A Systemic Approach to implement Education for Sustainable Development in Applied Sciences

A Case-study of the TU Delft Applied Sciences Faculty

P. Wijnia

TU Delft

Universiteit Leiden
The Netherlands

A Systemic Approach to implement Education for Sustainable Development in Applied Sciences

A Case-study of the TU Delft Applied Sciences Faculty

Thesis report

by

P. Wijnia

to obtain the degree of Master of Science
at the Delft University of Technology
and Leiden University
to be defended publicly on February 27, 2024 at 13:30

Thesis committee:

Supervisors:	Dr. A.R. Gammon
	Dr. L.M. Kamp
Place:	Faculty of Technology, Policy and Management, Delft
Project Duration:	September, 2023 - February, 2024
Student number:	4582977 - s3039897

An electronic version of this thesis is available at http://repository.tudelft.nl/.

Front cover generated by OpenAI. (2023). ChatGPT 4 (December 30th version) [Large language model]. https://chat.openai.com

Leiden University · Delft University of Technology

Preface

Dear reader,

I deeply appreciate your commitment to reviewing (excerpts of) my MSc thesis. Since my arrival at the TU Delft campus in 2017, I have been profoundly grateful for the opportunity to study among a community of highly talented and inspiring individuals. For quite some time, I have felt a strong desire to contribute to societal and environmental betterment. Throughout my tenure in Delft, I have actively participated in student boards such as Students4Sustainability and GreenTU, as well as various committees and teams, including the Greenteam Applied Sciences. These experiences have given me the community in which I have felt most at home: with the ones who want to make an impact.

As I approached the conclusion of my academic tenure, the determination to promote sustainability within the TU Delft system remained resolute, particularly with the publication of the *Vision, Ambition and Action Plan for a Climate University* still in mind (Van Den Dobbelsteen & Van Gameren, 2022). Given my background in BSc Nanobiology, the AS Faculty of TU Delft holds a special significance for me. Recognizing the potential impact of the faculty and its stakeholders in combatting climate change, I embarked on this thesis journey with a clear sense of purpose. The culmination of my experiences with GreenTU led me to select a thesis topic aligned with the collective vision of our community. Through collaboration with the participants of this study, I am optimistic about our ability to effect positive change and contribute meaningfully to TU Delft's overarching sustainability agenda. The primary focus of this thesis is to catalyze constructive change in accordance with the Vision, Ambition, and Action Plan of TU Delft, with the hope of igniting a cascade of positive transformation.

First of all, I would like to start by expressing my gratitude to my family: Charlie, my parents Ellen & Roy, Hessel, Oma Joke, Oma Coby, Leon, Sandra, Leslie, Arthur and the Tromp family. Thank you for always supporting me, applauding me during every step and making me the person I am today. In loving memory of Oma Dien, Opa John and Opa Meindert, who will always be remembered and cherished.

Second of all, I want to thank my supervisors Andrea and Linda for the constant support and guidance. These past six months, I have felt nothing but empowered by you. The advise you have given me did not only benefit this thesis, but will help me in my next steps in life. I am also grateful to all the interview and focus group participants who took part in this research and dedicated their time to share their invaluable insights.

Thirdly, I extend my gratitude to my friends. Your enthusiasm for my impact-driven character, your guidance, and your encouragement have not only enhanced the quality of my work but have also contributed to unforgettable moments throughout my student journey. I cherish our friendships and look forward to the continued joy and shared experiences ahead.

Lastly, I want to express my gratitude for the core-team of sustainability, who I am lucky to join during my next step as the project leader sustainability.

Feel free to reach out any time, I would love to talk more about my thesis topic, the climate related goals of TU Delft and actually everything sustainability and climate change related.

P. Wijnia
Rotterdam, February 2024

Executive Summary

This thesis addresses the imperative role of engineering education in preparing students for climate change challenges. Despite widespread efforts in higher (engineering) education institutions (H(E)EIs) to implement education for sustainable development (ESD), there is often a lack of effectiveness, leading to a return to the previous status quo. Additionally, literature on applied sciences (AS) institutions and (systemic) ESD implementation is lacking. The study focuses on the AS Faculty at TU Delft, which, despite ambitious climate goals, exhibited a low percentage of courses addressing sustainability. The emphasis is on a systemic approach for ESD implementation, aiming to provide recommendations for the education portfolio of the Climate Action Plan of the AS Faculty of TU Delft.

Initially, the study conducted an extensive literature review on the implementation of ESD and systemic change within HEEIs. The findings elucidated specific strategies, barriers, drivers, and uncertainty factors, with a particular emphasis on the significance of context and culture. The exploration of literature on ESD implementation in HEEIs aided in comprehending the system, while research on systems change facilitated the formulation of strategies for cultural and institutional transformation in the last phase of the research.

Following the literature review, two case studies on the NHL Stenden and Van Hall Larenstein universities of applied sciences were undertaken to connect theoretical insights to the context of the AS Faculty at TU Delft. The case studies provided real-life systemic ESD implementation examples and illustrated associated challenges and successes. Subsequently, the AS Faculty of TU Delft was investigated through interviews with a diverse array of stakeholders relevant to ESD implementation, ranging from management to students. The exploration revealed the faculty's engagement in (collaborative) top-down and bottom-up initiatives, such as modifications in the Master program in Chemical Engineering and the implementation of the Green Thread initiative. Additionally, in response to guidance from the university's sustainability core team, the faculty established a Climate Action Team comprising two local sustainability coordinators. This team is currently devising a Climate Action plan, including an educational portfolio, which can draw insights from the research conducted in this study.

Throughout two rounds of interviews, twelve influential thematic variables and their associated barriers, drivers, and uncertainty factors were identified. The twelve influential variables include Implementation Level, Integration Approach, Resources, Communication, Internal Collaborative Culture, Faculty Support, Student Support, Involvement of Internal AS Stakeholders, Perception of Sustainable Development-Faculty, Synergies between Different Areas, Internal Culture AS, and Perception of Own Influence. The overview of variables highlighted the fluidity and context-specificity of barriers, drivers and uncertainty factors. For instance, drivers can quickly become barriers or sources of uncertainty if not executed effectively. Moreover, the overview showed the complexity of and the relations between the thematic variables.

A focus group SWOT analysis further explored these variables, examining internal and external influences. The resultant SWOT outcomes were then synthesized with systemic change drivers identified in literature to develop five strategies (ST1 to ST5). These strategies aim to help structure the education portfolio of the AS Climate Action Plan and guide the faculty's systemic change approach to integrating ESD throughout its entire academic program. The five strategies focus on change direction (ST1), context and culture (ST2), planning and preparation (ST3), design and implementation (ST4), and maintaining momentum and sustaining change (ST5). These strategies recognize the interconnectedness of strengths, weaknesses, opportunities, threats, and systemic change drivers. ST1 highlights the significance of involving all levels of the organization and securing continuous support from top management. It suggests forming a task force alongside the Climate Action Team to ensure diverse participation and endorsement from higher authorities. ST2 aims to embed sustainability into the faculty's values and practices, addressing its individualistic, rational, competitive, and technology-driven culture. Encouraging open discussions, inclusivity, and transparency is emphasized for managing diverse viewpoints on sustainability and climate issues. ST3 underscores the need for establishing a dedicated management team, allocating time for impact assessments, and providing pedagogical training. Collaboration with external perspectives, other faculties, and ongoing engagement with identified factors are recommended. ST4 emphasizes active faculty

involvement in curriculum design, accommodating different teaching methods, and reviewing program objectives to smoothly integrate changes. It advocates for a collaborative approach to minimize resistance and avoid content redundancy. ST5 stresses the importance of continuous dialogue, systematic impact assessments, and ongoing faculty engagement in educational improvement. It highlights the need for consistent communication, reflective practices, and involving new faculty members post-implementation.

ST1, ST2, and ST3 play crucial roles in the initial stages of developing the Climate Action Plan for the AS Faculty, followed by the execution of ST4. Over the long term, priority should be given to ST5. As the plan progresses, it's vital to regularly evaluate all five strategies. Additionally, it's recommended to periodically review the identified drivers, barriers, uncertainty factors, strengths, weaknesses, opportunities, threats and their interconnections. The study emphasizes the significance of intrinsic motivation, institutional culture and the Climate Action Team, urging for resource allocation and sustained (public) support from the faculty's top-management. Team-based initiatives, such as the creation of a task force, are deemed beneficial for navigating the transition.

Furthermore, the study underscores the intricate nature of ESD implementation, requiring support at all organizational levels. Cultural aspects within the AS institution, such as its individualistic, rational, a technology-fix mindset, competitive character, and a keen interest in fundamental sciences, are deemed critical and should be embraced rather than seen as an obstacle in order for intrinsic motivation to be enhanced. The identified drivers, barriers, uncertainties, strengths, weaknesses, opportunities, and threats offer insights into the institutional culture, emphasizing the need for open discussions and transparent communication on the definition of sustainable development and climate change, and recognizing the threat of polarization within the faculty.

Despite acknowledging context-specificity, questions are raised about the transferability of data on barriers, drivers, and uncertainty factors from other institutions. Although cultural understanding is widely recognized as crucial, institutions should be urged to seek insights from one another rather than feeling compelled to innovate solely independently. Furthermore, the significance of sharing knowledge and experiences within the AS faculty is emphasized. Moreover, the study demonstrates how the SWOT analysis methodology can be effectively utilized within educational environments. It highlights the integration of SWOT analysis with other qualitative methods, such as interview-based preparatory steps and strategies outlined in existing literature. By constructing a detailed profile of the HEEI, this approach aims to refine the accuracy of the SWOT analysis, thereby enhancing the likelihood of successful strategy implementation. Similarly, the study suggests synthesizing SWOT outcomes with strategies derived from literature, thus enriching the analysis.

The study concludes by recommending a follow-up to monitor the effectiveness of proposed strategies and suggests further exploration of dynamics and outcomes related to the Climate Action Plan. Essentially, this study acts as a catalyst for instigating conversations within the faculty, endorsing the prospect of broader discussions similar to those held during the focus group, with the potential to positively impact the AS community.

