in society.

> "... there exists nearly no product today that doesn't have electronics in it, so it's a really, really important field for everything happening in society, when you put it like that. So-called enabling technology. ..."

Box 17: Educator 3 explaining what is being done for sustainability in the field of their course. Norwegian version in Box 47.

It should, yet again, be emphasized that the educators though it difficult to rank the competencies and learning themes, and that they felt like all the competencies and learning themes to be important. The educators often paused to think about how to rank these, and Educator 4 expressed that it was incredibly difficult, after thinking for about 15 seconds and asking for more information about the learning theme "consequences for humanity". Educator 5 was able to pick out "sustainable use of energy sources" and "impact on infrastructure" as two of the most important learning themes quickly, and "good working conditions" as one of the least important, but when trying to to rank the remaining ones they came to the following realization, in Box 18:

"... And the rest is kind of, it's almost so that they [learning themes] can all be there [at the top], and thus it is out of the question to put them as irrelevant. ..."

Box 18: Educator 5 when ranking learning themes. Norwegian version in Box 48.

Educator 3 summarized their reasoning for ranking the learning themes according to Box 19. One example of distribution between study programmes and fields could be that a chemical engineer should normally have a better understanding of the learning theme "limitations of harmful emissions", when compared to an electrical engineer. The summary from Educator 3 again highlights the difference in thinking processes between Educator 3 and Educator 5, mentioned earlier.

"... To be specific. They [learning themes] are all important, but there exist a fair share of other study programmes that should have this higher up on their agenda. One must have a certain division of work between different study programmes and different environments..."

Box 19: Educator 3 reasoning when ranking learning themes. Norwegian version in Box 49.

To sum up the theme, the educators found all competencies and learning themes to be important, and when ranking them for the study programme they focused on where the study programme in the best way can contribute to and influence society. Enabling technology seems to be central when assessing the contribution to society from the study programme. Even though it was hard for the educators to rank the competencies and learning themes, there was a distinct separation between some of them with the ranking system applied. Regardless, it seems like the educators agree that some of the competencies and learning themes are more important than others.

4.2.3 Integrating Sustainability in Specific Courses

This theme primarily attempts to answer the research question "What are the barriers for integrating sustainability into the specific courses today?" The theme looks at the thoughts educators have regarding integrating sustainability in their courses, and the challenges associated with doing this based on the three codes; "use of examples", "attitude towards sustainability" and "barriers integrating sustainability".

When filling out the worksheets, the educators often talked about how to further integrate sustainability in a better way, by the use of examples. This seems to be especially true for the learning themes. Educator 5 refers to the importance of connecting what the students are learning to sustainability. In that way, they can use their already existing sustainability knowledge, this can be seen in the quote from Box 12. Educator 3 meant that they could integrate several of the learning themes, before having a realization at the last learning theme, shown in Box 20.

"... But it's almost like you can implement every [learning] theme by the use of examples, but the question is how big of a function it has. What I mean is, if it becomes very far-fetched, it would maybe be a bit counterproductive maybe. I don't know."

Box 20: Educator 3 when filling out the worksheet for "impact on infrastructure". Norwegian version in Box 50.

The same educator also had a great analogy on how the use of examples can be important to help the students connect the theory they learn to the real world. See Box 21. The educator continues to point out how it is possible to integrate sustainability into the courses by the use of the same logic, but as they said in the previous quote, it is important to not be too vague, as this may work against its own purpose.

"It's what I call strength and endurance training. In order to become a good football player, naturally, you have to train with a football, but you also have to have a share of strength and endurance training. But if you only have strength and endurance training and never get to kick the ball, you won't become a football player. So I'm thinking also in the electronic courses. If you only work with constructed, abstract examples, you won't become an engineer. So we always try to tie the theory up against more concrete examples. ..."

Box 21: Educator 3 when filling out the worksheet for "anticipatory" competency. Norwegian version in Box 51.

The educators also mentioned on occasions that they can integrate learning themes by talking about "attitude towards sustainability". One example of this is when Educator 1 filled out the worksheet for "sustainable use of energy sources", as shown in Box 22. The educator meant they could include the learning theme by talking more about it and focusing more on it. Educator 1 also had a similar line of reasoning for other learning themes.

"... But it's not included. We talk little about it, and as I said before, we can talk some about it, but we don't focus that much on the consumption of power. ... So I think that we can check that [learning theme] as "can be included" there too, because it is kind of absolutely something to talk about."

Box 22: Educator 1 when filling out the worksheet for "sustainable use of energy sources". Norwegian version in Box 52.

Another example of this is when Educator 5 filled out the worksheet for "consequences for humanity". The project in that specific course can easily be related to this learning theme, and the educator suggests that an easy way to achieve integration is by talking about it, and having discussions around general attitude questions surrounding the theme. After the interviewer replied that it might be a good idea to make the students reflect around what they learn, and what that knowledge can be

used for. Educator 5 replied like in Box 23. The same educator also had similar reasoning for other learning themes. However, Educator 5 also pointed out that it is important to not have the same repetitive "we will now talk about attitude" talk in every course, as this may work against its own purpose.

> "Yes, because that's kind of what has to be the goal here. That you come out [graduate] from NTNU with a set of attitudes that makes one actually consider stuff like that, because it's probably many today that don't think about it at all."

Box 23: Educator 5 when filling out the worksheet for "consequences for humanity". Norwegian version in Box 53.

A point that came up was the need for the educator to be conscious about sustainability when making changes or designing courses. If the educators are to integrate sustainability, especially the learning themes, by the use examples or assignments, they need to think about sustainability when creating them, which is not a given. This is highlighted by Educator 3 when they were asked if they feel like they have sufficient knowledge to integrate sustainability into their course. See Box 24 for the reply. It is apparent from this quote that the educator had not been thinking about sustainability the last time they created new examples. However, this might change in the future, because of multiple aspects having raised their awareness around sustainability, i.e this interview, the arranged workshops and other efforts made towards sustainability in the department.

> "... so I think that the biggest challenge may be being conscious and thinking of it, and actually doing things for it as well. Because I don't think it's very difficult to implement more of it in my course. When considering what kind of example to use, but it has to be done, and one has to remember to do it, and prioritize to do it. That's probably where the challenge really lies."

Box 24: Educator 3 when asked if they feel like they have sufficient knowledge to integrate sustainability. Norwegian version in Box 54.

Educator 3 also mentioned how important it is to prioritize integrating sustainability, and that with the busy schedules of the teaching staff this would not necessarily be easy. When Educator 5 was asked about the best way to integrate sustainability, the varied participation on the sustainability workshops in the department came up. The educator then had some thoughts on how the educators in the department can be motivated. See Box 25. This means that it is important to make all these educators feel like they can have a significant contribution, and help them understand the context of what they are contributing to. If the educators could see this, the chance of them prioritizing to integrate sustainability would increase.

"... and it's kind of an infinite struggle with time in everyday life. What, where does one feel that one can contribute in a good way, and where one feels that one can contribute in a good way, there one spends time and contributes. ... and considering that we are scientifically employed and would rather not get too controlled by others, it shouldn't be the finger that points and says "You have to do this", but angled in a way that one can get motivated and understand the context. ..."

Box 25: Educator 5 when asked about the best way to integrate sustainability. Norwegian version in Box 55.

The educators think it is possible to further integrate sustainability into their courses with the knowledge that they already have, but they acknowledge that this knowledge can always be improved. Educator 3 also mentioned that the broadness of sustainability can be problematic. See Box 26. This suggests that they have the perception that other educators struggle to understand the sustainability term, and that this may be a problem.

"... Even though some of my colleagues think it's frustrating that this term is so diverse, and it is. ... So it's clear that the term sustainability is probably, is very diverse, and may be a bit diffuse. And a fair share of these goals can often stand against each other. That you can't fulfill all of these at the same time. So the term is not unproblematic. ..."

Box 26: Educator 3 when asked about the importance of teaching students about sustainability. Norwegian version in Box 56.

It is also possible that educators in the department don't grasp the broad nature of the term, even though they think they do. An example of this follows. When Educator 4 was asked about the biggest challenge with integrating sustainability in their course, they replied that integrating sustainability is not a problem, and that they think it is already well integrated in their course. However, when Educator 4 was asked if they think they have sufficient knowledge to integrate sustainability well, they replied according to Box 27. Looking at this, it is possible that Educator 4 felt like they had enough knowledge to integrate sustainability into their course, but in fact does not. However, it is difficult to tell from this limited amount of information.

"... Yes, it is. I'm no expert in sustainability when you put it like that, but I'm like a regular human being that pays attention to stuff, catches stuff, and it [sustainability] is a topic in many places, but it's clear that one can always become better at things as well. ..."

Box 27: Educator 4 when asked if they feel like they have sufficient knowledge to integrate sustainability. Norwegian version in Box 57.

When Educator 5 got asked the same question, they replied like in Box 28. This shows that the educator thinks they have sufficient knowledge about the most relevant competencies and learning themes for their course, but are missing knowledge to integrate competencies and learning themes that are not directly related to the course the way it is designed today. It may be difficult for educators to see the possibilities of integrating sustainability if they struggle to grasp the diverseness of the sustainability term.

> "... so for instance, in order for me to cover something like that in a course, I have to gather competency, or make use of guest lecturers, or something like that to be able to give a reasonable discussion around it. ... for what's relevant in my courses, I have an all right competency, but not on these bigger pictures [topics], no."

Box 28: Educator 5 when asked if they feel like they have sufficient knowledge to integrate sustainability. Norwegian version in Box 58.

An already available source that the educators can make use of is the students. Educator 3 talked about this at the end of the interview, as the quote in Box 29 shows. The educators share the perception that students are engaged and have knowledge about sustainability. Involving students when upgrading or changing courses can give the educators new perspectives that they can apply to courses. Involving students is also a way to prioritize sustainability with a busy schedule, as this can help the educators save time and still be able to integrate sustainability.

> "Yes, you have to be a little creative, and one can say that the time one doesn't have by oneself, well, I have very good experiences with giving students assignments to improve the course. Meaning, using summer students that can do tasks to improve things, and they can have lots of ideas that I haven't thought about, so there's definitely possibilities for those who want to do something."

Box 29: Educator 3 talking about involving summer students at the end of the interview. Norwegian version in Box 59.

To sum up the theme, the educators think that they can further integrate sustainability by using examples or by talking about or discussing sustainability. Consciousness around sustainability is important when educators design or make changes to the courses, though this is not a given today. Prioritizing sustainability seems to be a barrier for educators, because of their busy schedules. Making the educators feel that they can contribute is important in order to motivate them to prioritize sustainability. The educators think that they have sufficient knowledge to further integrate sustainability today, and acknowledge that they can always further improve their sustainability knowledge. Involving students to develop courses can be a resource both to gain new perspectives and to mitigate the problem of having a busy schedule.

4.2.4 Vision on Sustainability

This theme emerged from the inductive approach taken during the beginning of the thematic analysis. It does not focus on any research question in particular, but is considered important to include, as it contributes in answering the more general research question "What is the educators' perspective on sustainability in higher electronic engineering education?". The theme attempts to explore how the educators think sustainability should be integrated in the study programme, and what their future vision for sustainability is. The two codes for this theme are; "holistic approach" and "creating sustainability culture".

The educators think that sustainability needs to be integrated with a holistic approach, and that sustainability should permeate everything in the study programme. However, achieving this is not an easy task, and Educator 3 explains one of the reasons for this in Box 30 when asked about the importance of cooperation between different educators and their courses. Having a holistic approach is important in order to integrate sustainability, because courses and educators need to build on each other in order to be able to teach the students competencies and learning themes in a comprehensive way.

> "... One of the problems with education, and that's not only here, but in the whole world, and all institutions, is that things are very divided into parts. And that is not necessarily bad. It has to do with division of work, it has to do with specializations, and it has to do with concentration and focus. There are many reasons to divide education into different parts/subjects, but one mustn't miss the whole picture either."

Box 30: Educator 3 when asked about the importance of cooperation between courses and educators. Norwegian version in Box 60.

When discussing with Educator 5 how well sustainability is integrated on the study programme today, they shared their thoughts on what the mapping of sustainability should help achieve. See Box 31. The educator pointed out that the need for having a comprehensive plan is important, so the educators can build on each other, and so the tasks associated with integrating sustainability can be distributed between the courses. The need to distribute is important, because integrating everything into single courses is almost impossible, especially when trying to make it more than superficial.

> "... And that we have a holistic mindset around it, in such a way that it won't be scattered around in small parts in each course, and that there typically will be a lot of overlap between courses as well, because then it will work against its own purpose [if scattered]. So it has to. And we are definitely not there today. Because it's not made an overall plan for what should be taken care of in each course, at least as far as I know. ..."

Box 31: Educator 5 when discussion how well sustainability is integrated in the study programme today. Norwegian version in Box 61.

Educator 4 expressed that having a common goal is key when asked about the importance of cooperation between courses, indicating that a common goal can be a valuable driver for the educators when integrating sustainability into the courses. See Box 32.