Contents

Nomenclature

List of Abbreviations

ABET	Accreditation Board for Engineering and Technology
AISHE	Auditing Instrument Sustainability in Higher Education
AS	Applied Sciences
EOP	Engineering for One Planet
ESD	Education for Sustainable Development
ESE	Environmental and Sustainability education
GAP	Global Action Program
GreenTU	GreenOffice TU Delft
HE	Higher Education
HEEI	Higher Engineering Education Institution
HEI	Higher Education Institution
JRC	Joint Research Centre
LfS	Learning for Sustainability
LSC	Local Sustainability Coordinator
MT	Management Team
PI	Principle Investigator
R1	Interview Round 1
R2	Interview Round 2
R3	Focus Group Round 3
SD	Sustainable Development
SDG	Sustainable Development Goals
SE	Sustainability Education
SRQ	Sub-research question
TU	Technical University
TUD	Technical University of Delft
WIA	Whole Institution Approach

List of Figures

List of Tables

1

Introduction

1.1. The importance of education pertaining to climate change

Every second, our world faces an escalating array of environmental and social challenges that threaten Earth's sustainability and our very ability to inhabit it. What's truly astonishing, as highlighted by Vare et al. (2022), is that we are well aware of the consequences of our actions. The pressing question that looms is why we persist in behaviors that contribute to the depletion of our planet's resources—a conundrum commonly referred to as the knowledge/action gap in climate change (Knutti, 2019).

Sammalisto et al. (2015) emphasize a dual responsibility for universities when it comes to education: disseminating knowledge about sustainable development and nurturing education for sustainable development. Education must not only elucidate the mechanics of climate change but also illuminate pathways toward sustainable development, encompassing environmental, social, and economic dimensions. It's crucial to recognize that merely providing knowledge alone may not suffice (Knutti, 2019).

De Haan (2006) champions the pivotal role of scholars and educators, those who possess the agency to actively shape and mold our society's future. Educators wield substantial influence in shaping the trajectory of society, spanning social, economic, technological, and ecological dimensions, all in alignment with sustainable development goals. Wiek et al. (2011) accentuate the significance of integrating topics related to sustainable development and climate change into curricula and higher education programs. Graduates from institutions of higher learning are poised to constitute a workforce that assumes a pivotal role, leading by example and making critical decisions (Weiss et al., 2021).

Despite the global proliferation of sustainability courses and programs (Brundiers et al., 2021), the effectiveness of graduates in applying knowledge, concepts, and skills from this domain to real-world scenarios remains wanting (Trencher et al., 2018). This shortfall often arises from a disconnect between theoretical and conceptual knowledge and practical, experiential learning, including collaborative initiatives with societal stakeholders. Trencher et al. (2018) contend that research-focused programs should incorporate practical, real-world learning projects involving external stakeholders, potentially bridging the aforementioned knowledge/action gap.

Moreover, customization to specific audiences becomes paramount, as capacities and objectives significantly diverge across disciplines (Wiek & Lang, 2016). The overarching aim is to equip students with the competencies, motivations, and attitudes necessary to combat climate change. However, the strategies to attain this objective appear to vary across different career trajectories (Trencher et al., 2018).

One notable instance of educational institutions in need of restructuring pertains to engineering institutions, which have the potential to instill in all future engineers a profound comprehension of the fundamental tenets of environmental and social sustainability. This need of change is of high importance as the engineer will assume accountability for critical decisions that will have to be made in the near future and will be accountable for addressing global challenges and threats (Olga et al., 2020). As posited by Leydens and Lucena (2017), engineering education often exhibits a deep-rooted rigidity, predominantly emphasizing technical minutiae while overlooking the social dimensions of engineering. This inclination is attributed to

the prevailing engineering workforce and culture, which frequently neglects social injustices, traditions, and unconscious biases. The predicament appears systemic, necessitating comprehensive transformation at all levels (Graham, 2012).

1.2. The role of engineering education: a case-study of the Technical University of Delft

One of those engineering institutions is the Technical University of Delft, the Netherlands. In 2022 TU Delft published the Sustainable TU Delft: Vision, Ambition and Action Plan for a Climate University (Van Den Dobbelsteen & Van Gameren, 2022). A document in which TU Delft pledges for a climate neutral campus in 2030 and which has now been approved by their Executive Board. The document presents a comprehensive framework outlining the goals, aspirations, and strategic steps for establishing a climate-focused university. In this document, TU Delft sets two general aims and principles for its Education for Sustainability portfolio:

- To deliver scientists, engineers and designers who can contribute to a better world.
- To include the topic of climate change, climate mitigation and climate adaptation in all forms of education offered by TU Delft.

In order to reach these goals, one must have a critical attitude towards sustainability and the current education system of TU Delft. One must be attentive of the technical, environmental and social perspectives on sustainability of all stakeholders at the university, not of only the educators and the scholars. Every faculty has its own structure and often behaves as an ecosystem by itself. Frameworks and tools will have to be specifically adjusted to specific programs in order to be successful (Trencher et al., 2018). However, one must not lose systems perspective and get lost in the details of the university.

In September 2022 a project, led by researcher Monika Roeling, was initiated at TU Delft to investigate the current sustainability education status of all programs at TU Delft and to advise the best way forward. First, an inventory was made based on the Studiegids that showed that only 15 percent of all Bachelor and Master courses of TU Delft mention/have involved topics on sustainability and climate change (Figure 1.1). The next steps for Monika Roeling's research will focus on creating a sustainability education focused road map for TU Delft. The end goal is to have implemented sustainability in all different educational program types (TU Delft., n.d.-a). As the university has over 1200 courses this is an enormous task that could be partly accelerated by the support of this project.

Furthermore, TU Delft does have experience with employing (systemic) change strategies when it comes to sustainability focused education (Kamp, 2006). In 1998 the university adopted an environmental policy plan that demanded sustainability to be incorporated into engineering curricula, but this appeared to be deficient. A training about sustainability efforts only triggered resistance instead of motivating lecturers. The reason for this was the fear of the teaching staff of loss of authority. Success was found in Faculty Learning communities where the program was focused on Individual Interaction Method (also known as ask-the-teacher). Instead of forcing top-down change, the central question was how every (sub-)discipline could contribute to sustainability. This gave lecturers ownership of the issue and eventually resulted in courses being changed (Kamp, 2006). However, the current state of these modified courses is unknown. This emphasizes the importance of yearly evaluation and documentation.

An initiative called the Green Thread originated in 2020 in order to help lecturers implement more sustainability topics in their courses without losing time and energy. This bottom-up initiative connected teaching assistants with lecturers and aimed to incorporate sustainability horizontally into the education levels of TU Delft. However, this initiative was put on hold in September 2021 when Monika Roeling's project started.

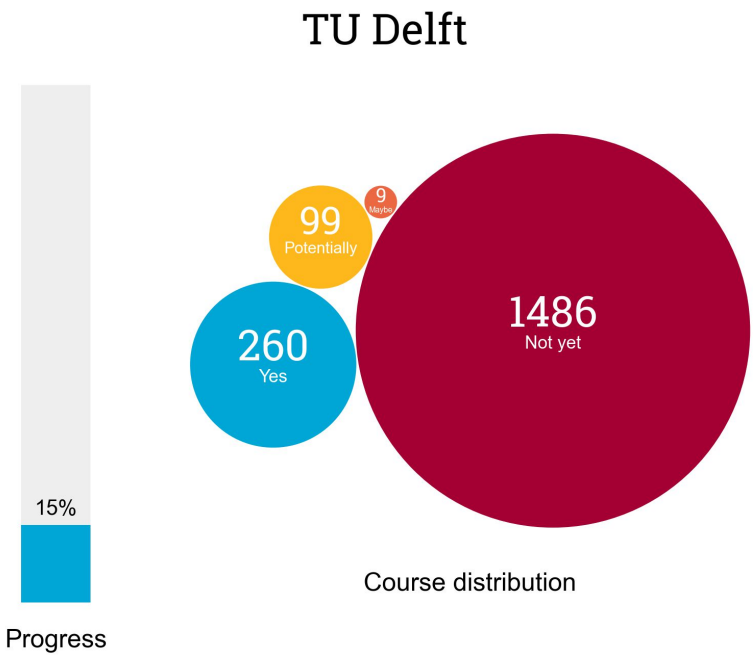

Figure 1.1: The total number of TU Delft courses that have (blue circle) or have not (red circle) included sustainability topics. The yellow circle shows that 99 courses have a high chance of having included sustainability topics, but of which it is not yet clear. The small light red circle shows that 9 courses have a low chance of having included sustainability topics, of which it is again not obvious from the Studiegids. Duplicated from researcher Monika Roeling's inventory performed in 2023 on 2023 data.

1.3. Education for sustainable development and systems change

In the context of the Vision, Ambition, and Action Plan for a Climate University, sustainable education encompasses dimensions of social, ecological, and economic sustainability (Van Den Dobbelsteen & Van Gameren, 2022). The plan emphasizes that sustainability implies an approach to development that fulfills immediate societal needs while safeguarding the prerequisites of future generations. The central inquiry at the university pertains to the nature of effective sustainability education and the characteristics of the most sustainable educational approach. Wiek et al. (2011) posit that sustainability education equips students with the skills to deconstruct and resolve sustainability challenges, anticipate and prepare for impending climate change threats, all the while facilitating the creation and utilization of opportunities for sustainability.

Sammalisto et al. (2015) underscore how education for sustainable development (ESD) empowers students to navigate the complexities of society and instills in them the responsibility to combat climate change. Radinger-Peer et al. (2021) highlight the distinctive features of higher ESD, which involve the co-creation of knowledge through collaborative partnerships with external entities and a heightened commitment to engaging with local and regional communities. Universities are urged to assume a sustainable developmental role, which encompasses endeavors such as the integration of regional imperatives into both educational and research endeavors.

Furthermore, universities are encouraged to pivot their focus towards interdisciplinary and trans-disciplinary methodologies, thereby facilitating the convergence of diverse forms of knowledge. Notably, these characteristics of ESD align with the foundational principles underpinning TU Delft's 2030 vision. There are large variations in perceptions on the concept of sustainability, which stresses the need for interpretational flexibility between different disciplines. This argument gives the opportunity to explore what education for sustainable development entails for a faculty of TU Delft.

Next to universities having difficulties to define the concept of sustainability, the issue appears to be systemic. Research shows that redesigning one aspect of the curriculum rarely leads to broader changes in undergraduate schools. Institutions should internally develop new methods that align with the institution's priorities and intentionally strive to be distinct (Sammalisto et al., 2015). This means that it is important to research first which specific strategies are needed for a faculty's educational programs to be changed systemically. Weiss et al. (2021) press that higher education institutions should examine their own systems and determine if any of these patterns (or a combination thereof) are applicable to their situation.

1.4. An opportunity for change at the applied sciences faculty of TU Delft

In the first months of 2024, all TU Delft faculties and services are expected to submit a proposal regarding their Climate Action Plan. These plans will help reach the university-wide 2030 Goals. In the upcoming months the Climate Action Team of the AS Faculty, existing of two local sustainability coordinators (LSCs), will be constructing their faculty specific climate road map. One of their portfolios focuses on education; specifically, increasing sustainability in the curriculum expected by the vision document. Monika Roeling's research shows how the Applied Sciences (AS) faculty has the lowest percentage of included sustainability topics (7 percent) of all faculties of TU Delft (Figure 1.2). This implies the possibility of addressing the problem at its fundamental core.

It is important to acknowledge the impact AS students and graduates have on climate change. According to the official TU Delft website, graduates in applied sciences discover career opportunities with prestigious companies, including leading energy giants like Shell and BP. Two other examples are the multinational consumer packaged goods giant Unilever, and one of the Netherlands' foremost financial institutions, ING (TUDelft., n.d.-b) (TUDelft., n.d.-c) (TUDelft., n.d.-d).

Research has shown that the upcoming years will have a critical impact on future climate change, risks, and long-term responses (Calvin et al., 2023). As global warming intensifies, the regional shifts in both average climate conditions and extreme weather events become increasingly extensive and noticeable. The IPCC argues that the predominant portion of greenhouse gas emissions, both in terms of quantity and their rate of increase, comes from the combustion of fossil fuels and industrial processes, primarily in the form of carbon dioxide (CO_2). On the 14th of June 2023 fossil fuel company Shell announced their plans to increase their fossil fuel production as the company's executives plan to grow Shell's natural gas

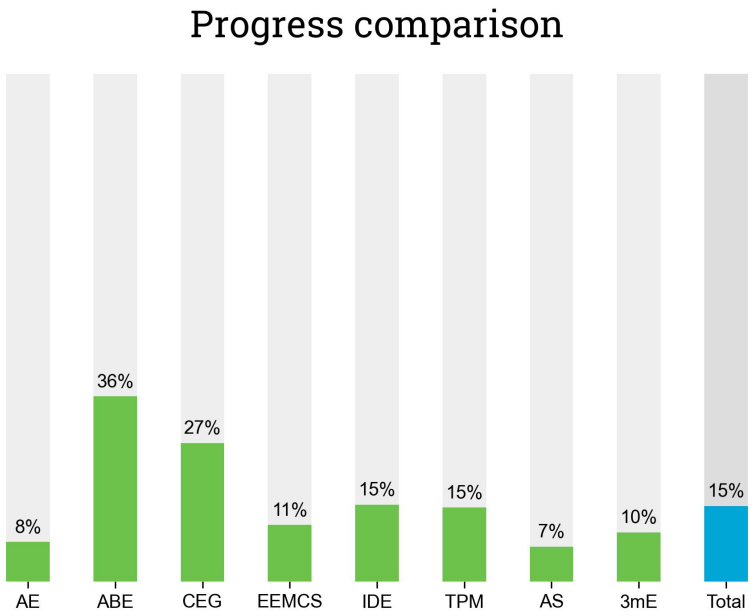

Figure 1.2: In this graph the percentage of courses that have involved sustainability topics is shown per TU Delft faculty, based on the Studiegids. AE stands for Aerospace Engineering. ABE stands for Architecture and the Building Environment. CEG stands for Civil Engineering and Geosciences. EEMCS stands for Electrical Engineering, Mathematics and Computer Science. IDE stands for Industrial Design Engineering. TPM stands for Technology, Policy and Management. AS stands for Applied Sciences. 3mE stands for Mechanical, Maritime and Materials Engineering. Duplicated from researcher Monika Roeling's inventory performed in 2023 on 2023 data.

business (Shell., n.d.). An analysis of these strategies in light of the data presented in the IPCC report reveals apparent discrepancies as can be seen in figure 1.3. It is of paramount significance that graduates in applied sciences, especially those employed by corporations such as Shell, possess a comprehensive understanding of the underlying principles of climate change and are equipped with the necessary skills to contribute effectively to climate mitigation and adaptation efforts.

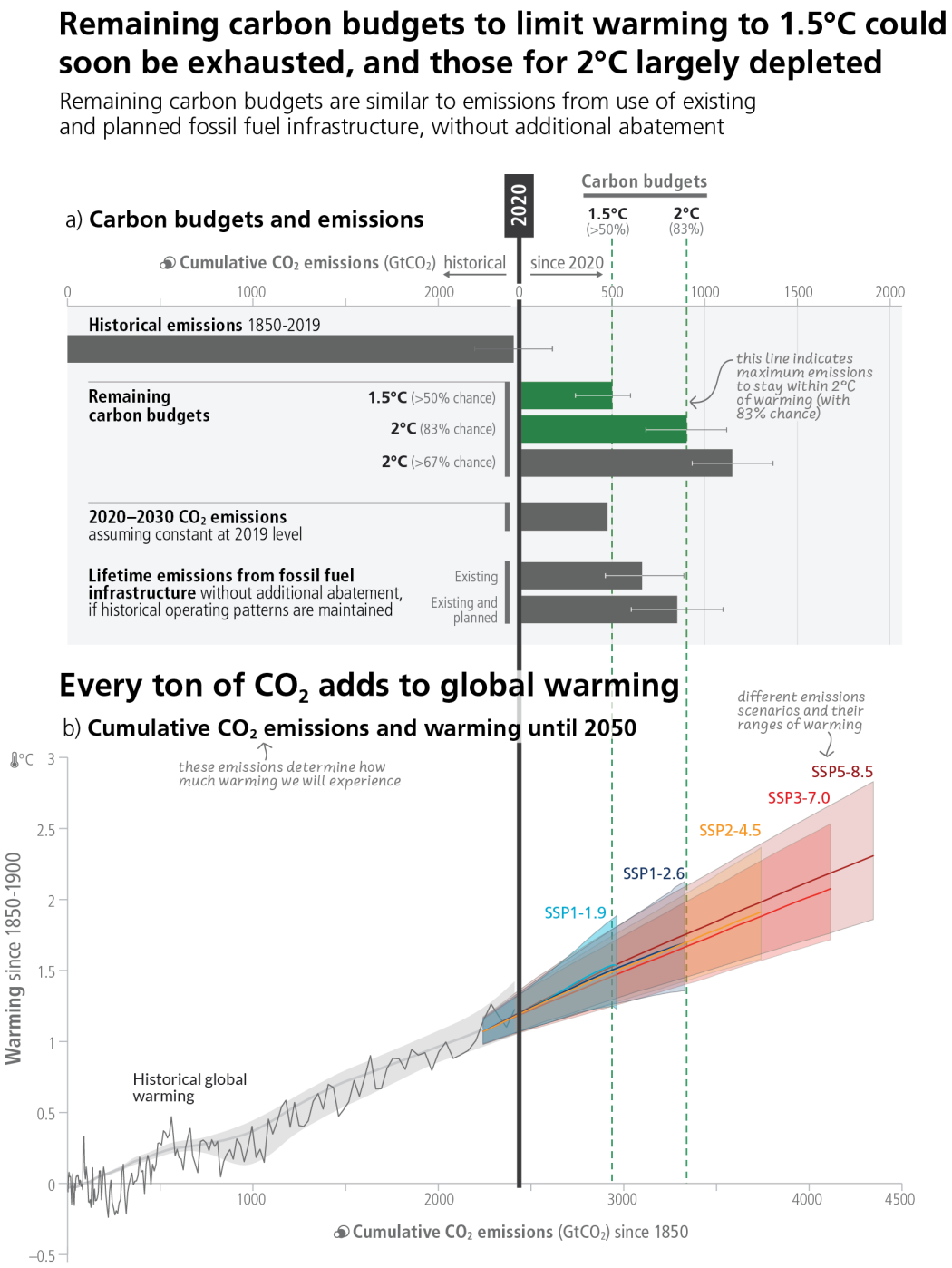

Figure 1.3: Illustrates the cumulative emissions and associated global temperature changes in relation to limiting global warming to 1.5°C, staying below 2°C with various likelihoods, and considering factors like emissions from 2019, existing and planned fossil fuel infrastructure. In Panel (a), it presents the remaining carbon budgets for different temperature targets and the uncertainty due to non-CO2 warming contributions. Additionally, it outlines the sensitivity range for lifetime emissions from fossil fuel infrastructure. Panel (b) shows the connection between cumulative CO2 emissions and the increase in global surface temperature. It incorporates historical emissions, observed temperature increases, and estimates of human-caused warming. The colored areas represent the likely range of temperature projections for different emission scenarios (SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5), with central lines indicating median estimates. Projections until 2050 are based on cumulative CO2 emissions for each scenario, encompassing contributions from all anthropogenic factors (IPCC, 2023).

2

Research Content

2.1. Knowledge gap - education for sustainable development implementation at applied sciences higher engineering education institutions

The IPCC 2023 report underscores the imperative need for a significant reduction in greenhouse gas emissions. One strategic approach to address this challenge is the preparation of future graduates to grapple with the intricate dimensions of climate change, mitigation, and adaptation (Calvin et al., 2023). As previously discussed in Chapter 1, the influence of graduates in applied sciences on the habitability of our planet is of paramount significance. Given the pivotal role these graduates play in combating climate change, it is essential that educational programs within applied sciences faculties commence the incorporation of ESD. Considering the systemic nature of the issue at hand, it becomes crucial to explore strategies for systemic change and the variables of influence. Whether an applied sciences faculty can fully overhaul its curriculum or is constrained to adopt an integration model will substantially shape the structure of the faculty's climate action plan.

Research by Monika Roeling highlights the Applied Sciences faculty of TU Delft as trailing behind all other faculties in its Climate Education Road map. Over the years, various frameworks have been developed for the integration of sustainability-focused education into the curricula of engineering schools. However, it is important to recognize that what works for study programs such as mechanical, civil, and environmental engineering may not necessarily be suitable for an applied sciences faculty. Research appears to be deficient in the context of applied sciences faculties and the implementation of ESD. With the imperative of systemic change in mind, it becomes essential to scrutinize and provide commentary on different HEEIs, considering their approaches' applicability and relevance in the context of the AS Faculty of TU Delft. Furthermore, it should first be explored what the reasoning is behind the current ESD implementation status quo at the faculty. What are the barriers that can hinder ESD implementation? What are the drivers that have been proven to benefit the implementation process? Furthermore, it is imperative to investigate uncertainty factors, variables for which not a hard distinction could be made between it being a driver or a barrier. A detailed explanation of drivers, barriers and uncertainty factor can be found in section 4.1.4. All in all, could this research be a first inventory that guides the AS faculty in their Climate Education Road map.

2.2. Research scope - the applied sciences faculty of TU Delft, the Netherlands

In the context of this research, the specific focus centers on the Applied Sciences (AS) faculty at TU Delft. The rationale for this particular scope is grounded in the author's background and experience. The author possesses a background in Nanobiology, which is one of the four academic programs offered by the AS Faculty. Furthermore, the author has previously participated in a sustainability education-oriented pilot program within the AS Faculty: the Green Thread pilot undertaken by the GreenTeam of

AS (GreenTeamAS). In addition to that has the author been actively engaged with the GreenOffice of TU Delft (GreenTU). The GreenTU involvement has provided the author with insights into the intricate and multifaceted nature of the TU Delft system, including the AS Faculty.