> "... but clearly it's important that we have a common goal that it should be part of the education and things like that ..."

Box 32: Educator 5 when asked about the importance of cooperation between courses and educators. Norwegian version in Box 62.

The educators think that sustainability should become part of the culture, and underpin everything that the university does. When asked if they think a course on sustainability could be an option, they rejected the idea. One example of this is from Educator 4 in Box 33.

> "... so, it is maybe just to implement it as a kind of culture, a mindset that lies there, [that's] just as important as sitting down and talking a lot about it. That it just underpins everything one does. ... but to have like an own sustainability course or something. I don't really see the point in that. I think that it should permeate everything, as already mentioned."

Box 33: Educator 4 when discussion how well sustainability is integrated in the study programme today. Norwegian version in Box 63.

When Educator 3 was asked about what they think is the best way to integrate sustainability today, and if a sustainability course could be an idea, they had similar thoughts as Educator 4. See Box 34. Both of the educators think that creating a culture for sustainability is important, and that it is something that the study programme should aim for. Having said that, changing the culture and attitude is a long and time consuming task.

> "No, it is absolutely not a separate course. It has to do with culture. It has to do with attitudes. And attitudes built a lot over time ... also has to emboss the whole way we work, and it's a long process, it probably is."

Box 34: Educator 3 after a question about if a sustainability course should be an option. Norwegian version in Box 64.

To sum up this theme, the educators think that having a holistic approach and a strategic plan when integrating sustainability is important. Sustainability should characterize everything the study programme does, and creating a sustainability culture should be the goal, in such a way that students automatically would consider sustainability issues after they graduate, as the quote by Educator 5 expressed in Box 23.

4.3 Mapping of the Study Programme

The mapping of sustainability in the study programme started with the pilot project presented in Section 2.3.1, and is still ongoing. Educators have so far filled out worksheets on three different occasions, as 8 shows. "Workshop" refers to a workshop arranged by the pilot project in autumn 2021. "Project" refers to the specialization project written by the author of this thesis between November 2021 and February 2022. "Thesis" refers to courses mapped during this thesis project. The fact that there is a large span between "Competency" and "Learning Theme" in the "Workshop" category is most likely due to the way the workshop was organized. As of now, 26 "Competency" worksheets and 16 "Learning Theme" worksheets have been filled out for the study programme. In the previous specialization project, the weight behind each check mark was explored based on two interviews, as well as the keywords on the worksheets that were filled out. This thesis will present the updated results from the mapping, but will not look further into the meaning behind each check mark. The tables and bar charts presented were developed during the specialization project, but have been updated with the new results, and translated into English. Section 4.3.1 presents the competencies, and Section 4.3.2 presents the learning themes.

	Competency	**Learning Theme**
Workshop	16	7
Project	3	3
Thesis	7	7
Total Mapped	26	16
Remaining	31	41

Table 8: Courses mapped in the workshop in autumn 2021, during the specialization project, and during this thesis. One course was remapped for the learning themes during this thesis. "Remaining" refers to remaining courses to map in the study programme.

4.3.1 Competencies

This section presents the results from the filled out competency worksheets. Figure 7 shows in percentage the competencies that are "already integrated" or "can be integrated" according to the educators. As the figure shows, "system thinking" is so far claimed to be integrated in 96% of the courses mapped, with 15% of the courses claiming it can be integrated/integrated further. Behind "system thinking" are the "critical thinking", "creativity" and "transdisciplinary" competencies with 81%, 73% and 69% respectively, for already integrated competencies. The remaining competencies range from 42% to 53% for "already integrated", with the exception of "self-awareness" competency, which is only integrated in 35% of the courses. All competencies range from 15% to 27% for "can be integrated", with the exception of "integrated problem-solving", which is up at 35%.

In the thematic analysis, four competencies were identified as typical engineering competencies. These were the "system thinking", "critical thinking", "creativity" and "integrated problem-solving" competencies. The first three of these look to be integrated more frequently, together with "transdisciplinary" competency compared to the others, which aligns with this assessment. Looking at the worksheets, the first three of these, together with the "transdisciplinary" competency, seem to be integrated more frequently than the rest of the competencies, which aligns with this assessment. However, "integrated problem-solving" is not as frequent, which is interesting, as it is seen as an important and typical engineering competency. A reason for this could be that this competency is comprehensively integrated in a few courses, as opposed to somewhat integrated in more courses. Examples of those few courses can be project courses that focus on problem-solving.

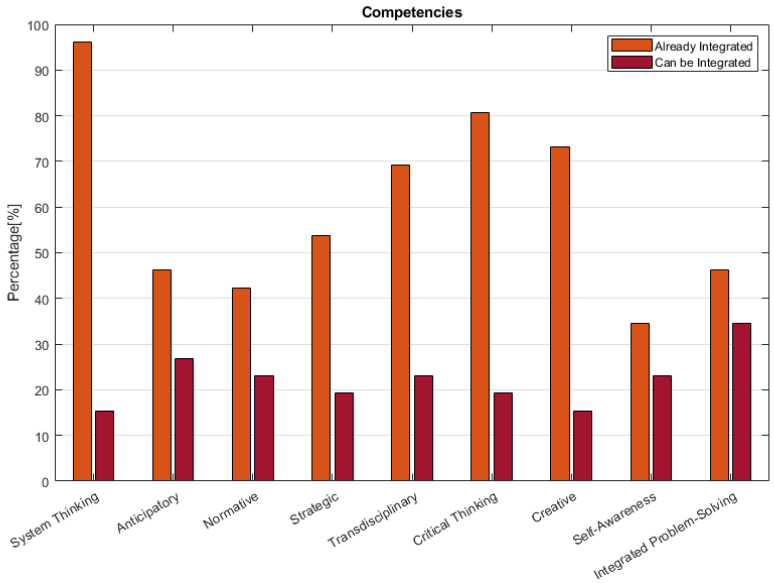


Figure 7: Competencies which are "already integrated" or "can be integrated" in the study programme.

Table 9 presents an overview of all courses that are mapped for competencies. The courses are sorted into study year, although not into the correct semester or specialization profile. An observation that can be made from this overview is that the brackets are mostly used for courses in the first three years. This could be a coincidence, or it could be due to the educators thinking that the basic courses in the first three years don't integrate competencies comprehensively enough, as they mostly focus on the basics. One can also see differences between the number of competencies integrated in each course, with some courses (e.g. TTT4234, TTT23) having integrated almost all competencies, and others (e.g. TTT4180, TTT4187) having integrated only a very few. This may actually be the case, as some of the courses may be specialized in such a way that only some of the competencies are a natural fit. Another possible explanation could be the educators having different criteria for ruling a competency as integrated or not. The most likely scenario is probably a combination of them both, but from the limited information and details from the interviews it is difficult to say.

The previously written specialization project attempted to look closer on the weight behind each check mark for each competency, but with limited success. However, the educators seemed to be able to competently justify whether or not the competencies were integrated in their respective courses.

		SST		**ANT**		**NRM**		**STR**		**TDC**		**CRT**		**CRE**		**SAN**		**IPS**	
Year	**Course**	AI	CI	AI	CI	AI	CI	AI	CI	AI	CI	AI	CI	AI	CI	AI	CI	AI	CI
1	**TTT4203**	Y	X		X					(Y)		(Y)	X	(Y)	X			(Y)	
	TTT4260	Y			X						X	Y		Y			X		X
	TTT4255	Y	X		(X)		X	(Y)	X	(Y)	X	(Y)	X	Y			(X)	(Y)	X
2	**TTT4265**	Y			X						X	Y		Y			X		X
	TFE4172	Y						Y		Y		Y		Y		Y		Y	
	TTT4270	Y	X		(X)		X	(Y)	X	(Y)	X	(Y)	X	Y			(X)	(Y)	X
3	**TFE4152**	Y		Y				Y											
	TFE4146	Y								Y		Y		Y					
	TTT4280	Y		Y		Y		Y		Y		Y		Y		Y		Y	
	TFE4130	(Y)	X	Y		(Y)	(X)			(Y)	(X)	(Y)	X	(Y)	(X)				(X)
4	**TTT4135**	Y			X	(Y)			(X)	Y		Y		Y		(Y)	X		X
	TFE4187	Y		Y				Y											
	TFE4188	Y		Y				Y											
	TTT4180									Y									X
	TTT4175	Y		Y			X				X		X		X				
	TFE4141	Y			X		X	Y	X			Y		Y				Y	
	TFE4169	Y								Y		Y		Y					
	TFE4161	Y				Y		Y		Y		Y		Y		Y		Y	
	TFE4166	Y				Y		Y		Y		Y		Y		Y		Y	
	TTT4234	Y		Y		Y		Y		Y		Y		Y				Y	
	TTT4235	Y		Y		Y		Y		Y		Y		Y				Y	
	TTT4250	Y				(Y)				Y		(Y)					(X)		
5	**TTT4285**	Y		Y		Y					X	Y			X	Y			X
	TFE4575	Y		Y		Y		Y		Y		Y		Y		Y		Y	
	TTT21	Y		Y			X	Y		Y		Y		Y		Y			X
	TTT23	Y		Y		Y			X	Y		Y		Y		Y		Y	

Table 9: Results for all completed competency worksheets. AI stands for "Already Integrated" and CI stands for "Can be Integrated", marked with Y and X respectively. A bracket means that the learning theme is partially integrated or can be partially integrated. See Table 3 for the abbreviations.

4.3.2 Learning themes

This section presents the results from the filled out learning theme worksheets. Figure 8 shows in percentage the learning themes that are "already integrated" and "can be integrated" according to the educators. The learning theme that is integrated the most is "sustainable use of energy sources" at 50%, with "consequences for humanity" following at 38%. "Consequences for biodiversity and wildlife" and "circular economy" are the learning themes that are the least integrated at 6%. When looking at "can be integrated" a large difference can be observed. "Circular economy" is the learning theme that the educators feel like they can integrate the most at 56%, while zero educators say that they can integrate the learning theme "good working conditions". However, 38% of the educators think that they can integrate "reasonable use of materials and resources" in their courses, and 31% for "consequences for humanity", but only 6% for "limitations of harmful emissions". When comparing the learning themes to the competencies, it is apparent that the competencies on average have a much higher percentage of integration. Nevertheless the percentage for learning themes that "can be integrated" are high at a selection of them, showing that there is potential for integrating these learning themes, especially for "circular economy", "reasonable use of materials and resources" and "consequences for biodiversity and wildlife", as these have a higher percentage for "can be integrated" than "already integrated".

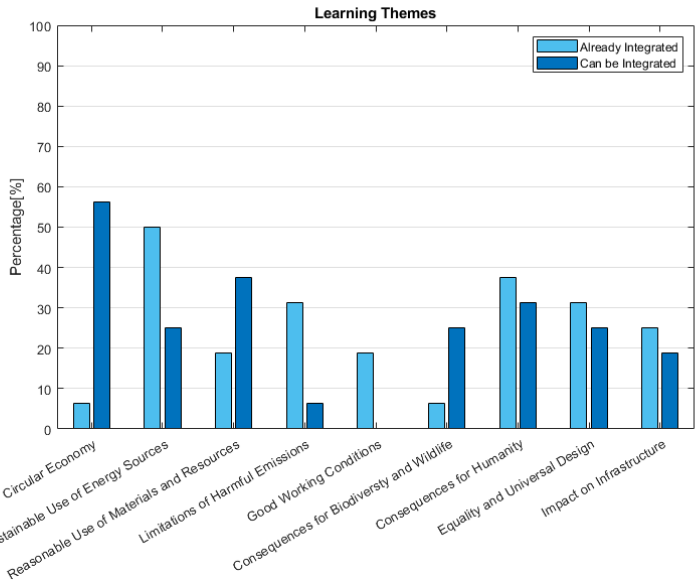


Figure 8: "Already integrated" or "can be integrated" learning themes in the study programme.

Table 10 presents an overview of all courses that are mapped for learning themes. The courses are sorted into study year, although not into the correct semester or specialization profile. The brackets around the check mark are used less for the learning themes in contrast to the competencies. It is difficult to determine why, but the learning themes are in general less diffuse than the competencies. This is a possible reason, as that makes it easier to decide if the learning themes are fully integrated. Another observation is that for the first three years, with an exception of "consequences for humanity", the learning themes are not integrated at all, but have the potential to be integrated for a number of learning themes. The reason for this is unknown, but might be worth looking into.

The previously written specialization project looked closer on the weight behind each check mark for each learning theme, and similarly to the competencies, had limited success doing so. Also here the educators seemed to be able to competently justify justify whether or not the competencies were integrated in their respective courses. However, here, the educators struggled more to be able to connect some of the learning themes to their courses, with "good working conditions" being the most prominent example, which is reflected by the mapping.