It is noteworthy that each faculty at TU Delft has been assigned a Local Sustainability Coordinator (LSC) tasked with guiding their respective faculty in achieving TU Delft's climate objectives. Part of this responsibility entails the development of faculty- and division-specific sustainability plans aligned with the overarching Vision, Ambition, and Action Plan of the university. At this current moment, the AS Faculty has assigned a team of two employees to take part in its Climate Action Team. During the initiating phase of this thesis, joint discussions with Dr. Ir. Vos, who serves as one of the LSCs, have underscored the potential of this project to contribute to the structuring of the educational road map within the AS Climate Action Plan.

2.3. Research aim & qualitative approach

The aim of this research is twofold: to better understand how systems change strategies could enhance the implementation of ESD within an applied sciences HEEI and to give guidance to the Applied Sciences Faculty of TU Delft on how to approach the education portfolio of their Climate Action Plan. The first objective of this research involves a literature research on the implementation of ESD and on systemic change approaches in engineering education. Furthermore, this objective involves conducting interviews with a diverse range of stakeholders at the AS faculty of TU Delft, with two additional interviews with the NHL Stenden and Van Hall Larenstein universities of Applied Sciences. These interviews offer a clear overview of the barriers, drivers and uncertainty factors (at the AS faculty of TU Delft) concerning the implementation of ESD and systemic change.

The second objective is to create recommendations for the AS Faculty of TU Delft. This objective involves performing a SWOT analysis during a focus group. The final deliverable consists out of five strategies that will be recommended to the Climate Action Team of the faculty. The outcomes could be used to inform ESD related decision-making, ESD related policy development and the overall successful implementation of ESD in the context of the AS faculty. Additionally, by integrating the qualitative interviewing insights and the literature, this research aims to provide valuable insights into the discussion on context-specificity and generalizability of the topic of ESD implementation.

As academic literature is deficient in providing guidance on (systemic) implementation of ESD within applied sciences HEEIs, this study adopts qualitative research approaches, using a literature study, two rounds of semi-structured interviews with experts and a focus group as data collection. Qualitative research serves to uncover correlations and patterns among insights offered by diverse experts within their respective domains (Marshall & Rossman, 2016). Through qualitative methodologies, researchers gain access to experts' perspectives and incentives regarding the structuring of information flow processes and the identification of impediments therein (Thyer, 2009).

2.4. Research questions

The main research question of this thesis is:

How can the Applied Sciences Faculty at TU Delft adopt a systemic change approach to incorporate education for sustainable development throughout its entire academic program?

The sub-questions following from the main research question:

1. What are the key factors, strategies, uncertainty factors and barriers of a successful implementation of ESD in engineering education?
2. What are the key factors, strategies, uncertainty factors and barriers of systems change in engineering education?
3. How are systemic change approaches used at applied sciences higher engineering education institutions to implement ESD?
4. What is the current situation of ESD implementation at the Applied Sciences Faculty of TU Delft?
5. Which strategies can be used to implement ESD in a systemic manner at the AS Faculty of TU Delft?

2.5. Structure of the report

This report comprises eight chapters. Chapters 1, 2 and 3 will introduce the problem, the structure and the methodology of the thesis. Chapter 4 will present an in-depth literature review concerning ESD and strategies for systems change in engineering education. Chapter 4 will address Sub-Questions 1 and 2, respectively. Chapter 5 will concentrate on Sub-Question 3, forming a bridge between the literature study and real-life cases. The chapter will involve the synthesis of two case studies conducted at the NHL Stenden and Van Hall Larenstein Universities of Applied Sciences in the Netherlands, drawing from a desk study, two interviews, and prior findings from the literature review.

Chapter 6 will focus on Sub-Questions 4 and 5. Sub-Question 4 will be addressed through a desk research initiative supplemented by two rounds of interviews involving key stakeholders from the AS Faculty. Sub-question 5 will be answered by amalgamating data obtained from interview rounds 1 and 2, alongside insights from the literature review. This chapter will involve conducting a SWOT (Strengths, Weaknesses, Opportunities, Threats) Analysis facilitated by a focus group comprising additional AS Faculty stakeholders. The SWOT analysis is conducted to ascertain the applicability and relevance of the findings specifically tailored for the AS Faculty of TU Delft. At the end of the chapter, the findings from the SWOT analysis are synthesized by the researcher with the existing literature pertaining to systemic change. The resultant strategies aim to facilitate the implementation of ESD through a systemic approach.

Chapters 7 and 8 will further synthesize the findings into a final recommendation, provide generalizations, draw conclusions, and offer recommendations for future research. The illustration in figure 2.1 demonstrates the research framework and the correlation of the applied methodologies with the sub-research inquiries.

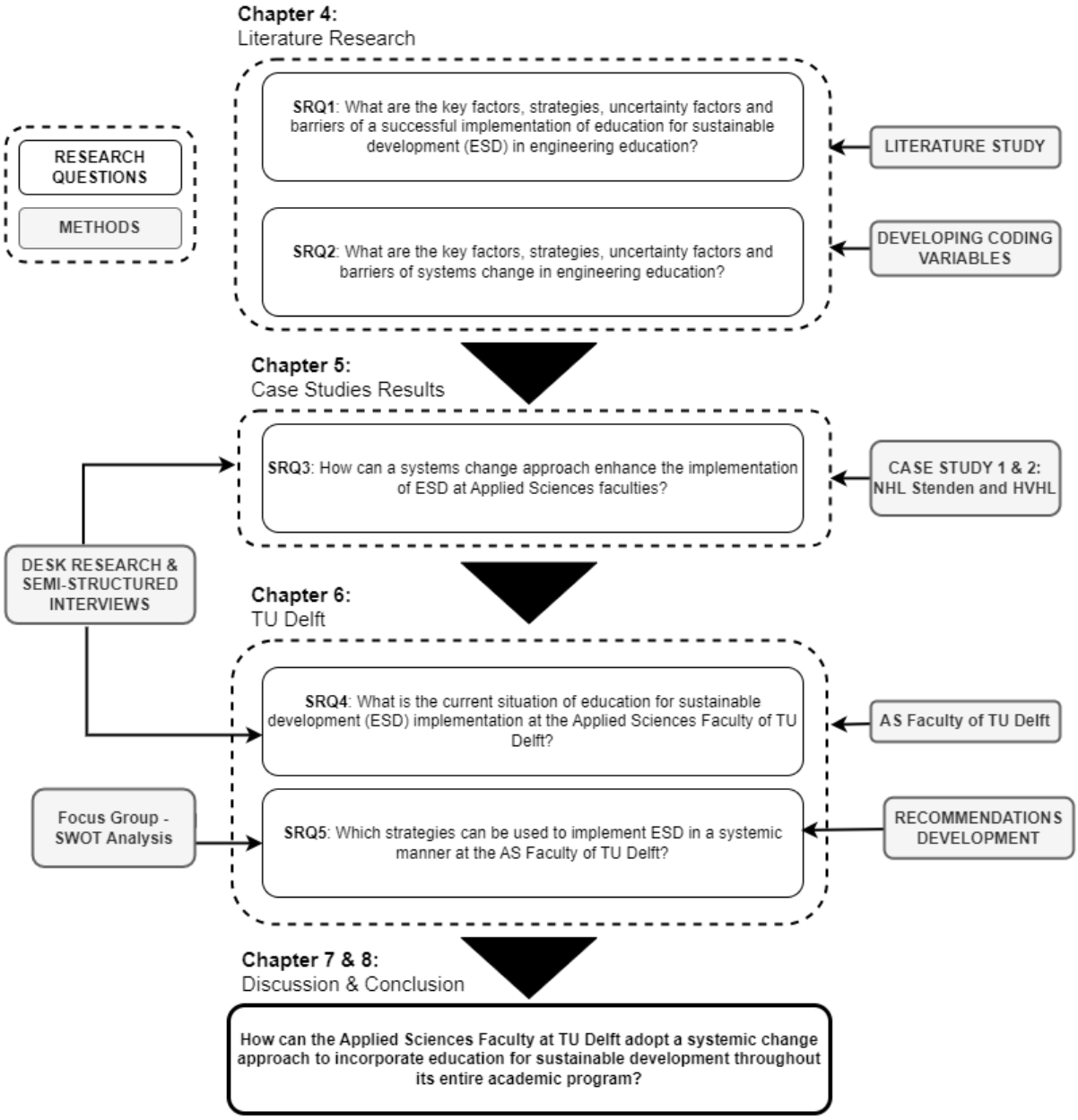

Figure 2.1: Research Design.

3

Methodology

In the subsequent section, the data collection procedures, the analysis method and the participant selection will be delved into. This research is primarily a case-study on the Applied Sciences Faculty of TU Delft, based on a literature study combined with two rounds of interviews and a focus group.

3.1. Ethical conduct

As this study entails conducting interviews and a focus group, there are multiple ethical considerations that require careful attention. TU Delft upholds an ethical code of conduct that mandates compliance for all researchers. Essential guidelines for ethically sound research involving interviews with adult subjects encompass securing informed consent, safeguarding anonymity, and ensuring data security. To uphold ethical standards in research, the responsible researcher is required to seek approval from the Ethics Review Committee through a formal application process. The data collected from these semi-structured interviews and focus group is structured and handled in adherence to the ethical guidelines established by TU Delft and was approved on the 26Th of September 2023. The findings are disseminated in an anonymous manner. Audio recordings of the interviews were transcribed, and significant quotations and conclusions were translated as needed. After the translation phase, the audio recordings were eliminated. The interview transcripts, as well as the coded versions of these transcripts, are retained by the researcher but are not publicly accessible. Interested parties can gain access to this data by reaching out to the core team of Sustainability of TU Delft.

3.2. Literature review

The literature study exists of two sections. First, the implementation of ESD in engineering education and its strategies, drivers, barriers and uncertainty factors are explored. Second, the strategies, drivers, barriers and uncertainty factors of systems change in engineering education are researched.

First, an unstructured approach involved engaging with sustainability networks such as GreenTU, and the TU Delft core sustainability team, which the author of this study has established over several years. Requesting relevant articles and sources from colleagues and pertinent university personnel streamlined the research process, conserving time and resources for conducting more extensive research. Secondly, a search through the proposed papers' citations and articles helped find keywords. Some of the found keywords are ”higher education”, ”(higher) engineering education”, ”education for sustainable development”, ”sustainability”, ”drivers”, ”barriers”, ”implementation process”, ”frameworks”, ”systems change” and ”institutional change”. The data sources utilized during the snowballing phase of the literature review include prominent academic databases such as the University of Leiden Catalog, Science direct, Scopus and the TU Delft repository. Additionally, Google Scholar and general Google searches were used.