		CCE		**SUE**		**RUM**		**LHE**		**GWC**		**CBW**		**CHU**		**RUD**		**IMI**	
Year	**Course**	AI	CI	AI	CI	AI	CI	AI	CI	AI	CI	AI	CI	AI	CI	AI	CI	AI	CI
1	**TTT4203**		(X)		X		X		(X)										
	TTT4260		X		X									Y	X		X		
	TTT4255		X				X						X		X		X		X
2	**TTT4265**		X		X									Y	X		X		
	TTT4270		X				X						X		X		X		X
3	**TFE4130**			(Y)	X		(X)									(Y)		(Y)	
4	**TTT4135**			Y												Y			
	TTT4180									Y				Y		Y			
	TTT4175							Y				Y							
	TFE4141		X	Y			X						X		X				X
	TTT4234		X	Y		Y		Y											X
	TTT4235		X	Y		Y		Y											X
	TTT4250																		
5	**TTT4285**		X	Y		Y		Y		Y			X	Y		Y			
	TFE4575	Y		Y			X	Y		Y				Y		Y		Y	
	TTT23			Y										Y					

Table 10: Results for all completed learning theme worksheets. AI stands for "Already Integrated" and CI stands for "Can be Integrated", marked with Y and X respectively. Brackets mean the learning theme is partially integrated or can be partially integrated. See Table 4 for the abbreviations.

5 Discussion

The goal of this thesis has been to explore the research question "What is the educators' perspective on sustainability in higher electronic engineering education?" by answering the three sub-questions: "How do educators perceive sustainability on Electronic Systems Design and Innovation?", "Which competencies and learning themes do educators see as the most important for the study programme, and how does the study programme perform on these today?" and "What are the barriers for integrating sustainability into the specific courses today?".

By doing thematic analysis of the interviews, it was found that the educators have difficulties judging the level of sustainability integration today. However, they perceive that the study programme performs well in the four competencies; "system thinking", "critical thinking", "integrated problem-solving" and "creativity". When ranking the competencies and learning themes, the educators expressed that all of them are important, but for this study programme, some competencies and learning themes are more favorable than others. The educators think that they have sufficient knowledge to further integrate sustainability in their courses, but prioritizing actually doing this is a challenge that must be overcome. According to the educators, a strategic and holistic approach is important in order to increase the likelihood of integration, and sustainability mapping can help in achieving this.

In this section, the meaning of the results are discussed and put in context with previous research. Section 5.1 further explores the perception on sustainability by the educators, with Section 5.1.1 comparing the educators' rankings to the mapping of sustainability on the study programme. Section 5.1.2 looks at the understanding the educators have of two of the competencies. Section 5.2 looks closer on why the educators don't integrate sustainability in more creative ways, with Section 5.3 dives deeper into the drivers and barriers for integrating sustainability. Section 5.4 attempts to place the study programme in one of the levels of implementation in the curricula, given by Sterling & Thomas [33], as well as the six clusters identified by Weiss, Barth % Wehrden [35]. Section 5.5 is about the limitations of the thesis and its applied methods. The last Section 5.6 gives recommendations for the study programme, and suggestions to future research.

5.1 Educators' Perception on Sustainability

The educators think that teaching the students about sustainability is important, but as already mentioned, they have difficulties judging the current level of integration in the study programme, because they lack the necessary overview to do this. However, Educator 5 and Educator 3 expressed that they think the study programme is on track in integrating sustainability, compared to other study programmes in Norway. By expressing this, Educator 5 also implies that the current ambition is not to become one of the leading study programmes in Norway in terms of integrating sustainability. This is also reflected by the study programme not having a strategic plan of this. During the interviews, the educators seemed to make relevant and important reflections around the competencies and learning themes, as well as around the goal of the study programme is in terms of sustainability. Hopefully, initiating these reflections is a positive contribution to the integration of sustainability in the study programme. By making the educators aware of the topic, it may work as a catalyst for making a change.

When looking at the mapping of competencies and learning themes, it is apparent that generally, the competencies are claimed to be more integrated than the learning themes. The educators expressed that the competencies are not necessarily integrated with sustainability in mind. This implies that it is more of a coincidence that the study programme performs well in some of the sustainability competencies, because they are necessary in order for the students to become electrical engineers. However, this is not the case when it comes to the learning themes, as they are more closely related to sustainability, and thus require the educator to more actively think about sustainability in order to be able to integrate them. This seems to be especially true for "circular economy", which is only integrated in one course, and 56% of the educators claim that it can be integrated in their courses. Even though they are integrated without sustainability in mind, the competencies will still contribute in giving the students tools to tackle sustainability issues in the future. However, it is important to educate students to become aware of sustainability, so that they will actually consider sustainability issues when becoming working professionals, something the competencies cannot achieve on their own.

With the competencies being integrated without sustainability in mind, the mapping of sustainability may give a false sense of the level of integration. This means that even though many of the competencies are integrated in over 50% of the courses, it does not automatically mean that the study programme has a focus on integrating sustainability. It does, however, indicate a great starting point when it comes to further integrating sustainability, as the foundation for integrating sustainability is already fairly good. Here, one can look at the analogy Educator 3 made in Box 21 about strength and endurance training and becoming a great footballer. If the study programme integrates the learning themes more comprehensively, it can help the students create a better connection between sustainability and the competencies they acquire, and thus make them able to understand these connections later in life.

5.1.1 The Ranking by the Educators Compared to the Mapping of Sustainability

The educators think that the study programme is performing well in the four competencies "system thinking", "critical thinking", "integrated problem-solving" and "creativity". Three of these (except "critical thinking") are ranked as the most important competencies for the study programme (Table 7). The mapping of the study programme shows that three of these (except "integrated problem-solving) are also the most frequently integrated competencies (Figure 7). "Self-awareness" is the competency that is least frequently integrated on the study programme, and is ranked as the least important competency by the educators. When looking at the learning themes, some similarities can be pointed out. "Sustainable use of energy sources" is ranked as the most important learning theme by the educators, and is also the learning theme most frequently integrated (Figure 8). "Good working conditions" is ranked as the least important learning theme, and even though it is not the least frequently integrated learning theme, it has zero percentage of "can be integrated", and thus has the least potential to be integrated.

This correlation between the ranking, mapping and perceived competency strengths is interesting. As presented in the Results section, they perceive the competencies and learning themes that the study programme is performing well in to be the most important today. There is always the possibility of the educators being biased when ranking the competencies and learning themes, meaning that they think too much about the current situation in the study programme, and not about how it

should be in the future. However, this is not necessarily the case, as they are likely working towards integrating the competencies and learning themes that they perceive as the most important for the study programme.

5.1.2 Educators' Understanding of Competencies

The aim of having the competency cards is to help the educators understand each competency in the same and intended way, but whether or not they actually do this is difficult to judge. This section will attempt to look closer at the educators' understanding of the two competencies "system thinking" and "integrated problem-solving", as it seems to be around these two terms that there is the most confusion.

When the educators think of "system thinking", it seems like they are mainly thinking about "hard systems", and not "soft systems". One example of this is when Educator 3 expressed that "system thinking" is unavoidable in order to understand an electronic system (Box 7). "Hard systems" generally have a clear purpose and defined goals, and can easily be divided into sub-systems. Much like the systems that are relevant for electrical engineers. On the contrary, "soft systems" are more about big complex problems that are more difficult to define, often with substantial human components being involved. "Soft systems thinking" is among other things found to be more appropriate to when assessing SDG interactions [76]. With sustainability challenges often including a lot of human components and uncertainties, the need for "soft systems thinking" to solve sustainability challenges becomes clear. As the competency "system thinking" according to the mapping is integrated in almost every course, it is difficult to tell how well "soft systems thinking" is integrated, but this is something to have in mind going forward.

According to the competency card (Appendix D), "integrated problem-solving" is both the solving of complex problems and combining competencies. From the mapping, it seems like the educators do not fully understand the complexity of this term. An example of this is when Educator 1 expressed that engineers learn how to solve complex problems (Box 9). Here, it seems like the educator was only regarding "complex problem-solving" as important, not including the combining of competencies. Another example is when Educator 5 expressed that "integrated problem-solving" is not integrated in connection to the competency card, but rather in such a way that it combines engineering competencies, which lead to the educator checking "integrated problem-solving" as integrated (this quote is not included in this thesis).

5.2 Educators' Methods of Integration and the Lack of Creativity

The educators suggest that they can integrate learning themes by talking about or discussing attitude towards sustainability, or by including the learning themes in examples. This is a good suggestion for raising awareness among students, and to help them think about and reflect more around sustainability, and thus be more conscious about it in the future when solving complex problems and inventing new solutions. However, whether or not talking about attitude or using examples will achieve this effect is uncertain, especially if there is no coordination allowing the educators to build on each other. If the students, for example, get the same repetitive lecture in each course talking

about sustainability, it will probably not contribute much towards helping the students reflect and think more about sustainability. The importance of coordination is also identified by Weiss et al., with coordination being the top key driver (Table 2). Additionally, all educators emphasized the importance of coordination between courses when integrating sustainability.

The fact that the educators rarely mention different ways of integrating sustainability, other than using examples or talking about attitude towards sustainability, can be a sign that they lack the sustainability knowledge to integrate it in a more comprehensive and creative way. It should be taken into consideration that coming up with a comprehensive plan to integrate sustainability in the curricula on the spot during an interview is difficult, but it does nevertheless show that they have not thought much about this in advance. If the educators have limited sustainability competence, they may see limited possibilities of integrating sustainability in their courses. Interdisciplinary competence was the top key barrier identified by Weiss et al. in Table 2, and this may be a barrier for this study programme, even though the educators do not themselves perceive it. Another reason for the educators not having more creative solutions may be their lack of time, with them already having busy schedules. Naturally, this lack of time could lead to prioritizing, which again could lead to integration that lacks creativity. A solution here, as will be further explored later, could be, for instance, stressing the importance of sustainability to the educators, in for example meetings in the department. This could lead to them prioritizing sustainability in the future. However, the interviewed educators did seem eager to further integrate sustainability in their courses. A reason for this though, could be that the educators deciding to participate in these interviews may already be more engaged in sustainability than the educators who did not participate.

Educator 3 expressed that if desired, it is possible to integrate almost all of the learning themes by using examples. Doing this is certainly a good idea, but doing this alone will not be enough to reach a redesign (education as sustainability, See Box 1) level of implementation of sustainability in the curricula. It may only reach a build-in (education for sustainability) level when combined together with the competencies. This indicates the need to offer more professional development opportunities for sustainability in order to increase the knowledge, as well as raise the awareness of the teaching staff. Better knowledge about sustainability gives the educators the tools to recognize more opportunities of integrating sustainability into their courses, and raising the awareness will make them more conscious about sustainability when designing courses or making changes.

5.3 Driver and Barriers for Integration of Sustainability

The educators have, as already mentioned, a very busy schedule, and with most courses already well-established, it is difficult for the educators to prioritize changing them to contain more sustainability. This makes integrating sustainability into the courses a slow process, as sustainability might only be integrated when the courses are changed for other, unrelated, reasons. The difficulty of prioritizing integrating sustainability is also identified as one of the key barriers by Weiss et al. in Table 2. To motivate the educators to prioritize integrating sustainability, the head of the department can come up with a common goal for the study programme. This may work as an important driver, as it may make the educators unite when working towards a common goal. Weiss et al. also identified "vision" as both a key driver and barrier, emphasizing the importance of having something to work towards.

Today, there is no strategic plan for integrating sustainability on the study programme. If the educators think this is a barrier for integrating sustainability is not fully answered, but having a strategy could work as an important driver for integrating sustainability further. Educator 5 directly expressed the need for having a comprehensive plan, and that the mapping of the study programme should help in accomplishing this. The plan should attempt to decide which courses should focus on what topics, and give concrete tasks to the educators. Having a strategic plan is also identified as one of the top drivers by Weiss et al. in Table 2. A strategic plan would also help achieve a holistic approach, and guide the educators on what they should focus on when integrating sustainability. To achieve a holistic approach using a horizontal or a combining of horizontal and vertical approach is needed [30][31]. However, creating such a plan in itself can be a big challenge, but a first step can be finding a common goal. Today, it seems like it is up to each educator to initiate the integration of sustainability in their own courses. This can be a problem when the educators already struggle with having an overview of the study programme, as they are uncertain on how to build on knowledge from previous courses.

Communication is identified as a key driver, and collaboration as a key barrier by Weiss et al. in Table 2. Both of these could be improved by having regular meetings with sustainability on the agenda. Today there is no such thing, as far as the author is aware. Having regular meetings would help with sharing knowledge and experiences about integrating sustainability, and thus speed up the process of integration. Meeting like these could be inspirational and motivational for the educators. However, as prioritizing integrating sustainability is a barrier, the participation of these meetings would likely be low. This is reflected by two workshops arranged by the pilot project presented in Section 2.3.1. The first workshop had decent participation, as the 16 competency worksheets filled out during the workshop reflects (Table 8). However, when arranging the second workshop, the first attempt had to be cancelled, because of very few accepted invitations. On the second attempt, about 12 educators accepted the invitation and participated in the workshop. This number is out of around 35 to 40 educators in total. Figuring out how to motivate the educators to participate in these workshops, or in potential sustainability meetings, is a difficult challenge that is yet to be successful.

5.4 Level of Implementation of Sustainability in the Curricula

When looking at the perception of the educators and the mapping of the study programme, it seems like the study programme is the closest to bolt-on level of integration (education about sustainability, Table 1), with tendencies to be on build-in level of integration (education for sustainability). This is because integrating sustainability with the use of examples or talking about attitude towards sustainability doesn't necessarily mean that sustainability is integrated in the curricula, and also, the competencies are not necessarily integrated with sustainability in mind.

The six clusters presented in Box 1 are aimed at HEIs, but it can still be valuable to place the study programme in one of the clusters. Today, the study programme is closest to cluster six, named "limited institutional change". This cluster is described as having bottom-up activities that struggle to establish long-lasting internal cultural change and long lasting activities. On the study programme today, there is limited efforts in integrating sustainability. However, the pilot project is currently working on integrating sustainability, and is, among other things, affecting two courses. These courses will begin by making a small change in the curricula, in favor of sustainability. There

are also some other, smaller and isolated, efforts made towards integrating sustainability. However, none of these efforts qualify the programme to be placed in another cluster. Additionally, cluster six is characterized by a number of barriers, with for example the lack of a strategic plan, weak professional development opportunities and weak interdisciplinary competence. All of which have been mentioned in regards to the study programme during this discussion.

As of what can be done for improving these levels, in order to reach build-in level of integration, it would be necessary to start combining the competencies together with the learning themes. In this way, the students would be able to clearly see the connection between their knowledge and sustainability. It would also be necessary for the educators to a larger degree consider how the competencies can contribute towards sustainability, with for example attempting to focus more on "soft systems thinking". If this starts to catch momentum, and a common goal is developed, the study programme can move towards cluster two, which is named "bottom-up, evolving institutional change". Also, if the pilot project continues, it can attempt to make a strategic plan for integration of sustainability in the study programme, leading to a redesign level of integration. However, getting there requires hard work and patience [23], as well as overcoming the barriers along the way.

5.5 Limitations

The sample size for the thematic analysis is low, with only three educators answering part two of the interview (Interview guide in Box 3). This limits the generalizability of the thematic analysis, and affects the certainty of the findings in this thesis. It was attempted to conduct more interviews, but as mentioned in Section 4.1, this attempt was not successful. The current data amount seems to not be approaching data saturation, so having more participants would definitely contribute to more certain and better insight.

Also, the educators self-reporting their own courses may be a problem. Self-reporting may lead to the result being positively biased in favor of sustainability being integrated, when in fact it is not. However, self-reporting may be the only viable way of conducting the mapping of the courses. This is because it is a relatively quick way for the educators to complete, in addition to them being the ones that have the best insight in their own courses.

An additional limiting factor is the limited experience of the author when it comes to conducting interviews and doing thematic analysis. Having more experience conducting interview would help in developing questions before, as well as in asking better follow-up questions during the interview. This again would contribute to obtaining greater insight from the educators. The process of analyzing the transcription would also benefit from the analyzer having more experience, as this can possibly be a subjective process.

Even after taking all these limitations into consideration, this thesis gives insight into the perspective of the educators on electrical engineering programs, making it a good foundation for those continuing the research on this topic in the future.

5.6 Recommendations and Future Work

The following recommendations are for the study programme, and they are based on all the work that has gone into this thesis. The recommendations are:

- for the study programme to find a common goal or vision. The educators' perspective on sustainability found in this thesis can be used as a starting point when discussing this.
- for the study programme to create a strategic plan for integration of sustainability. This can be based on the common goal or vision, mapping of sustainability, and the expertise of all the educators on the study programme.
- to offer more professional development opportunities for sustainable development to the educators.
- to arrange regular meetings with sustainability on the agenda, where educators can share knowledge and experiences regarding integration of sustainability. Note that having a strategic plan before doing this is necessary for these meetings to have a clear purpose. These meetings should contribute to knowledge and experience sharing, as well as increase the collaboration between the educators.
- to continue the mapping of sustainability on the study programme.

6 Conclusion and Future Work

The aim of this thesis was to explore the educators' perspective on sustainability in higher electronic engineering education. Based on the thematic analysis of the interviews that were held, it can be concluded that the educators think that teaching the students about sustainability is important, and they consider all of the competencies and learning themes to be important, even though they favour some over others. The educators perceive the four competencies; "system thinking", "critical thinking", "integrated problem-solving" and "creativity" to be competencies the study programme performs well in today, and that these competencies are essential for electrical engineers to master. When integrating sustainability in their courses, the educators lack in creativity. The cause for this could be that the educators have a shortage in time, or that they have limited knowledge, making them see limited possibilities to integrate sustainability. The main barrier mentioned by the educators is their difficulties of prioritizing integration of sustainability. This thesis identified three possible key drivers that can help the educators overcome this barrier, and motivate them to further integrate sustainability. The three drivers are finding a common goal, developing a strategic plan and offering professional development opportunities.

Recommendations for future research are to further explore the educators' perspective by asking more in-depth questions, based on the findings from this thesis. Topics for these questions can be the educators' understanding of the competencies, questions about barriers and drivers and questions about what the vision for electronic engineering education programmes should be. As the sample size for this thesis was low, it is also important to confirm that its findings are reasonable.

References

[1] Rebecca Lindsey & Luann Dahlman. *Climate Change: Global Temperature*. URL: https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature. (accessed: 11.04.2022).

[2] NOAA National Centers for Environmental information. *Climate at a Glance: Global Time Series*. URL: https://www.ncdc.noaa.gov/cag/global/time-series. (accessed: 17.04.2022).

[3] United Nations. *UN climate report: It's 'now or never' to limit global warming to 1.5 degrees*. URL: https://news.un.org/en/story/2022/04/1115452. (accessed: 11.04.2022).

[4] Masson-Delmotte et al. "Summary for Policymakers". In: (2018), p. 11. URL: https://www.ipcc.ch/sr15/chapter/spm/.

[5] United Nations. *Sustainability*. 2022. URL: https://www.un.org/en/academic-impact/sustainability. (accessed: 22.06.2022).

[6] United Nations. *Transforming our world: the 2030 Agenda for Sustainable Development*. 2015. URL: https://sdgs.un.org/publications/transforming-our-world-2030-agenda-sustainable-development-17981. (accessed: 22.06.2022).

[7] United Nations. *UN Communications materials, SDG poster and individual goals for web and print*. URL: https://www.un.org/sustainabledevelopment/news/communications-material/. (accessed: 16.04.2022).

[8] lovdata.no. *Lov om universiteter og høyskoler (universitets- og høyskoleloven)*. URL: https://lovdata.no/dokument/NL/lov/2005-04-01-15. (accessed: 01.06.2022).

[9] Texas Instruments. *Corporate citizenship*. 2022. URL: https://www.ti.com/about-ti/citizenship-community/overview.html. (accessed: 22.06.2022).

[10] Apple. *Environmental Progress Report*. 2022. URL: https://www.apple.com/environment/pdf/Apple_Environmental_Progress_Report_2021.pdf. (accessed: 22.06.2022).

[11] RBA. *About the RBA*. 2022. URL: https://www.responsiblebusiness.org/about/rba/. (accessed: 22.06.2022).

[12] Micah S. Ziegler & Jessika E. Trancik. "Re-examining rates of lithium-ion battery technology improvement and cost decline". In: (2021). URL: https://doi.org/10.1039/D0EE02681F.

[13] Opplysningsrådet for veitrafikken (OSV). *2021 was the record year for new car registrations*. URL: https://ofv.no/produktinfo/2021-was-the-record-year-for-new-car-registrations. (accessed: 16.04.2022).

[14] Our World in Data. *Why did renewables become so cheap so fast?* URL: https://ourworldindata.org/cheap-renewables-growth. (accessed: 22.06.2022).

[15] Lazard. "Lazard's Levelized Cost of Energy Analysis—Version 15.0". In: (2021), p. 8. URL: https://www.lazard.com/media/451905/lazards-levelized-cost-of-energy-version-150-vf.pdf.

[16] Martin Haigh & Valerie A. Clifford. "Integral vision: a multi-perspective approach to the recognition of graduate attributes, Higher Education Research & Development, 30:5, 573-584". In: (2011). URL: https://doi.org/10.1080/07294360.2011.598448.

[17] Jeffrey D. Sachs et. al. "Six Transformations to achieve the Sustainable Development Goals. Nat Sustain 2, 805–814." In: (2019). URL: https://doi.org/10.1038/s41893-019-0352-9.

[18] Guillermo Murillo Vargas et. al. “Mapping the Integration of the Sustainable Development Goals in Universities: Is It a Field of Study? Journal of Teacher Education for Sustainability. 22. 7-25. 10.2478/jtes-2020-0013.” In: (2020). URL: https://doi.org/10.2478/jtes-2020-0013.

[19] Angelo Riccaboni & Francesca Trovarelli. “Transition Towards Sustainable Development: The Role of Universities. In: Leal Filho, W., Brandli, L., Kuznetsova, O., Paço, A. (eds) Integrative Approaches to Sustainable Development at University Level. World Sustainability Series. Springer, Cham.” In: (2015), pp. 293–305. URL: https://doi.org/10.1007/978-3-319-10690-8_20.

[20] Arjen E. J. Wals. “Sustainability in higher education in the context of the UN DESD: a review of learning and institutionalization processes, Journal of Cleaner Production, Volume 62, Pages 8-15, ISSN 0959-6526”. In: (2014). URL: https://doi.org/10.1016/j.jclepro.2013.06.007.

[21] Håkan Rodhe & Don Huisingh Alexander Lidgren. “A systemic approach to incorporate sustainability into university courses and curricula, Journal of Cleaner Production, Volume 14, Issues 9–11, Pages 797-809, ISSN 0959-6526”. In: (2006). URL: https://doi.org/10.1016/j.jclepro.2005.12.011.

[22] Alberto Platt & Jorge Taddei Luis Velazquez Nora Munguia. “Sustainable university: what can be the matter? Journal of Cleaner Production, Volume 14, Issues 9–11, Pages 810-819, ISSN 0959-6526”. In: (2006). URL: https://doi.org/10.1016/j.jclepro.2005.12.008.

[23] Norman Evans & Lynn Henrichsen. “Long-term Strategic Incrementalism: An Approach and a Model for Bringing About Change in Higher Education. Innov High Educ 33, 111–124”. In: (2008). URL: https://doi.org/10.1007/s10755-008-9067-y.

[24] D. Ferrer-Balas et al. ““An international comparative analysis of sustainability transformation across seven universities”, International Journal of Sustainability in Higher Education, Vol. 9 No. 3, pp. 295-316.” In: (2008). URL: https://doi.org/10.1108/14676370810885907.

[25] Elli Verhulst & Wim Lambrechts. “Fostering the incorporation of sustainable development in higher education. Lessons learned from a change management perspective, Journal of Cleaner Production, Volume 106, Pages 189-204, ISSN 0959-6526,” in: (2014). URL: https://doi.org/10.1016/j.jclepro.2014.09.049.

[26] Luis R. Pertierra & Rodrigo Lozano Norka Blanco-Portela Javier Benayas. “Towards the integration of sustainability in Higher Education Institutions: A review of drivers of and barriers to organisational change and their comparison against those found of companies, Journal of Cleaner Production, Volume 166, Pages 563-578, ISSN 0959-6526”. In: (2017). URL: https://doi.org/10.1016/j.jclepro.2017.07.252.

[27] Maria Barreiro-Gen et al. Rodrigo Lozano. “Developing Sustainability Competences Through Pedagogical Approaches”. In: (2021). URL: https://doi.org/10.1007/978-3-030-64965-4.

[28] K. Ceulemans & M. De Prins. “Teacher’s manual and method for SD integration in curricula, Journal of Cleaner Production, Volume 18, Issue 7, Pages 645-651, ISSN 0959-6526,” in: (2010). URL: https://doi.org/10.1016/j.jclepro.2009.09.014.

[29] Caroline Noyes & Michael Rodgers Mary Katherine Watson Rodrigo Lozano. “Assessing curricula contribution to sustainability more holistically: Experiences from the integration of curricula assessment and students’ perceptions at the Georgia Institute of Technology, Journal of Cleaner Production, Volume 61, Pages 106-116, ISSN 0959-6526”. In: (2013). URL: https://doi.org/10.1016/j.jclepro.2013.09.010.

[30] K.F Mulder & A. Bijma D.-. Peet. ""Integrating SD into engineering courses at the Delft University of Technology: The individual interaction method", International Journal of Sustainability in Higher Education, Vol. 5 No. 3, pp. 278-288." In: (2004). URL: https://doi.org/10.1108/14676370410546420.