Lastly, keyword combinations were used to get a more detailed overview on the existing literature. For the section on ESD implementation at engineering education, the following keyword combinations were used:

- ”engineering education” AND ”sustainable development” OR ”climate change” OR ”climate frameworks”

- ”engineering” AND ”education for sustainable development” OR ”climate education” OR ”sustainability focused education”
- ”higher education” AND ”sustainable development” OR ”climate change” OR ”climate frameworks”
- ”engineering education” AND ”implementation process” AND ”education for sustainable development” AND ”barriers” OR ”drivers”

For the systems change and engineering education section the following keyword combinations were used:

- ”engineering education” AND ”systems change” OR ”systemic change” OR ”systems change framework” OR ”systemic change framework”
- ”education” AND ”systems change” OR ”systemic change” OR ”systems change framework” OR ”systemic change framework”
- ”engineering education” AND ”implementation process” AND ”barriers” OR ”drivers”
- ”engineering education” AND ”systems change” AND ”barriers” OR ”drivers”
- ”engineering education” AND ”institutional change” AND ”barriers” OR ”drivers”

3.3. Interview design

A total of 11 interviews were conducted through two successive rounds of in-depth, semi-structured interviews involving subject matter experts. To facilitate these interviews, an interview protocol was established in advance. This protocol encompasses guidelines for obtaining informed consent, interview preparation, an introductory overview provided to each interviewee, a strategy for handling and organizing data, as well as a set of prepared interview questions. Different types of interviewees require different sets of questions, therefore three types of interview protocols were created for round one (R1). One for the stakeholders of the AS faculty, and one for both the external experts of NHL Stenden and the van Hall Larenstein Universities of Applied Sciences. The Interview Guide can be found in Appendix A. The interview set-up for round two (R2) can likewise be found in this Guide.

The interviews followed a semi-structured format, signifying that while certain questions are predefined, the flow of conversation and the interviewee’s depth of knowledge influence the subjects explored (Marshall & Rossman, 2016). This affords the interviewer some latitude to shape the dialogue based on the interviewee’s responses. Consequently, not all the questions from the interview protocol were invariably addressed, and new inquiries emerged during the interview process. This interviewing method offered flexibility and enhanced the qualitative depth of the data. Nonetheless, it is important to note that it comes with a relatively lower level of validity and the potential for bias (Thyer, 2009).

The interview inquiries in the initial round were fashioned upon the systemic change methodologies outlined by Reinholz and Apkarian (2018) and Graham (2012), and analyse the status quo and the history of ESD implementation at TU Delft and NHL Stenden and the Van Hall Larenstein, two universities of applied sciences. The two supplementary case studies involved were scrutinized to derive insights from their shortcomings and successes. Subsequently, the data gathered from the first round underwent categorization using descriptors rooted in the variables articulated by Weiss et al. (2021). This classification process aims to delve into the existing state of ESD implementation and windows of opportunity for systems change. More explanation on the coding framework used can be found in the section below.

Noteworthy emphasis was placed on cultural nuances and the incorporation of pertinent norms and values. The influence of the variables found in R1 in facilitating the integration of ESD are scrutinized. These fresh insights were then deliberated upon during R2. R2 primarily concentrates on two participants from the initial round and pertinent insights from two additional stakeholders affiliated with the AS faculty. The analysis done on the data from R1 is evaluated and the interviewees were asked for new, missing insights. The identified objectives from the analysis of R2 were then further explored in the focus group in round three (R3).

3.4. Analyzing & coding interview data

The transcripts of the interviews underwent coding using the Atlas.ti software, a tool instrumental in organizing and managing conducted interviews, along with their respective assigned codes. The coding process involved identifying themes, sub-themes, and specific codes derived from the interviews. The

complete code book, containing a comprehensive coding of the interviews, can be referenced in Appendix C, titled 'Code Framework.'

3.4.1. Interview round 1 (R1) - code framework

The coding process of the first round of interviews with the TU Delft stakeholders followed a methodology primarily based on the variables delineated by Weiss et al. (2021), which will be elaborated on in Chapter 4. Their variables include predefined themes such as 'Faculty Support,' 'Students Support,' and 'Implementation Level,' which represent broad facets crucial to this research. Additional codes such as 'Top-down,' 'Bottom-Up,' and 'Internal Culture (AS)' were included to offer deeper insights into the history and current status of ESD implementation and systemic change mechanisms within the institutions. Additionally, 'Barriers,' 'Drivers,' and 'Uncertainty Factors' were incorporated, considering these as the focal variables examined specifically in the context of AS faculties and (systemic) ESD implementation. The categorization of barriers, drivers, and uncertainty factors in the interviews primarily stemmed from the interviewees' statements. At times, a classification was applied even if the specific terms weren't mentioned, relying on an analysis of the context and the researcher's familiarity with the subject matter.

Following one interview and a desk research endeavor per case-studies 1 and 2, it became evident that there was an insufficiency of information to align with the variables as delineated by Weiss et al. (2021). Consequently, the coding process primarily centered on identifying barriers, drivers, and uncertainty factors encountered throughout the systems change process. The objective was to derive insights from past errors and successful strategies. Similar to the other interviews in R1, the classification of barriers, drivers, and uncertainty factors in the interviews was mainly derived from the interviewees' comments. Occasionally, categorization was implemented even in the absence of explicit terms, based on an analysis of the context and the researcher's knowledge of the subject.

Post the initial round of TU Delft interviews, a set of crucial variables was selected based on the co-occurrence analysis of Barrier, Driver, Uncertainty Factor, and Status quo with the variables outlined by Weiss et al. (2021). Furthermore, the Status Quo variable's co-occurrences with the Top-down and Bottom-up variables were compared to better understand the initiatives that are currently in place at the AS Faculty (table C.1). In order to lower the amount of variables in the analysis of R1, an arbitrary threshold of 30 co-occurrences was chosen. In case a variable reached the threshold of 30 or more in one of their co-occurrences with the barriers, drivers or uncertainty factors variables, it was brought to the second round of interviews. All in all, twelve thematic variables and their drivers, barriers and uncertainty factors were analysed in detail and brought to R2.

3.4.2. Interview round 2 (R2) - variable reduction methodology

Following the R1 analysis, the consolidation of variables was further refined with input from R2 interviewees. All twelve thematic variables were discussed, and R2 participants were queried to validate and provide insights on these topics. Variables that were not mentioned as barriers, drivers, or uncertainty factors were subsequently excluded from the collection.

Moreover, R2 was utilized to deliberate on the drivers, barriers, and uncertainty factors identified in the case studies conducted on universities of applied sciences, examining their relevance to the AS Faculty of TU Delft. Variables applicable to the TU Delft case but not discussed during the R1 interviews with AS stakeholders were integrated into the R2 lists. Subsequently, three new lists of drivers, barriers, and uncertainty factors were formulated and presented to the focus group during R3.

3.5. Participant selection

The selection of interview participants was meticulously curated through a comprehensive analysis of the (educational) framework of the Applied Sciences Faculty at TU Delft, leveraging both extensive desktop research and the researcher's professional network and experience. The selection process for interviewees within the AS faculty at TU Delft primarily relied on network exploration and a snowballing approach initiated during the initial round of interviews. A snowballing method was employed by seeking recommendations for potential interviewees during R1. The general criteria for the interviewee selection in all three rounds were the following:

- Works or studies at an Applied Sciences HEEI

- Has been involved or is interested in ESD implementation
- Willing to participate in the interview

The comprehensive selection aimed to represent diverse perspectives from various roles within the AS Faculty. Chapter 4's literature review delves into the exploration of top-down and bottom-up initiatives. Understanding the efficacy of these initiatives and the role of different stakeholders necessitated the involvement of students, (top-)management, and diverse teaching staff, thereby ensuring a comprehensive analysis. The sections below elaborate on the additional focused criteria that were added in all three rounds specifically. An even more detailed overview can be found in Appendix A.

3.5.1. Interviewees R1

Using the selection process described above, seven interviewees were selected for the first round. Five out of seven R1 interviewees are currently working or studying at the AS Faculty of TU Delft: Assistant Professor 1, Assistant Professor 2, Student 1, Program Director 1 and Top-management. Two external experts, not affiliated with TU Delft, were included in the interview process of R1. Specifically, one individual represented NHL Stenden University of Applied Sciences, while the other hailed from van Hall Larenstein University of Applied Sciences (HVHL). These experts were actively engaged in the ESD implementation within their respective institutions. The selection criteria for these interviewees involved an extensive investigation conducted via online resources to identify key figures driving the formulation and implementation of ESD-related frameworks and policies in the HEEIs. The rationale behind including these external experts stemmed from the value in gleaning insights from other HEEIs in the Netherlands. The objective was to not only understand their accomplishments but also to ascertain and learn from their missteps in the context of systemic ESD implementation.

3.5.2. Interviewees R2

Regarding the interviewees of round two (four in total), two interviewees from the initial first round were asked for another interview. These two interviewees, both Assistant Professor 1 and 2, provided insightful feedback and validation on the analysis of the first round of interviews. A particular emphasis should be placed on the second interview conducted with Assistant Professor 1. This interview served as an intermediary phase between interview round 2 and the subsequent focus group SWOT analysis. The participant contributed to the validation and testing of the structure and setup of R3.

The two new interviewees, Program Director 2 and Student 2, were invited to give additional insights that might have been overlooked by the interviewees of round one. Program Director 2 had experience in both universities of Applied sciences and universities. This interviewee was specifically asked about the differences between these types of institutions and potential strategies that can be used for both. The second new interviewee was chosen to be a student as the opinion on the role of students and their support varied in R1. Student 2 has experience as Greenteam member and as the GreenTeam Coordinator and Head of Education of the GreenTU Board. All in all, R2 was used for data validation and evaluation.

3.5.3. Focus group participants round 3 (R3)

The participants of the focus group were picked on their expertise at the AS Faculty and included someone from middle-management (Assistant Professor 3), two students (Head of education of the study association Technologisch Gezelschap (TG) and an old GreenTeamAS member) and a core team of sustainability member, all active in the education portfolio. To get as many insights possible from as many stakeholders as time allowed, different participants were chosen than the interviewees from R1 and R2.