[31] V. Cappuyns & W. De Coninck K. Ceulemans M. De Prins. "Integration of sustainable development in higher education's curricula of applied economics: Large-scale assessments, integration strategies and barriers. Journal of Management & Organization, 17(5), 621-640". In: (2011). URL: https://doi.org/10.5172/jmo.2011.17.5.621.

[32] D. Allen et al. B. Allenby C.F. Murphy. "Sustainable engineering education in the United States. Sustain Sci 4, 7". In: (2009). URL: https://doi.org/10.1007/s11625-009-0065-5.

[33] Stephen Sterling & Ian Thomas. "Education for sustainability: the role of capabilities in guiding university curricula, International Journal of Innovation and Sustainable Development, 2006 Vol.1 No.4, pp.349 - 370". In: (2006). URL: https://doi.org/10.1504/IJISD.2006.013735.

[34] M. Barth & H. von Wehrden M. Weiss. "The patterns of curriculum change processes that embed sustainability in higher education institutions. Sustain Sci 16, 1579–1593". In: (2021). URL: https://doi.org/10.1007/s11625-021-00984-1.

[35] Matthias Barth & Henrik von Wehrden Marie Weiss. "The patterns of curriculum change processes that embed sustainability in higher education institutions. Sustain Sci 16, 1579–1593." In: (2021). URL: https://doi.org/10.1007/s11625-021-00984-1.

[36] UNESCO. *Education for Sustainable Development Goals: learning objectives*. 2017, pp. 10–11. ISBN: 978-92-3-100209-0. URL: https://unesdoc.unesco.org/ark:/48223/pf0000247444.

[37] W. Lambrechts et al. "The integration of competences for sustainable development in higher education: an analysis of bachelor programs in management, Journal of Cleaner Production, 48, Pages 65-73". In: (2013). URL: https://doi.org/10.1016/j.jclepro.2011.12.034.

[38] M. Rieckmann & U. Stoltenberg M. Barth J. Godemann. ""Developing key competencies for sustainable development in higher education", International Journal of Sustainability in Higher Education, Vol. 8 No. 4, pp. 416-430". In: (2007). URL: https://doi.org/10.1108/14676370710823582.

[39] L. Withycombe & C.L. Redman A. Wiek. "Key competencies in sustainability: a reference framework for academic program development. Sustain Sci 6, 203–218". In: (2011). URL: https://doi.org/10.1007/s11625-011-0132-6.

[40] A. Wiek et al. "Operationalising competencies in higher education for sustainable development. In: Barth, M., Michelsen, G., Rieckmann, M., Thomas, I. (Eds.). Handbook of Higher Education for Sustainable Development. Routledge, London. pp. 241-260." In: (2015). URL: Google%20Scholar:%20http://tinyurl.com/WiekEtAl15.

[41] M. Barth & G. Cebrián et al. K. Brundiers. "Key competencies in sustainability in higher education—toward an agreed-upon reference framework. Sustain Sci 16, 13–29". In: (2021). URL: https://doi.org/10.1007/s11625-020-00838-2.

[42] The United Nations Economic Commission for Europe (UNECE). *ESD Strategy: The development of the regional Strategy on Education for Sustainable Development*. 2005. URL: https://unece.org/esd-strategy. (accessed: 01.07.2022).

[43] Marco Rieckmann. *Key themes in Education for Sustainable Development, page 61-84, Issues and trends in Education for Sustainable Development*. 2018. URL: https://unesdoc.unesco.org/ark:/48223/pf0000261445. (accessed: 01.07.2022).

[44] Arnim Wiek & Henrik von Wehrden Marie Weiss Matthias Barth. "Drivers and Barriers of Implementing Sustainability Curricula in Higher Education - Assumptions and Evidence. Higher Education Studies. 11. 42. 10.5539/hes.v11n2p42." In: (2021). URL: https://doi.org/10.5539/hes.v11n2p42.

[45] Ron Griffiths. "Knowledge production and the research–teaching nexus: the case of the built environment disciplines, Studies in Higher Education, 29:6, 709-726". In: (2004). URL: https://doi.org/10.1080/0307507042000287212.

[46] Valeria Ruiz Vargas et. al. "Implications of vertical policy integration for sustainable development implementation in higher education institutions, Journal of Cleaner Production, Volume 235, 2019, Pages 733-740, ISSN 0959-6526". In: (2019). URL: https://doi.org/10.1016/j.jclepro.2019.07.022.

[47] M. Bauer et. al. "Sustainability governance at universities: Using a governance equalizer as a research heuristic. Higher Education Policy, 31(4), 491-511." In: (2018). URL: https://doi.org/10.1057/s41307-018-0104-x.

[48] R.A. Hanneman et al. S. Brint K. Proctor. "Who are the early adopters of new academic fields? Comparing four perspectives on the institutionalization of degree granting programs in US four-year colleges and Universities, 1970–2005. High Educ 61, 563–585". In: (2011). URL: https://doi.org/10.1007/s10734-010-9349-z.

[49] H. Henriksen & J.D. Spengler W.M. Purcell. ""Universities as the engine of transformational sustainability toward delivering the sustainable development goals: "Living labs" for sustainability", International Journal of Sustainability in Higher Education, Vol. 20 No. 8, pp. 1343-1357." In: (2019). URL: https://doi.org/10.1108/IJSHE-02-2019-0103.

[50] M. Ralph& W. Stubbs. "Integrating environmental sustainability into universities. High Educ 67, 71–90". In: (2014). URL: https://doi.org/10.1007/s10734-013-9641-9.

[51] Matthias Barth & Marco Rieckmann. "Academic staff development as a catalyst for curriculum change towards education for sustainable development: an output perspective, Journal of Cleaner Production, Volume 26, Pages 28-36, ISSN 0959-6526," in: (2012). URL: https://doi.org/10.1016/j.jclepro.2011.12.011.

[52] Hans Dieleman & Sylvie Turpin-Marion Margarita Juárez-Nájera. "Sustainability in Mexican Higher Education: towards a new academic and professional culture, Journal of Cleaner Production, Volume 14, Issues 9–11, Pages 1028-1038, ISSN 0959-6526," in: (2006). URL: https://doi.org/10.1016/j.jclepro.2005.11.049.

[53] Rodrigo Lozano & William Young. "Assessing sustainability in university curricula: exploring the influence of student numbers and course credits, Journal of Cleaner Production, Volume 49, Pages 134-141, ISSN 0959-6526". In: (2013). URL: https://doi.org/10.1016/j.jclepro.2012.07.032.

[54] U.M Azeiteiro & S. Leal A.M. Aleixo. "UN Decade of Education for Sustainable Development: Perceptions of Higher Education Institution's Stakeholders. In: Leal Filho, W., Azeiteiro, U., Alves, F., Molthan-Hill, P. (eds) Handbook of Theory and Practice of Sustainable Development in Higher Education. World Sustainability Series. Springer, Cham." In: (2017). URL: https://doi.org/10.1007/978-3-319-47877-7_28.

[55] V.O. Lovren. “Promoting Sustainability in Institutions of Higher Education—The Perspective of University Teachers. In: Leal Filho, W., Azeiteiro, U., Alves, F., Molthan-Hill, P. (eds) Handbook of Theory and Practice of Sustainable Development in Higher Education. World Sustainability Series. Springer, Cham.” In: (2017). URL: https://doi.org/10.1007/978-3-319-47877-7_32.

[56] L. Agirreazkuenaga. “Embedding Sustainable Development Goals in Education. Teachers’ Perspective about Education for Sustainability in the Basque Autonomous Community. Sustainability 2019, 11, 1496”. In: (2019). URL: https://doi.org/10.3390/su11051496.

[57] I.-B. Skogh & E. Strömberg K. Edvardsson Björnberg. ““Integrating social sustainability in engineering education at the KTH Royal Institute of Technology”, International Journal of Sustainability in Higher Education, Vol. 16 No. 5, pp. 639-649”. In: (2015). URL: https://doi.org/10.1108/IJSHE-01-2014-0010.

[58] F. Moreno-Pino et al. “Training in mathematics education from a sustainability perspective: A case study of university teachers’ views. Education Sciences, 12(3), 199”. In: (2022). URL: https://doi.org/10.3390/educsci12030199.

[59] A. Ibrahim & M. Koç W. Al-Thani. “Education as a critical factor of sustainability: Case study in Qatar from the teachers’ development perspective. Sustainability, 13(20), 11525”. In: (2021). URL: https://doi.org/10.3390/su132011525.

[60] UNESCO. *Framework for the UN DESD international implementation scheme*. 2006. URL: https://unesdoc.unesco.org/ark:/48223/pf0000148650. (accessed: 02.07.2022).

[61] UNESCO. *Education for sustainable development: sourcebook*. 2012. URL: https://unesdoc.unesco.org/ark:/48223/pf0000216383. (accessed: 02.07.2022).

[62] R. Lozano et al. “Connecting Competences and Pedagogical Approaches for Sustainable Development in Higher Education: A Literature Review and Framework Proposal. Sustainability 2017, 9, 1889.” In: (2017). URL: https://doi.org/10.3390/su9101889.

[63] F. Lozano & K. Sammalisto R. Lozano M. Barreiro-Gen. “Teaching Sustainability in European Higher Education Institutions: Assessing the Connections between Competences and Pedagogical Approaches. Sustainability. 11. 10.3390/su11061602.” In: (2019). URL: https://doi.org/10.3390/su11061602.

[64] W. Filho & C. Chiappetta-Jabbour S. Caeiro U. Azeiteiro. “Sustainability assessment tools in higher education institutions: Mapping trends and good practices around the world. 10.1007/978-3-319-02375-5.” In: (2013). URL: https://doi.org/10.1007/978-3-319-02375-5.

[65] UNESCO. *Education for sustainable development: a roadmap*. 2020. URL: https://unesdoc.unesco.org/ark:/48223/pf0000374802.locale=en. (accessed: 02.07.2022).

[66] Vlaanderen. *EHE KIT: Ecodesign in higher education?* URL: https://ecodesign.vlaanderen-circulair.be/en/tools/ehe-kit. (accessed: 17.04.2022).

[67] E. Verhulst & K. Van Doorsselaer. “Development of a hands-on toolkit to support integration of ecodesign in engineering programmes, Journal of Cleaner Production, Volume 108, Part A, Pages 772-783, ISSN 0959-6526,” in: (2015). URL: https://doi.org/10.1016/j.jclepro.2015.06.083.

[68] Solve Sæbø et. al. “SDG - Quality in higher education: Developing a platform for sharing of ideas and practices within the universities”. In: (2020). URL: https://www.uib.no/sites/w3.uib.no/files/attachments/sdg_-_quality_in_higher_education_-_report_feb_2020.pdf.

[69] Joanna E.M. Sale & Stephen Thielke. "Qualitative research is a fundamental scientific process, Journal of Clinical Epidemiology, Volume 102, Pages 129-133, ISSN 0895-4356," in: (2018). URL: https://doi.org/10.1016/j.jclinepi.2018.04.024.

[70] W. Wick & C. Gumbinger L. Busetto. "How to use and assess qualitative research methods. Neurol. Res. Pract. 2, 14". In: (2020). URL: https://doi.org/10.1186/s42466-020-00059-z.

[71] Tegan George. *Semi-Structured Interview — Definition, Guide & Examples*. URL: https://www.scribbr.com/methodology/semi-structured-interview/. (accessed: 10.05.2022).

[72] Annette Brooks. *What Are the Different Types of Transcription?* URL: https://www.upwork.com/resources/types-of-transcriptions. (accessed: 18.04.2022).

[73] Jack Caulfield. *How to Do Thematic Analysis — A Step-by-Step Guide & Examples*. 2019. URL: https://www.scribbr.com/methodology/thematic-analysis/. (accessed: 15.06.2022).

[74] Virginia Braun & Victoria Clarke. "Using thematic analysis in psychology, Qualitative Research in Psychology, 3:2, 77-101". In: (2006). URL: https://doi.org/10.1191/1478088706qp063oa.

[75] Ditte Hvas Mortensen. *How to Do a Thematic Analysis of User Interviews*. URL: https://www.interaction-design.org/literature/article/how-to-do-a-thematic-analysis-of-user-interviews. (accessed: 15.06.2022).

[76] M. Cardenas-Vélez et al. E. Hernández-Orozco I. Lobos-Alva. "The application of soft systems thinking in SDG interaction studies: a comparison between SDG interactions at national and subnational levels in Colombia. Environ Dev Sustain 24, 8930–8964". In: (2022). URL: https://doi.org/10.1007/s10668-021-01808-z.

A Course Overview - Electronic Systems Design and Innovation

First Three Years

Year	Semester	Code	Course
1	Autumn	TDT4110	Information Technology, Introduction
		TMA4101	Mathematics 1
		TTT4203	Introduction to Analog and Digital Electronics
		TTT4255	Electronic System Design, Basic Course
	Spring	TDT4102	Procedural and Object-Oriented Programming
		TMA4106	Mathematics 2
		TMA4245	Statistics
		TTT4260	Electronic System Design and Analysis I
2	Autumn	TDT4160	Computers and Digital Design
		TFY4115	Physics
		TMA4111	Mathematics 3
		TTT4265	Electronic System Design and Analysis II
	Spring	TFE4120	Electromagnetism
		TFE4172	Basics for Solid State Electronics
		TMA4120	Mathematics 4
		TTT4270	Electronic System Design, Project
3	Autumn	EXPH0300	Examen philosophicum for Science and Technology
		TFE4146	Semiconductor Devices
		TFE4152	Design of Integrated Circuits
		TTT4120	Digital Signal Processing
	Spring	TFE4130	Electromagnetic and Acoustic Waves
		TIØ4252	Technology Management
		TTT4280	Sensors and Instrumentation
		TTK4145	Real-time Programming
		TTT4275	Estimation, Detection and Classification

Table 11: All courses for the three first year of ELSYS are obligatory, with the exception of the last two courses, coded TTK4145 and TTT4275. Here students choose one of the two. The three first letters of the code represents which department the course belongs to. A code starting with TTT or TFE belongs to the DES. Courses that are not part of the DES are colored in gray.

Acoustics

Year	Semester	Code	Course	Status
4	Autumn	TTT4180	Technical Acoustics	M
		TTT4175	Marine Acoustics	1A
		TTT4197	Music Acoustics and Technology	1A
	Spring	TTT4250	Acoustical Measurement Techniques	M
		Unknown	Experts in Teamwork (EiT)	M
5	Autumn	TTT4285	Acoustics of the Built Environment	1B
		TFE4595	Specialization Course	1B
		TFE4580	Specialization Project	M
	Spring	TFE4940	Master's Thesis	M

Table 12: Mandatory courses or courses the student must choose from in Acoustics. Optional topics are not included. M = Mandatory, 1A = At least 1 from A, 1B = At least 1 from B.

Analog Circuit Design and Radio Systems

Year	Semester	Code	Course	Status
4	Autumn	TFE4187	Analog CMOS 1	2A
		TTT4201	Radio System Design and RF/Microwave Measurement Techniques	2A
		TTT4205	Microwave Techniques	2A
	Spring	TFE4188	Advanced Integrated Circuits	2B
		TTT4145	Radio Communications	2B
		TTT4215	Antenna Engineering	2B
		Unknown	Experts in Teamwork (EiT)	M
5	Autumn	TFE4595	Specialization Course	M
		TFE4580	Specialization Project	M
	Spring	TFE4940	Master's Thesis	M

Table 13: Mandatory courses or courses the student must choose from in Analog Circuit Design and Radio Systems. Optional topics are not included. M = Mandatory, 2A = At least 2 from A, 2B = At least 2 from B.

Design of Digital Circuits & Embedded Systems

Year	Semester	Code	Course	Status
4	Autumn	TFE4141	Design of Digital Systems 1	M
	Spring	TFE4171	Design of Digital Systems 2	M
		Unknown	Experts in Teamwork (EiT)	M
5	Autumn	TFE4595	Specialization Course	M
		TFE4580	Specialization Project	M
	Spring	TFE4940	Master's Thesis	M

Table 14: Mandatory courses for both Design of Digital Circuits & Embedded Systems. Optional topics are not included. M = Mandatory

Nano Electronics and Photonics

Year	Semester	Code	Course	Status
4	Autumn	TFE4161	Photonics I	M
		TFE4169	Nanoelectronics	M
	Spring	TFE4166	Photonics II	1A
		TFE4167	Micro- and Nanofabrication	1A
		Unknown	Experts in Teamwork (EiT)	M
5	Autumn	TFE4575	Physical Methods for Nanostructuring and Characterization	1B
		TFE4595	Specialization Course	1B
		TFE4580	Specialization Project	M
	Spring	TFE4940	Master's Thesis	M

Table 15: Mandatory courses or courses the student must choose from in Nano Electronics and Photonics. Optional topics are not included. M = Mandatory, 1A = At least 1 from A, 1B = At least 1 from B.

Signal Processing and Communications

Year	Semester	Code	Course	Status
4	Autumn	TTT4130	Digital Communication	1A
		TTT4185	Machine Learning for Signal Processing	1A
	Spring	TTT4135	Multimedia Signal Processing	1B
		TTT4145	Radio Communications	1B
		Unknown	Experts in Teamwork (EiT)	M
5	Autumn	TFE4595	Specialization Course	M
		TFE4580	Specialization Project	M
	Spring	TFE4940	Master's Thesis	M

Table 16: Mandatory courses or courses the student must choose from in Signal Processing and Communications. Optional topics are not included. M = Mandatory, 1A = At least 1 from A, 1B = At least 1 from B.

Remaining Courses From Department

Code	Course
TTT4234	Space Technology I
TTT4235	Space Technology II
TTT4170	Audio Technology
TTT4150	Navigation Systems

Table 17: Remaining courses from the department that are never included as a mandatory or must choose a course from the department that the students of ELSYS can choose from.

Specialisation Courses

Code	Course
TFE01	Low-power design
TFE02	Hardware/Software co-design with embedded systems
TFE07	Analog CMOS 2
TFE12	Advanced methods in optics
TFE13	Photonic components
TTT03	Acoustic remote sensing
TTT09	Communication and coding theory for wireless channels
TTT12	Numerical acoustics, selected topics
TTT14	Numerical Electromagnetics and CAD
TTT16	Speech technology, selected topics
TTT18	Active Microwave Integrated Circuits
TTT19	Marine Acoustics, selected topics
TTT20	Bioacoustics
TTT21	Satellite Systems Engineering
TTT22	Room acoustics
TTT23	Biomediscal image- and signal processing and communication
TTT24	Advanced multimedia applications
TTT26	Radar

Table 18: Specialization courses for the autumn semester in the fifth year. Each specialization course counts for 3.75 points, and each student chooses two specialization courses each.

B Competency Worksheet

SPILLEREGLER STEG 1

1. Skriv emne øverst til venstre.
2. Gå nedover listа med kompetanser og sett kryss i første kolonne om kompetansen allerede *er integrert* i emnet.

Kompetansene står i BLOKKBOKSTAVER og stikkordene med undertema til høyre er til hjelp for å forstå hva kompetansene inneholder.

Alle stikkordene trenger IKKE være knyttet til ditt emne for at faget inneholder kompetansen. Bruk kompetansekortene for utdypende forståelse.

3. I neste kolonne skriver du i stikkordsform hvordan kompetansen *er integrert* i emnet. Hvordan blir kompetansen undervist i emnet?

SPILLEREGLER STEG 2

4. Gå nedover listа med kompetansene og sett kryss i tredje kolonne om kompetansen *kan integreres* i emnet.

Dette betyr IKKE at alle stikkordene må dekkes for å integrere kompetansen i emnet. (Husk at en kompetanse kan både være integrert og bli integrert mer i samme emne).

5. I neste kolonne skriver du i stikkordsform hvordan kompetansen *kan integreres* i emnet. Hvordan kan man integrere kompetansen i emnet?

EMNE:

COMPETENCY		STEG 1		STEG 2	
		ALLEREDE INTEGRERT (sett kryss)	HVORDAN? (skriv stikkord)	KAN INTEGRERES (sett kryss)	HVORDAN? (skriv stikkord)
SYSTEM THINKING COMPETENCY	- The bigger picture - Understand relationships - Influnece on the system				
ANTICIPATORY COMPETENCY	- Future scenario - Foresee possible problems - Future effects				
NORMATIVE COMPETENCY	- Norms and values - Trade-offs - Conflicts of interests				
STRATEGIC COMPETENCY	- Long-term planning - Develop goals - Collective actions				
TRANSDISCIPLINARY COLLABORATION COMPETENCY	- Cooperation - Respect different fields - Deal with conflicts				
CRITICAL THINKING COMPETENCY	- Analyze problems - Questioning - Reflection on pros and cons				
CREATIVITY COMPETENCY	- Think outside the box - Innovation - Complex problem-solving				
SELF-AWARENESS COMPETENCY	- Your impact - Your contribution - Evaluate actions				
INTEGRATED PROBLEM - SOLVING COMPETENCY	- Complex problems - Combining competencies				

C Learning Themes Worksheet

SPILLEREGLER STEG 1

1. Skriv emne øverst til venstre.
2. Gå nedover lista med læringstema og sett kryss i første kolonne om temaet allerede *er integrert* i emne.
   Læringstemaene står i BLOKKBOKSTAVER og stikkordene med undertema til høyre er til hjelp for å forstå hva læringstemaene inneholder.
   Alle undertemaene trenger IKKE være knyttet til ditt emne for at faget inneholder læringstemaet. Bruk læringstema-kortene for utdypende forståelse.
3. I neste kolonne skriver du i stikkordsform hvordan læringstemaet *er integrert* i emnet.
   Hvilke undertemaer blir allerede undervist?

SPILLEREGLER STEG 2

4. Gå nedover lista med læringstema og sett kryss i tredje kolonne om temaet *kan integreres* i emnet.
   Dette betyr IKKE at alle undertemaene må dekkes for å integrere læringstemaet i emnet. (Husk at et tema kan både være integrert og bli integrert mer i samme emne).
5. I neste kolonne skriver du i stikkordsform hvordan læringstemaet *kan integreres* i emnet.
   Hvilke undertemaer kan integreres i undervisningen?

EMNE:		STEG 1		STEG 2	
LÆRINGSTEMA		ALLEREDE INTEGRERT (sett kryss)	HVORDAN? (skriv stikkord)	KAN INTEGRERES (sett kryss)	HVORDAN? (skriv stikkord)
SIRKULÆR ØKONOMI	- Råvarebruk - Design, produksjon og distribusjon - Forbruk - Gjenbruk, resirkulering og avfall - Miljøregnskap				
BÆREKRAFTIG BRUK AV ENERGIKILDER	- Fornybar energi - Energisparing i produksjon - Energisparende innovasjon				
FORNUFTIG BRUK AV MATERIALER OG RESSURSER	- Farlige materialer - Færre materialer - Sjeldne materialer - Effektivisere ressurser - Konfliktskapende materialbruk				
BEGRENSNING AV SKADELIGE UTSLIPP	- På land, i vann og i luft - Under produksjon - Under forbruk				
GODE ARBEIDSFORHOLD	- Bedriftens ansvar - Rettferdig lønn - Fokus på helsen til arbeiderne - Utjevne fattigdom				
KONSEKVENSER FOR BIOMANGFOLD OG DYRELIV	- Dyr i havet og på land - Naturkatastrofer - Habitatforstyrrelse				
KONSEKVENSER FOR MENNESKER	- Lokale og globale samfunn - Individpåvirkning - Helsepåvirkning - Samhold og kommunikasjon - Forbrukermønstre				
LIKESTILLING OG UNIVERSIELL UTFORMING	- Funksjonsnedsatt tilpasning - Antirasistisk teknologi - Kjønnsnøytral teknologi				
PÅVIRKNING PÅ INFRASTRUKTUR	- Organisatoriak og fysisk - Innovative byer og industri - Effektivisere transport og veinett - Hjelpemidler i utdanning - Digital samhandling				

D Competency Cards (3 pages)

COMPETENCY

KEYWORDS

- See the bigger picture
- Understand relationships
- Influence on the system

SYSTEM THINKING COMPETENCY

UNESCO'S DEFINITION

The ability to

- recognize and understand relationships.
- analyse complex systems.
- think of how systems are embedded within different domains and different scales.
- deal with uncertainty.

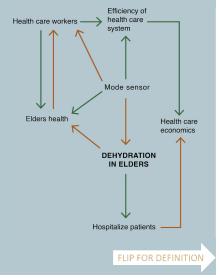
FLIP FOR EXAMPLE

EXAMPLE

Dehydration is a big problem for elders' health and the health care system because of increased hospitilization of patients, leading to high costs.

A sensor can detect when an elder is dehydrated and decrease the amount of resources needed.

Not only will the sensor better elders' health, it will also make the health care system more efficient, but can also lead to less interaction between careworker and elderly.



FLIP FOR DEFINITION

COMPETENCY

KEYWORDS

- Future scenario
- Foresee possible problems
- Future effects

ANTICIPATORY COMPETENCY

UNESCO'S DEFINITION

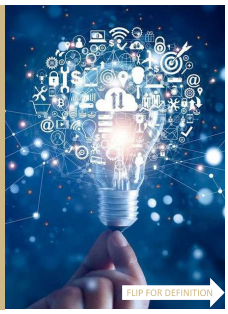
The ability to

- understand and evaluate multiple futures – possible, probable and desirable
- create one's own visions for the future
- apply the precautionary principle
- assess the consequences of actions
- deal with risks and changes

FLIP FOR EXAMPLE

EXAMPLE

When designing an electronic system today, it is important to keep in mind how available the resources you use will be in the future. If you use components made of rare metals, will this be as easily accessible in the future as it is today? Are there other materials that can be more sustainable for the future?