3.6. A SWOT analysis focus group

The data collection and analysis conducted during R1 and R2 yielded a comprehensive compilation comprising barriers, drivers, and uncertainty factors pertaining to (systemic) implementation of ESD within applied sciences institutions. This gathered data possesses the potential to offer profound and valuable insights during the strategic planning phase of the Climate Action Road map for the AS Faculty of TU Delft, particularly concerning the inception of systemic change. The selection of a SWOT analysis was deliberate, as the method offers a strategic perspective for problem analysis (Yuan, 2013). In alignment with the overarching objective of amalgamating strategies gleaned from literature with the data on barriers, drivers, and uncertainty factors specific to the TU Delft case, it was deemed a convenient methodology. A

SWOT analysis serves as a guiding tool during the strategic planning stage, providing practical implications for management teams to facilitate strategic decision-making, and the method has been used during other types of implementation phases in the higher education sector (Benzaghta et al., 2021). As elucidated by Benzaghta et al. (2021), the SWOT analysis method enables an initial comprehension of potential future outcomes, offering a pragmatic assessment of institutional strengths and weaknesses. Moreover, it facilitates a comparative analysis between the present state and envisioned future plans, while also aiding in discerning competitive landscapes. Notably, SWOT analysis is esteemed for its user-friendly nature and does not necessitate the use of sophisticated computer systems or software.

Furthermore, the choice of employing a focus group at this juncture was deliberate, affording participants an opportunity to collectively reflect on the amassed data. This collaborative engagement transcends mere responses to interview questions, fostering interactive dialogue among participants. Guided by the researcher and structured around the SWOT analysis framework, the focus group participants engaged in collective brainstorming, thus enhancing the applicability of research outcomes to the AS Faculty. By discerning strengths, weaknesses, opportunities, and threats, the focus group facilitated the initial steps toward formulating recommendations for the educational portfolio of the climate action plan.

The digital collaboration platforms Teams and Miro were chosen for conducting the focus group. The script can be found in appendix D. The SWOT analysis was done in four steps, pictured in figure 3.1. The analysis is usually performed by a panel of experts who can assess the organization from a critical perspective (Scharwächter, 2023, 10 July). Hence why for this SWOT Analysis, a focus group was organised with the following four participants: a core team of sustainability member, an assistant professor, a GreenTeam student and a student member of one of the study associations of the AS Faculty.

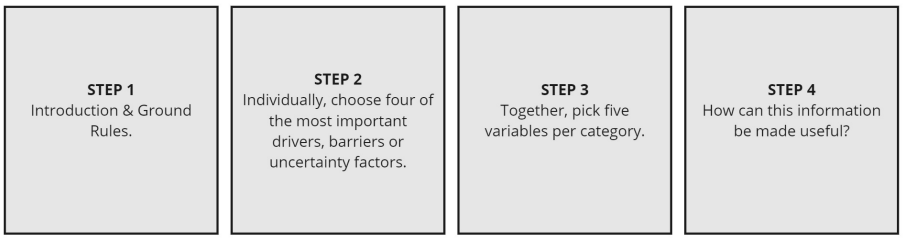

Figure 3.1: An overview of the four phases of the SWOT analysis focus group.

After an introduction of the researcher, the participants were instructed to individually select the four most significant drivers, barriers, and uncertainty factors in step two. During the third stage, participants engaged in collective discussions to determine the variables to be included in the SWOT matrix. Following the SWOT definitions of Benzaghta et al. (2021), Yuan (2013) and Scharwächter (2023, 10 July), the SWOT elements were defined as:

- Strengths - Positive tangible and intangible attributes, internal to an organisation and within the organisation's control.
- Weaknesses - Internal factors within an organisation's control that detract from the organisation's ability to attain the desired goal. Which areas might the organisation improve?
- Opportunities - Attractive factors that represent the reason for an organisation to exist and develop. What opportunities exist in the environment, which will propel the organisation and facilitate identified learning outcomes?
- Threats - Factors beyond the organisation's control which could place the organisation mission or operation at risk. The organisation may benefit by having contingency plans to address them should they occur. Try to identify their severity and probability of occurrence.

The internal considerations (strengths and weaknesses) help understand the variables that facilitate or interfere with (systemic) ESD implementation inside the AS Faculty. The external considerations (opportunities and threats) help understand the variables present on a university-wide level and those outside the TU Delft campus that influence the success of the education portfolio of the Climate Action Plan. The R2 participants sequentially presented and justified their choices, considering both the identified

R2 variables and the internal cultural characteristics unique to the AS Faculty of TU Delft, in line with the emphasis of systemic change approaches on institutional culture.

At the end of Chapter 6, the outcomes of the SWOT analysis were juxtaposed by the researcher with the drivers essential for effecting systemic change within the realm of engineering education. Subsequently, strategies were devised to assist the AS Faculty of TU Delft in implementing ESD. An overview of the Research Design can be found in Figure 3.2.

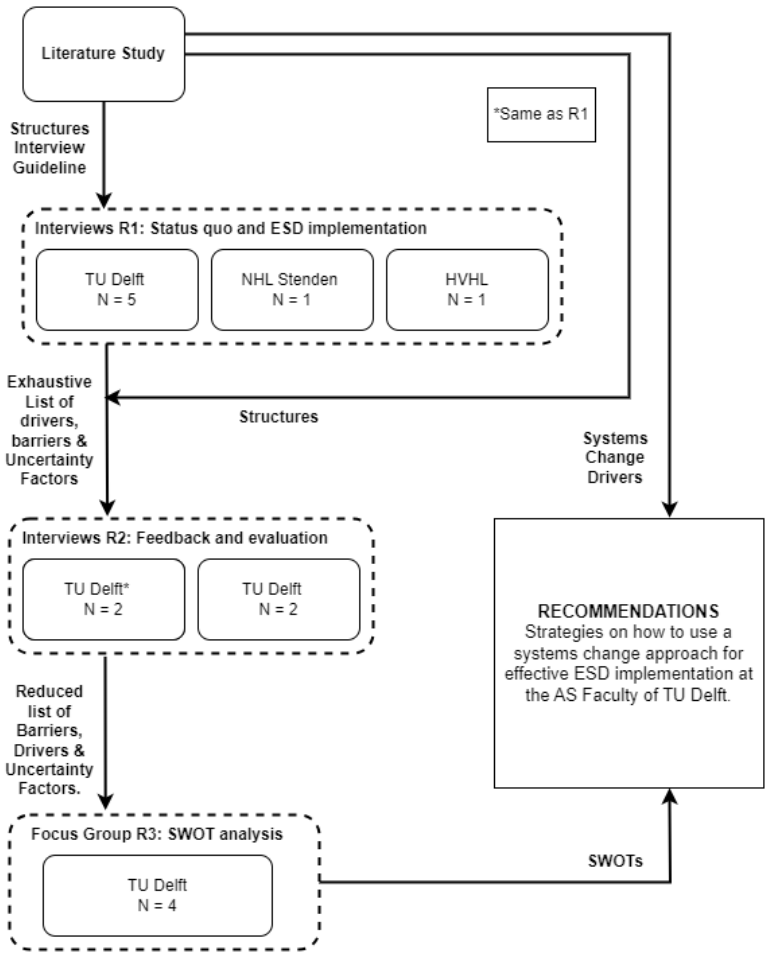

Figure 3.2: Interview Design. R1 and R2 are the two Rounds of interviews. R3 is the Focus group in which a SWOT analysis is performed. N is the number of interviewees. The final recommendations are a synthesis of the outcomes of the SWOT analysis in R3 and the literature study on systemic change drivers.

4

Literature Review

In this chapter a literature study is performed to answer sub-questions 1 and 2:

- *SRQ1:* What are the key factors, strategies, uncertainty factors and barriers of a successful implementation of ESD in engineering education?
- *SRQ2:* What are the key factors, strategies, uncertainty factors and barriers of systems change in engineering education?

This literature review aims to shed light on the definition and implementation of ESD and systems change in HEEIs. Drivers, Barriers and Uncertainty factors are delved into and the gap between theory and implementation is explored, emphasizing the knowledge gap and need for this research. These new insights will help structure the interviews and the focus group performed later in this research. Furthermore, the acquired literature will be tested and compared in chapter 5 and 6 to the data found in the semi-structured interviews and the focus group.

4.1. Higher (engineering) education institutions & education for sustainable development

4.1.1. Implementation and integration strategies

Over the past thirty years, universities have been increasingly striving to incorporate sustainability into their portfolios. A growing number of H(E)EIs have actively pursued the integration of sustainable development (SD) across education, research, community engagement, operational practices, assessment and reporting procedures, collaboration with other institutions, institutional structure, programs for training educators, campus initiatives, university administration, campus sustainability efforts, institutional policies, and engagement of the academic community (Blanco-Portela et al., 2017)(Verhulst & Lambrechts, 2014). Weiss et al. (2021) compared 131 case studies of H(E)EIs that tried to implement ESD into their educational programs. The authors describe how ESD implementation exists out of two phases: Phase 1, the initiation of sustainability curriculum implementation and Phase 2, achieving and sustaining more comprehensive ESD implementation. The authors found there are six implementation patterns:

1. *Collaborative paradigm change pattern* - encapsulates instances where the entire institutional curriculum incorporates sustainability through a redesign strategy marked by diverse relationships and connections.
2. *Bottom-up, evolving institutional change pattern* - involves grassroots, value-based changes that surpass the initially anticipated or planned implementation level. This leads to a redesigned approach in implementing sustainability curriculum with occasional built-in tendencies.
3. *Top-down, mandated institutional change pattern* - encompasses instances mandated by presidential leadership, with overlooked opportunities to foster a more profound, value-driven cultural shift, primarily resulting in a built-in implementation.
4. *Externally driven initiatives pattern* - involves instances characterized by limited internal support, partially offset by robust external support, leading to either a bolt-on or built-in implementation level.

5. *Isolated initiatives pattern* - comprises instances where initiatives face challenges in collaborating with each other and are accompanied by inadequate priority setting, resulting in a build-in or bolt-on implementation.
6. *Limited institutional change pattern* - includes instances of bottom-up initiatives that encounter difficulties in establishing their initiatives permanently due to numerous barriers and insufficient support, ultimately leading to a bolt-on or build-in implementation level.

Nonetheless, Weiss et al. (2021) argue how specific patterns appear to be more favorable for achieving a more thorough and sustainable implementation, particularly during the phase of full integration. This stage encompasses various implementation approaches, including both bottom-up and top-down methods to attain complete implementation. When one zooms in on a curriculum change level, there appear to be three conventional teaching incorporation approaches (Kolmos et al., 2016): vertical (add-on), horizontal (integration) and redesign (rebuild). All three need dissimilar approaches for changing curricula and behavior. The add-on strategy involves an assimilation approach, where sustainability topics are incorporated into the official curriculum without a shift in the educational paradigm. This strategy is used in the limited institutional change, isolated initiatives and externally driven initiatives patterns.