FLIP FOR DEFINITION

COMPETENCY

KEYWORDS

- Norms and values
- Trade-offs
- Conflicts of interests

NORMATIVE COMPETENCY

UNESCO'S DEFINITION

The ability to

- understand and reflect on the norms and values that underlie one's actions
- negotiate sustainability values, principles, goals, and targets, in a context of conflicts of interests and trade-offs, uncertain knowledge and contradictions.

FLIP FOR EXAMPLE

EXAMPLE

When planning wind turbine parks, there are many aspects to evaluate. There are differences in values and norms between developers, owners and people living close by. This leads to conflicts concerning wildlife and renewable energy production. Developers need to reflect to find the most ethical compromise.

FLIP FOR DEFINITION

COMPETENCY

KEYWORDS

- Long-term planning
- Develop goals
- Collective actions

STRATEGIC COMPETENCY

UNESCO'S DEFINITION

The ability to

- collectively develop and implement innovative actions that promote sustainability at the local level and further afield.

FLIP FOR EXAMPLE

EXAMPLE

The department of electronic systems is planning to integrate sustainability in the curriculum at their studies. This requires strategies and concrete goals. Some strategies are already developed, but the strategic focus area on sustainability must be used by all parts of the department, in different parts of the curriculum, to together educate students on sustainability. Continuous goals must also be made.

FLIP FOR DEFINITION

COMPETENCY

KEYWORDS

- Cooperation
- Respect different fields
- Deal with conflicts

TRANSDICIPLINARY COMPETENCY

UNESCO'S DEFINITION

The ability to

- learn from others and to transcend the traditional boundaries of one's own discipline or profession
- understand and respect the needs, perspectives and actions of others (empathy)
- understand, relate to and be sensitive to others (empathic leadership)
- deal with conflicts in a group
- facilitate collaborative and participatory co-creation for problem solving

FLIP FOR EXAMPLE

EXAMPLE

In order to develop new medical technology, the stakeholders must work together. The patients, health care workers and the municipality must cooperate to understand the needs and communicate them to the engineers. The engineering company will also have needs that must be fulfilled, which the engineer must take into consideration in order to obtain a satisfying result.

FLIP FOR DEFINITION

COMPETENCY

KEYWORDS

- Analyze problems
- Questioning
- Reflection on pros and cons

CRITICAL THINKING COMPETENCY

UNESCO'S DEFINITION

The ability to

- question norms, practices, opinions and established theories
- reflect on own one's values, perceptions, perspectives and actions
- take a position in the sustainability discourse.

FLIP FOR EXAMPLE

EXAMPLE

Electrical cars and bikes are seen by many as the most sustainable choice for transport. However, this is not always the case. Even though they are driven by clean energy in Norway, it may not be the case in other countries as fossil fuels may be used to produce electricity. In addition, they contain batteries which are difficult to recycle or reuse. You must consider pros and cons and compare with other means of transport to find the most sustainable choice.

FLIP FOR DEFINITION

COMPETENCY

KEYWORDS

- Think outside the box
- Innovation
- Complex problem solving

CREATIVITY COMPETENCY

UNESCO'S DEFINITION

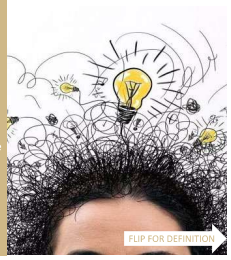
The ability to

- combine anticipatory, transdisciplinary collaborative and critical thinking competencies to be innovative and to think creatively about solutions to complex problems.

FLIP FOR EXAMPLE

EXAMPLE

In the future resources will become more scarce. This might mean that we need to move away from ownership to sharing goods. As engineers, this shift forces us to find creative solutions for offering functionality rather than products, like transport or cleaning instead of a car or vacuum cleaner. As an example, one can design an app which makes it possible to share things like a car, a vacuum cleaner and tools between neighbours.



FLIP FOR DEFINITION

COMPETENCY

KEYWORDS

- Your impact
- Your contribution
- Evaluate actions

SELF-AWARENESS COMPETENCY

UNESCO'S DEFINITION

The ability to

- reflect on one's own role in the local community and (global) society.
- continually evaluate and further motivate one's actions.
- deal with one's feelings and desires.

FLIP FOR EXAMPLE

EXAMPLE

You must be aware of how you can take actions to contribute to sustainable development such as:

- using your smartphone for 5 years instead of 1
- starting recycling initiatives
- consider the values of the company you work at, and how they work towards a sustainable development
- reflect on how your innovations may affect society and the world

FLIP FOR DEFINITION

COMPETENCY

KEYWORDS

- Complex problems
- Combining competencies

INTEGRATED PROBLEM-SOLVING COMPETENCY

UNESCO'S DEFINITION

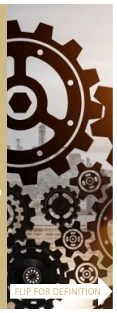
The overarching ability to

- apply different problem-solving frameworks to complex sustainability problems and develop viable, inclusive and equitable solution options that promote sustainable development, integrating the other eight competences.

FLIP FOR EXAMPLE

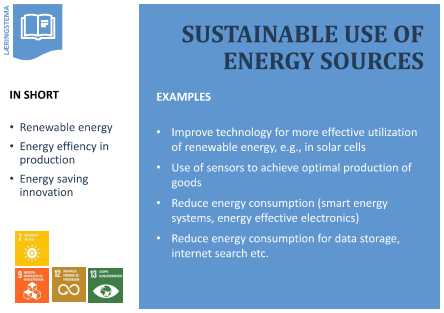
EXAMPLE

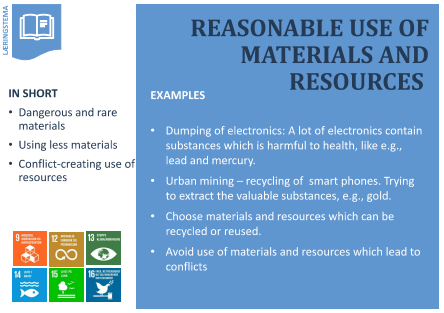
In Mo i Rana industrial park, there is a future vision to succeed on circular economy. In order to make this happen they must think alternatively and innovatively. One of the suggestions is to utilize the waste heat and CO2 from the industry and the nutritious waste water from the fish farms in order to grow vegetables. There are several things to think about when projecting the new greenhouse, and a strategic plan must be made. For example one must reflect on how this facility will affect the city, and maybe integrate a meeting place (like a restaurant) in order to contribute to a more social sustainable city. One also has to be critical and figure out how these vegetables can compete with imported vegetables in the stores. Will the facility be economical beneficial for the company so they can afford a fair wage to its workers?

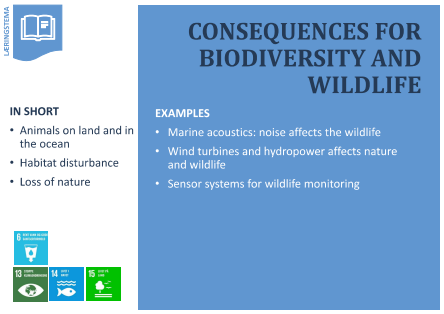


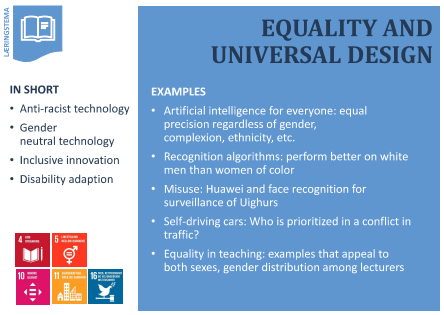
FLIP FOR DEFINITION

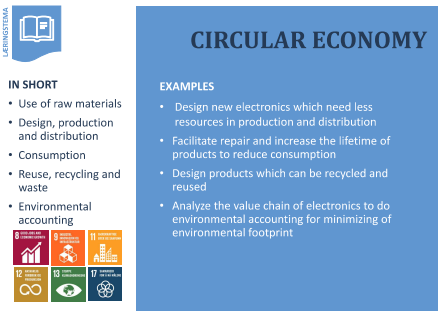
E Learning Theme cards (2 pages)











LÆRINGSTEMA

IN SHORT

- Local and global societies
- Individual impact
- Health impact
- Society and communication
- Consumption patterns

CONSEQUENCES FOR HUMANITY

EXAMPLES

- Dumping of electronics in low-income countries may lead to negative impact on the locals' health
- Social media's impact on mental health
- Positive consequence of digitization: digital socializing during the Covid-19 pandemic
- Online surveillance, hacking, etc.
- Consider the social consequences of technology: toll roads, position applications on mobile apps, internet algorithms

LÆRINGSTEMA

IN SHORT

- In the air, on land and in the ocean
- During production
- During consumption

LIMITATIONS OF HARMFUL EMISSIONS

EXAMPLES

- Promote local production to reduce transport distance when distributing goods
- Sensor systems for environmental surveillance can detect and prevent pollution
- New battery technology can facilitate transition to emission-free societies
- Limit harmful waste under production: e.g., hydrofluoric acid for solar cell production

LÆRINGSTEMA

IN SHORT

- Organizational, physical and digital infrastructure
- Aids in health and education
- Digital interaction
- Innovative cities and industries

IMPACT ON INFRASTRUCTURE

EXAMPLES

- Automation and robotics streamline urban societies and promotes more sustainable transport: electric cars, self-driving busses and ferries
- New technology change the job market: self-checkouts, robotized industry
- Sharing society: develop an app which facilitates for car sharing
- Digital communication reduces travelling and improves community services: e.g., Digipost, online banking, Skype
- Digital tuition and lectures
- Medical technology improves health services

F Interview Guide - Norwegian

Intervjuguide

Del 1 ca. 30 min
Utfylling av arbeidsark

Del 2 ca. 30 min
Spørsmål - semistrukturert

1. Plasser de tre viktigste kompetansekortene fremst. Deretter plasser de tre minst viktigste bakerst. *(husk: ta bilde)*
    a. Hvilke kompetanser har du inntrykk av at er godt integrert i dag?
    b. Hvilke kompetanser tror du burde være bedre integrert?

2. Plasser de tre viktigste læringstemakortene fremst. Deretter plasser de tre minst viktigste bakerst. *(husk: ta bilde)*
    a. Hvilke læringstemaer har du inntrykk av at er godt integrert i dag?
    b. Hvilke læringstemaer tror du burde være bedre integrert?

3. Har du en formening om hvor godt bærekraft er integrert på studieprogrammet i dag?

4. Hvor viktig synes du det er å lære studentene om bærekraft på studieprogrammet?
    a. Hva tror du er den beste måten å integrere bærekraft i studieprogrammet?
        i. Hvorfor?
    b. Hvor viktig tror du samarbeid mellom emner og faglærere vil være?

5. Vet du hva som blir gjort for bærekraft innenfor fagfeltet til emnet?
    a. Hva er bærekraftsutfordringene i dag?
        i. Hvilke barrierer er det som må brytes?
        ii. Langsiktige utfordringer

6. Hva er de største utfordringene for å integrere bærekraft i ditt emne?
    a. Føler du at du har nok kunnskap om bærekraft til å integrere det?
        i. Er det vanskelig å vite hvordan man kan integrere bærekraft?
    b. Er det vanskelig å få plass til bærekraft i emnet?
        i. Passer bærekraft dårlig inn i emnet?

7. Kan jeg ta kontakt med deg igjen om jeg har tilleggsspørsmål på et senere tidspunkt?

8. Er det noe mer du ønsker å ta opp før vi avslutter?

G Individual Ranking of Competencies and Learning Themes by Educators

G.1 Educator 3

Competency	Points	Learning Theme	Points
Creativity Competency	2	Circular Economy	2
Integrated Problem-Solving Competency	2	Reasonable Use of Materials and Resources	2
System Thinking Competency	2	Sustainable Use of Energy Sources	2
Self-Awareness Competency	-2	Consequences for Biodiversity and Wildlife	-2
Normative Competency	-2	Equality and Universal Design	-2
Strategic Competency	-2	Good Working Conditions	-2

Table 19: Ranking of competencies and learning themes by Educator 3.

G.2 Educator 4

Competency	Points	Learning Theme	Points
System Thinking Competency	3	Impact on Infrastructure	3
Transdisciplinary Collaboration Competency	2	Reasonable Use of Materials and Resources	2
Integrated Problem-Solving Competency	1	Sustainable Use of Energy Sources	1
Anticipatory Competency	-1	Consequences for Biodiversity and Wildlife	-1
Strategic Competency	-2	Equality and Universal Design	-2.5
Self-Awareness Competency	-3	Good Working Conditions	-2.5

Table 20: Ranking of competencies and learning themes by Educator 4.