The integration strategy changes both content and values, leading to program modifications, while the fundamental educational paradigm remains unchanged, indicating an integration strategy. The patterns that use this strategy are the bottom-up/evolving institutional change, the top-down/mandated institutional change patterns, the externally driven initiatives and the isolated initiatives patterns.

The rebuild strategy, however, is a transformative, epistemic learning response that necessitates a shift in the entire educational paradigm involving the complete learner and the entire institution, or at least a whole Faculty or School. This demands a curriculum and organizational rebuild strategy. Example patterns are the collaborative paradigm change, the bottom-up/evolving institutional change and the top-down/mandated institutional change patterns.

Figure 4.1 gives a detailed overview of the conceptual framework of add-on, integration and rebuilding educational change strategies. Kolmos et al. (2016) mention how within an institution all three strategies can be employed for systemic change at varying stages or within different departments of the change process. The authors mention the increasing advocacy for systemic change, which necessitates institutions to develop comprehensive curriculum responses. This ranges from the incorporation of new subjects into the discipline, to the adoption of new values and objectives for education, and, at the most intricate stage of systemic change, the alteration of the epistemological foundation and fundamental identity of educational frameworks. However, the researchers mention how engineering schools most often opt for the add-on and the integration strategy. Many engineering institutions struggle with the daunting task of completely overhauling their curriculum, which is why they typically lean toward implementing smaller, incremental modifications instead.

	Add-on strategy	Integration strategy	Re-building strategy
Curriculum	Small changes to existing curriculum structure, e.g. new electives	Competence integration in existing courses and high degree of coordination	Crossing or merging disciplines with a high degree of coordination and management
Levels of systemic change	Systemic maintenance and optimization	Academic negotiation and collaborative curriculum coordination with system support	Academic shared vision and system change
Leading systemic change	Micro: preserver and response to external requirements. Bottom up and academic freedom	Meso: strategic coordinator and motivator. Both top and bottom up	Macro: vision, motivator and change agent. Both top down and bottom up
Faculty development strategy	Focus on the individual academic staff level	Focus on the individual and institutional level within disciplines	Focus on the individual, institutional level beyond existing disciplines

Figure 4.1: The three systemic curriculum response strategies explained by Kolmos et al. (2016). The Add-on Strategy involves an assimilation approach, where sustainability topics are seamlessly incorporated into the official curriculum. There is no shift in the fundamental educational paradigm. In contrast, the integration strategy aims to modify both content and values within the program without the core educational paradigm changing. The rebuild strategy necessitates a comprehensive shift in the entire educational paradigm, impacting not only the complete learner but also the entire institution, or at least a whole Faculty or School.

4.1.2. Definition of education for sustainable development

The concept of Education for Sustainable Development (ESD) aims at the facilitation of the transition towards a fairer, greener economy and society (Weiss et al., 2021). This definition stresses how ESD calls for a large transition at a fundamental level, in which education can play a crucial part. The main objectives of ESD are the ability to think and act in a systemic, anticipatory and critical manner that guides the transition to a more sustainable world (Sammalisto et al., 2015). Next to the concept of ESD, authors concurrently use the concepts environmental and sustainability education (ESE), sustainability education (SE) and learning for sustainability (LfS) (Vare et al., 2022). While there are differences between these definitions, ESD in this research is used as an educational approach that equips students with the essential knowledge, competencies, values, and mindsets required to engage with and to make meaningful contributions to the worldwide issues connected to climate change. Especially H(E)EIs are seen as the providers of the decision-makers of tomorrow, offering their students the chance not only to cultivate skills related to sustainability (as emphasized by Wiek et al., 2011), but also to engage in thoughtful introspection about their personal values. Furthermore, Graham (2012) underscores the role of ESD in engineering education in explaining the distinctive responsibility of engineers in shaping the future world. By implementing ESD in their educational programs, H(E)EIs can teach their students how to apply these values and the knowledge gained not only to their future careers, but to their overall life.

4.1.3. Framework usage for education for sustainable development implementation

Through the years, ESD implementation has received increasing attention and multiple efforts have been made to advance the implementation process in HEIs by initiatives such as UNESCO, the Global Action Program (GAP) and the Sustainable Development Goals (SDGs) (Weiss et al., 2021). The SDGs can for example be used to guide engineering curricula in how to align their course content with particular goals and how to inspire students to create solutions that help overcome these challenges. In 2022, the Joint Research Centre (JRC), the European Commission's science and knowledge service, published a Science for Policy report called GreenComp containing the European sustainability competence framework (Bianchi et al., 2022). GreenComp is an example of a competency-based-framework in which competencies are meant to be used as a general reference model for anyone involved in lifelong learning. The Greencomp

framework is an example tool created at EU-level that could be used by H(E)EIs as a starting point. The creation of this recently published framework shows the desire for H(E)EIs to work together more and to gain the same qualities and values. However, as literature stresses how context specific effective ESD implementation is, it is questionable if a framework like GreenComp will work for all European H(E)EIs.

Scoping in on TU Delft's own country, the Netherlands, a well known ESD framework is the (Auditing Instrument of) Sustainability in Higher Education ((AI)SHE) method, created in 2000-2001. The (AI)SHE assessment framework has been designed for educational programs seeking to integrate sustainability within the context of the SDGs. This integration is tailored to the specific domain or professional sector for which these programs provide instruction (Leerdam & van Gulik, 2020). Both case-studies on the universities of Applied Sciences use SHE to monitor and report their processes.

The framework that is currently used to research ESD implementation at TU Delft is the Engineering for One Planet (EOP) Framework (Anderson & Cooper, 2022). This project is led by the core-team of sustainability member Monika Roeling, who is the assigned researcher on ESD. The EOP framework was developed with the goal to prepare future engineers with the skills and principles of environmental sustainability. The framework offers an extensive approach to include sustainability into one's education system with 43 core concepts that focus on systems thinking. These outcomes are grouped into eight subcategories and all align with the United Nations' SDGs. This makes it easier for education systems to implement and to follow the progress of the sets of outcomes. This reduces assessment burdens and has been one of the reasons why the EOP framework was chosen for the TU Delft sustainability assessment. The framework is used as a basis to create a guideline for the teaching staff of TU Delft who would like to implement ESD.

However, as this framework is based on the ABET (Accreditation Board for Engineering and Technology) criteria for accreditation and not based on the specific Dutch educational standards, one should remain critical. Another uncertainty is the fact that the framework has not been used yet for an applied sciences institution. A framework that works for mechanical, civil and environmental engineering might not work for an AS faculty.

The usage of frameworks seems to be a key element in the implementation of ESD at H(E)EIs. A framework can be used as a red learning line through all educational programs, however it is often claimed that these frameworks should be made specific to the context they are used in to work effectively. Institutions tend to internally develop new methods that align with the institution's priorities and intentionally strive to be distinct, similarly with the current projects happening at TU Delft. Wiek et al. (2011) mention how institutions should stop searching for the most ideal model and should start acting now. H(E)EIs do not have to invent the wheel themselves, but can easily adapt frameworks that have been invented through the years and start experimenting with their own systems, needs and values right away. What is noteworthy about ESD focused frameworks, is the focus on systems thinking and the acknowledgement of how an institution has to change throughout in order for (educational) goals to be met. This emphasizes the need for a systemic approach in the process of implementing ESD for the changes to be durable.

4.1.4. Drivers, barriers and uncertainty factors

It appears that the widespread use of frameworks suggests the existence of general practices applicable across various curricula. During their case-survey research Weiss et al. (2021) outlined a comprehensive list of drivers and barriers that encompasses a wide array of internal and external stakeholders, each driven by distinct motivations. The perspectives that fit the six defined implementation patterns of Weiss et al. (2021) vary on sustainability and change, diverse underlying assumptions about ESD, and the utilization of distinct organizational instruments (such as strategic policies and participation mechanisms). Additionally, these factors are influenced by different institutional and educational cultures.

The authors chose variables per implementation pattern and described possible drivers and barriers. Additionally, the authors classified variables as medium (described, but with unclear/differing impact), other (if no category matched the description) or not described (missing information). The finding of these three classifications (in addition to time constraints of this study) underscored the necessity of the introduction of a third term: *an uncertainty factor*. In this thesis, uncertainty factors are variables that are unpredictable and can not be classified as a definite driver or barrier, but are highly depended on context (Figure 4.2). As described in Appendix C, some example Weiss et al. (2021) value labels that are covered by the term uncertainty factor are *partly driver*, *differing* and *occasional*.

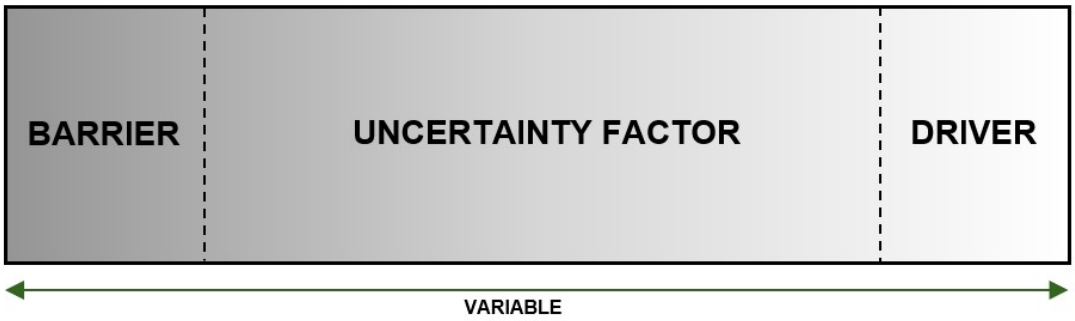

Figure 4.2: The fluidity of barriers, drivers and uncertainty factors explained in a simplistic figure. Dependent on the context of an institution, a variable moves more towards the label of barrier or driver. If it is not categorised as a definite driver or barrier, it can be seen as an uncertainty factor. In this thesis, the fluidity of variables is dependent on the context and culture of a HEEI. In the figure this is emphasized by the use of a gradient.

Drivers of education for sustainable development implementation

Considering drivers, Weiss et al. (2021) concluded that a combination of different variables could help H(E)EIs implement ESD into their institution. First of all, ensuring a consistent vision statement and involving all stakeholders actively cultivates a feeling of ownership, contributing to its enduring impact. Collaborative efforts among separate ESD initiatives and diverse stakeholders facilitate the exchange of knowledge and resources. Secondly, effective informal collaboration and communication can mitigate the absence of formal leadership support from higher management.

Additionally, meticulous planning, including the formulation of a detailed strategy and equitable distribution of responsibilities among internal stakeholders, facilitates comprehensive ESD implementation. It appears critical to recognize the gradual accomplishments of individual change agents within HEIs. Furthermore, do the authors state that the more stakeholders of a HEI participate, the more favorable change results can be observed as long as the actions of stakeholders align with the overarching vision for the change. This observation hints to the necessity of a systemic approach.