G.3 Educator 5

Competency	Points	Learning Theme	Points
Creativity Competency	3	Sustainable Use of Energy Sources	3
Integrated Problem-Solving Competency	2	Impact on Infrastructure	2
Strategic Competency	1	Consequences for Biodiversity and Wildlife	1
Self-Awareness Competency	-2	Equality and Universal Design	-1.5
Normative Competency	-2	Consequences for Humanity	-1.5
Transdisciplinary Collaboration Competency	-2	Good Working Conditions	-3

Table 21: Ranking of competencies and learning themes by Educator 5.

H Quotes in Norwegian from Section 4.2

H.1 Perception on Sustainability Today

> "... men husk at på universitetet tar det veldig lang tid å snu kulturen, så jeg tror vi er på god vei egentlig, ... Så vi erkjenner at vi har et stort potensial for forbedring, og det er krefter på instituttet som jobber for å få den forbedringen."

Box 35: Educator 3 on how sustainability is integrated in the study programme today. English version in Box 5.

> "... Men det jobbes med det, det gjør det jo. Og vi er nok ikke, jeg tror ikke vi er noe bak. Altså det finnes helt sikkert studieprogram på NTNU og ellers i Norge som ligger fremfor oss, men jeg tror også vi ligger fremfor ganske mange, så vi er vel sånn relativt brukbart i prosess med det."

Box 36: Educator 5 on how sustainability is integrated in the study programme today. English version in Box 6.

> "... Altså systemtenkning det er helt ufrakommelig når du skal forstå et elektronisk system ..."

Box 37: Educator 3 reasoning when filling out worksheet for "system thinking" competency. English version in Box 7.

> "Og NTNU har jo, hva er det, "Konstruktiv, Kreativ, Kritisk og" en ting til. Ja, i hvert fall kreativ er blant dem her fire ordene til NTNU. Og det er vel kanskje en av dem styrkene som norske ingeniører har sammenlignet med mange andre også. At når dere kommer ut herfra, så har dere en grunnholdning til at her kan vi finne på mange lure ting. ..."

Box 38: Educator 5 reasoning when ranking three most important competencies. English version in Box 8.

> "... Så jeg tenker de lærer jo å bli ingeniører, og ingeniører lærer å løse komplekse problemer ..."

Box 39: Educator 1 reasoning when filling out worksheet for "integrated problem-solving" competency. English version in Box 9.

"... Selv om at når vi trener studentene i disse tingene her, så tenker vi ikke nødvendigvis bærekraft, men mer sånn generelle kompetanse, men at vi da sikkert nok kan få det inn å tenke, og også bruke det ovenfor bærekrafttematikk da."

Box 40: Educator 3 reasoning when asked about which competencies the study programme are performing well in. English version in Box 10.

"Ja, altså i den forstand, altså hvis knyttet opp mot bærekraftsutfordringer sånn som det står der, så gjør vi jo ikke det, men mer sånn på ingeniørkompetanse, så er det jo igjen prosjektoppgaven hvor du får øving i det da."

Box 41: Educator 5 reasoning when filling out worksheet for "integrated problem-solving" competency. English version in Box 11.

"... altså dem aller fleste studentene våre har jo veldig god både kunnskap på det generelle nivået og ser det som viktig. Så det vi må prøve er jo da å eksemplifisere det, så godt som mulig da sånn at man konkretisere det i det enkelte fag og i studieprogrammet. At, sånn at man, når man da kommer ut i andre enden faktisk kan ta det man har lært om sirkulær økonomi eller om energieffektiv elektronikk om ja, og anvende det da, for en bedre verden da."

Box 42: Educator 5 when asked about the importance of teaching students about sustainability. English version in Box 12.

"Altså jeg tror jo ikke det er noe ukjent begrep for studenter i dag. Eller, det er ikke noe man kommer med som er veldig nytt, så det er jo bare å minne om bærekraften i alle fag da. At man har fokus, hva skal jeg si, at man har det med i tankegangen. Sånn at det på en måte bare kommer inn med, blir en del av ryggmargsrefleksen å tenke på sånne ting når man siden skal ut i jobb å bidra i samfunnet da. ... "

Box 43: Educator 4 when asked about the best way to integrate sustainability in the study programme. English version in Box 13.

H.2 Important Competencies and Learning Themes for the Study Programme

"... Så jeg vil si at det er de tre viktigste, i betydning, dem tre områdene der vårt studieprogram faktisk kan ha et vesentlig bidrag. ... så er det ikke for at dem her ikke er viktige, men jeg tror at vi har et mindre potensial for å ha et viktig bidrag på dem."

Box 44: Educator 3 reasoning when ranking competencies. English version in Box 14.

"... at ikke det er det som er hovedfokus som læringsmål i våre fag. Men allikevel er det viktig at studentene våre får det i fag, i studieløpet, men ikke nødvendigvis i de fagene som vi gir selv da. Og hvis vi da på motsatt rekkefølge, sier da, skal si "ok, hvilke av de her er naturlig at blir direkte berørt av fag som vi gjør". "

Box 45: Educator 5 reasoning when ranking learning themes. English version in Box 15.

"... Men det er jo også den muliggjøringsteknologien som vi fremkaller, som jo gjør at mange andre samfunnssektorer kan sørge for bærekraftig bruk av energikilder da. ..."

Box 46: Educator 5 reasoning when ranking learning themes. English version in Box 16.

"... det finnes nesten ikke produkt i dag som ikke har elektronikk i seg, så det er nå et veldig, veldig viktig fagfelt for alt som skjer i samfunnet, når du tenker på det på den måten. Såkalt muliggjørende teknologi, enabling technology. ..."

Box 47: Educator 3 answering about what is being done for sustainability in the field for their course. English version in Box 17.

"... Og resten er på en måte, det er nesten sånn at alle dem andre kan på sett og vis ligg der, og dermed så blir dem ganske uaktuell å ha som at dem ikke er relevant da. ..."

Box 48: Educator 5 when ranking learning themes. English version in Box 18.

"... For å si det spesifikt. Alle sammen er viktige, men det finnes en del andre studieprogram som bør ha dette her høyere på agendaen. Enn må ha en viss arbeidsdeling mellom forskjellige studieprogram og forskjellige miljø ... "

Box 49: Educator 3 reasoning when ranking learning themes. English version in Box 19.

H.3 Integrating Sustainability in Specific Courses

"... Men det er nesten sånn at alle tema kan du vri til i eksempelbruk, men spørsmålet er hvor stor funksjon har det. Altså hvis det blir veldig søkt, så blir det kanskje heller litt mot sin hensikt, kanskje. Jeg vet ikke."

Box 50: Educator 3 when filling out the worksheet for "impact on infrastructure". English version in Box 20.

"Det er det som jeg kaller styrke og kondisjonstrening. Hvis du skal bli en god fotballspiller så må du naturligvis øve på å sparke fotball, men man må også ha en del sånn styrke og kondisjonstrening. Men hvis bare styrke og kondisjonstrening, og du aldri får sparke i ballen, så blir du ikke fotballspiller. Så jeg tenker også i elektrofaget. Hvis man bare sitter og regner på konstruerte abstrakte eksempler, så blir du ikke ingeniør. Så vi prøver hele tiden å knytte teorien opp mot konkrete eksempel. ..."

Box 51: Educator 3 when filling out the worksheet for "anticipatory" competency. English version in Box 21.

"... Men det er ikke inkludert i hvert fall. Vi snakker lite om det, som sagt så kan vi nok snakke litt om det, men vi fokuserer ikke så mye på strømforbruket. ... Så jeg tenker vi kan smekke den "kan inkluderes" der også, fordi det på en måte er absolutt noe å tenke på å snakke om."

Box 52: Educator 1 when filling out the worksheet for "sustainable use of energy sources". English version in Box 22.

"Ja, fordi det er det som på en måte må være målet i det her da. At man går ut ifra NTNU med et sett av holdninger som gjør at man faktisk vurderer sånt, fordi det er det vel mange som ikke tenker over i det hele tatt i dag."

Box 53: Educator 5 when filling out the worksheet for "consequences for humanity". English version in Box 23.

"... så jeg tror nok kanskje største utfordringen er det å være bevisst, tenke på det, og faktisk gjøre ting for og. For jeg tror ikke, det er ikke veldig vanskelig å få inn mer av det i emnet mitt. Når det gjelder hva slags eksempel en bruker, men det må gjøres, og da må en huske å gjøre det, og en må prioritere å gjøre det. Det er vel der utfordringen ligger egentlig."

Box 54: Educator 3 when asked if they feel like they have sufficient knowledge to integrate sustainability. English version in Box 24.

"... også det her er jo en sånn evig kamp om tiden i hverdagen. Hva, hvor føler man at man kan bidra på en god måte, og der man føler at man kan bidra på en god måte, der, det bruker man tid på og deltar på. ... og i og med at vi er vitenskapelig ansatte som helst ikke vil styres alt for mye, så bør det ikke være pekefingeren som sier at "Du skal gjøre det her", men vinklet på en sånn måte at man blir motivert og skjønner sammenhengen. ..."

Box 55: Educator 5 when asked about the best way to integrate sustainability. English version in Box 25.

"... Selv om enkelte av kollegaene mine synes det er frustrerende at dette her begrepet er så mangfoldig, og det er det. ... Så det er klart at det begrepet bærekraft er nok, er veldig mangfoldig, og blir kanskje litt diffust da. Og en del av disse her målsetningene kan ofte og stå mot hverandre. At du kan ikke oppfylle alle disse her på en gang. Så begrepet er ikke uproblematisk ..."

Box 56: Educator 3 when asked about the importance of teaching students about sustainability. English version in Box 26.

"... Ja, altså det er jo. Jeg er jo ikke noen ekspert i bærekraft sånn sett, men jeg er jo som et normalt menneske som følger med på ting, som plukker opp ting, og det er jo tema mange steder, men det er klart at man kan alltid bli bedre på ting også da. ..."

Box 57: Educator 4 when asked if they feel like they have sufficient knowledge to integrate sustainability. English version in Box 27.

"... så hvis jeg for eksempel skal dekke noe sånt i et fag, så må jeg tilegne meg kompetanse, eller hente inn gjesteforelesere, eller ett eller annet i den banen for å kunne gi en fornuftig diskusjon rundt det da. ... for det som er relevant i kursene som jeg holder på med, så har jeg vel grei kompetanse, men ikke på de her litt mer store bildene, nei."

Box 58: Educator 5 when asked if they feel like they have sufficient knowledge to integrate sustainability. English version in Box 28.

"Ja, du må være litt kreativ, og det kan en si at den tiden du ikke har selv, altså jeg har veldig gode erfaringer med å gi studentene oppgaver til å forbedre faget. Altså bruke sommerstudenter, og gjør en del oppdrag i å forbedre ting, og de kan ha masse ideer som jeg ikke har tenkt på, så her er absolutt muligheter for den som ønsker å gjøre noe."

Box 59: Educator 3 talking about involving summer students at the end of the interview. English version in Box 29.

H.4 Vision on Sustainability

"... Noe av problemet med utdanning, det gjelder ikke bare her, det gjelder over hele verden, og alle institusjoner, er at ting er veldig oppdelt i båser. Og det er nok ikke bare dumt. Det har med arbeidsdeling å gjøre, og det har med spesialisering å gjøre, og det har med konsentrasjon og fokus å gjøre. Det er mange grunner til å dele opp utdanningen i ulike emner, men man må ikke gå glipp av helheten heller."

Box 60: Educator 3 when asked about the importance of cooperation between courses and educators. English version in Box 30.

"... Og at vi har en helhetlig tankegang rundt det, sånn at det ikke bare blir klatt i hvert enkelt fag, og at det da typisk vil bli masse overlapp mellom fagene også, fordi da virker det mot sin hensikt. Så det må. Og der er vi definitivt ikke i dag. For det er ikke lagt en overordnet plan for hva som skal håndteres i hvilke fag, så vidt som jeg vet i hvert fall ..."

Box 61: Educator 5 when discussion how well sustainability is integrated in the study programme today. English version in Box 31.

"... men det klart det er jo viktig at vi har et felles mål om at det skal være en del av undervisningen og slike ting ..."

Box 62: Educator 5 when asked about the importance of cooperation between courses and educators. Norwegian version in Box 32.

"... så er jo kanskje det og bare få det inn som en sånn kultur, tankegang som ligger der vel så viktig som å sette seg ned å snakke enn masse om det. At det bare understøtter alt man gjør. ... men å ha noe sånt eget bærekraftfag eller noe sånt. Det ser jeg egentlig ikke noe poeng med da. Jeg synes det skal gjennomsyre alt som sagt."

Box 63: Educator 4 when discussion how well sustainability is integrated in the study programme today. English version in Box 33.

"Nei, det er absolutt ikke et eget fag. Dette har med kultur å gjøre. Det har med holdninger å gjøre. Og holdninger de bygger mye over tid ... også må prege hele måten vi arbeider på, og det er en lang prosess, det er nok det altså."

Box 64: Educator after a question about if a sustainability course should be an option. English version in Box 34.