Barriers and uncertainty factors of education for sustainable development implementation

On the other hand, example barriers are a lacking strategic plan, no faculty support and weak leadership (Weiss et al., 2021). Verhulst and Lambrechts (2014) underscore three elements that play a critical barrier in the implementation of ESD: lack of awareness, the structure of HEI and lack of resources. Additionally, these authors stress the importance of the constant consideration of human factors when trying to overcome these barriers. The authors agree with Weiss et al. (2021) and mention how not all barriers apply to a HEI, but how it depends on the context and culture of an institution.

The variables that do apply to a particular situation constantly interfere and influence each other. The process of integration is not consistently linear; instead, it experiences fluctuations and the potential for adverse effects, including sustainability fatigue and a lack of motivation among individuals. While initial personal commitments can lead to project funding and can facilitate synergy between bottom-up and top-down approaches, they also introduce the risk of lack of motivation when (external) resources cease. A substantial reservoir of resources may serve as a catalyst for the successful implementation of ESD initiatives; however, it is imperative to acknowledge that these resources can be rapidly depleted, subsequently transforming into an impediment.

Some additional examples of the barriers and drivers can be found in Table 4.1, in which the term uncertainty factor is added to underscore the context-specificity and fluidity of the variables. The influence of a variable changes substantially depending on the context and culture of the explored cases.

Overview drivers, barriers and uncertainty factors

A pertinent aspect to consider within the context of general versus case-specific knowledge in ESD pertains to the correlation between recognizing factors that drive or impede progress and the implementation of ESD. Identifying influential variables, seems to maintain an interest in the notion of applying generalized practices

across different cases but with a greater focus on specific nuances. Gaining insights into the factors that drive or obstruct progress within an institution has the potential to alleviate resource demands for the development of their ESD action plan. This comprehension may streamline the quest for or construction of an ESD framework that aligns more suitably.

The variables by Weiss et al. (2021) will be used as a basis during the interview coding step of this research. An overview can be found in Appendix C. It can be observed that barriers, drivers, and uncertainty factors are interconnected concepts that may transition into one another when not appropriately managed or monitored. A variable can support change in a specific context, while it hampers the process in another. The communication variable for instance, can be seen as a driver for the collaborative paradigm change pattern and the bottom-up change pattern, while it can play the role of a barrier for the Isolated initiatives change pattern and the Limited institutional change pattern (Weiss et al., 2021). This instance underscores the significance of contextual considerations and cultural observations.

Variable	Drivers	Barriers	Uncertainty Factors
Strategic Plan	Clear and detailed plan.	Lack of.	Medium/Differing.
ESD related Vision	Mentioned in current (general) strategic vision of the institution, which is publicly available (online).	Not mentioned in strategic vision,	Mentioned, but not publicly available (online).
Resources	Enough resources.	Lack of.	Medium/Differing.
Professional Development Opportunities	Present.	Lack of.	Medium/Differing.
Incentives	Present.	Lack of.	Medium/Differing.
Communication	Present.	Lack of.	Medium/Differing.
Coordination	Present.	Lack of.	Medium/Differing.
Internal collaborative culture	The collaborative environment of the organisation is described as a driver.	The competitive environment of the organization is described as a barrier or the collaboration needs to be strengthened.	Medium/Differing (some or differing efforts to work collaboratively, but not described as a barrier).
Organizational structure	Sufficient (changed) structure.	Lack of.	Medium/Differing.
Interdisciplinary space	Present.	Lack of.	Medium/Differing.
Leadership	Strong leadership (strong support, e.g., vision, strategic planning, incentives).	Weak leadership (no support, no interest, no awareness)	Inconsistent leadership (changes in the top management, different phases, changing priorities, vision but no strategy).
Faculty Support	High support.	No support.	Medium/Differing.
Students Support	High support.	No support.	Medium/Differing.
Sustainability Champions	Present.	Lack of.	Medium/Differing,

Table 4.1: Some example variables that could influence the implementation of ESD, together with their drivers, barriers and uncertainty factors.The influence of a variable differs per implementation pattern. Adapted from Weiss et al. (2021).

4.2. Systems change & higher engineering education institutions

As previously noted, the successful implementation of ESD frequently necessitates a systemic approach (Weiss et al., 2021)(Kolmos et al., 2016). Oftentimes, for educational changes to endure, there must be a shift in the culture of a H(E)EI. However, effecting such a cultural transformation, contingent upon the degree of ESD implementation, is not readily achieved. The subsequent text will first expound on the necessity of a systemic, whole-institution approach when implementing ESD and on the definition of such a transition. Secondly, the text will explore strategies for systemic change in engineering education. In the end, an overview of drivers, barriers and uncertainty factors is given. These insights will be used for the analysing of the desk research and the interviews of the case-studies on the two universities of applied sciences in Chapter 5. Furthermore, is the information used to create potential strategies to implement ESD at the AS Faculty of TU Delft in Chapter 6.

4.2.1. A call for a systemic approach

In order for HEEIs to be able to equip their graduates with the tools to endure the new and complex challenges of the 21st century, a change is needed. Research shows that significant and sustainable change rarely happens by spreading established best practices (Graham, 2012). Redesigning one aspect of the curriculum rarely leads to broader changes in undergraduate schools. Successful strategies often reject a fragmented approach and show a need for complete systems change.

The study by Kolmos et al. (2016) delineated diverse methods for altering curricula and behavior. They emphasized the necessity of systemic approaches across all strategies in order for changes to be durable. Similarly, Weiss et al. (2021) highlighted the challenges in sustaining change across their six specified implementation patterns. Throughout their work, the authors underscored the pivotal role of collaborative endeavors — encompassing both top-down and bottom-up initiatives — and the significance of comprehending the context and culture within the entire system of a HEI. Employing a systemic approach that recognizes the multifaceted aspects of an institution may facilitate successful educational change and foster behavioral transformation.

4.2.2. Definition systems change in higher (engineering) education institutions

The term *systemic change* within the realm of engineering education signifies a profound and revolutionary transformation in the planning, delivery, and incorporation of engineering education to advance specific objectives. This entails a complete overhaul and reconfiguration of the educational framework, aiming to intricately infuse principles and practices into the curriculum, teaching approaches, and the overall institutional ethos (Kolmos et al., 2016).

Fullan (2007b) advocates a systemic perspective, underscoring how the result of an educational change process extends beyond altering student learning; it also entails enhancing organizational capabilities. It's important to note that faculty and institutional policies and practices are enduring elements as students eventually graduate (Kolmos et al., 2016). Additionally, Fullan (2007a) underscores that change is an ongoing journey, rather than a one-time occurrence. This underscores the importance of educators and academic leaders who engage in reflection.

Holst (2023) acknowledges the importance of a systemic change and proposes Whole Institution Approaches (WIAs). The essential features of WIAs can be grouped into five fundamental principles *(consistency, ongoing learning, involvement, accountability, enduring dedication)*, seven tightly interconnected domains of activity *(governance, curriculum, campus, community, research, communication, capacity enhancement)*, the foundational organizational culture, and essential prerequisites for effective execution. Embracing a WIA involves collectively shifting the prevailing mindset of all established social norms towards sustainability. This indicates that education should work closely together with all other domains of activity in order for the systemic ESD implementation to succeed. Holst (2023) presses how forthcoming research could place increased focus on exploring the distinctive trajectories that organizations follow in their pursuit of sustainability, taking into account both successful models and the inherent difficulties and conflicts encountered in the process of organizational change. This aspect will be investigated during the interview phase of this research.

4.2.3. The direction of the change effort

Efforts to instigate change within a department can follow different approaches, such as top-down, bottom-up, or a combination of both. Regardless of the approach, those initiating the change must actively engage others early in the process and involve them in meaningful ways; otherwise, considerable effort may yield minimal results. Reinholz and Apkarian (2018) state how existing hierarchies within academia have marginalized specific groups of individuals. However, agents of change can deliberately devise solutions aimed at disrupting these hierarchies and advancing equity.

Subsequently, the change agent can commence the process of crafting a shared vision for the department's future, identifying necessary adjustments or creations in organizational structures, and recognizing attitudes and beliefs that could influence the adoption of changes and by whom they are embraced. It is worth noting that change agents are not always required to act individually. There is a growing trend towards the initiation of change efforts that involve teams (Olmstead et al., 2019). TU Delft itself is a good example of this trend, having initiated its first sustainability core team in 2019.

Change leadership should facilitate transformation at both the individual and organizational levels, with equal attention to both the curriculum and the cultural aspects (Kolmos et al., 2016). Similar to Fullan (2007b), Reinholz and Apkarian (2018) mention how organizational change research could help education institutions to understand their own system. The authors advocate for an approach that considers broader systemic factors and an inherent motivation right from the beginning. This underscores the profound cultural aspect of systemic change. Culture encompasses historical and evolving frameworks and symbols, as well as the resulting power dynamics among individuals. If there is a need to transform this culture, the change must carry significant meaning for all parties involved.

A tool that could help an institution to understand its own systems, is the four frame model for systemic change in STEM departments of Reinholz and Apkarian (2018). The authors claim that university departments are the pivotal agents of change within the campus environment. The model was created for researchers and change agents aiming to investigate and implement systemic changes within STEM departments. The four frames are *structures*, *symbols*, *people* and *power*.

The first frame *structures* is defined as the roles, duties, customs, habitual activities, and motivations that shape interpersonal interactions. In the realm of academia, these structures materialize in formal positions (such as faculty or staff roles), the framework of committees, the allocation of course responsibilities, expectations for research, provisions for travel, class arrangements, the design of common curricula, and a multitude of other governing policies. These structures can originate at the departmental level or emerge from various facets of the educational institution.

The second frame *symbols* is defined as the cultural elements, language, accumulated knowledge, myths, values, and overarching vision that individuals within a department employ to inform their thought processes. In this context, symbols represent the fundamental cognitive frameworks that imbue meaning into the existing structures within a department.

The third frame *people* focuses on the fact that departments consist of individuals, each possessing their own distinct goals, capacity for action, requirements, and unique identities. This perspective underscores that, even within communities that share commonalities, the essential building blocks are the individuals themselves.

The fourth frame *power* focuses on how within a department, interpersonal dynamics are influenced by power dynamics, status, positioning, and the formation of political alliances. Disparities in power can emerge through various channels, including formal roles (such as department chair, associate professor, or assistant professor), one's achievements and prestige in the field, or other aspects of one's identity, like race, gender, sexual orientation, or ability status. The presence of power is constant and cannot be disregarded, as existing power structures significantly shape both individuals and decision-making processes.

The authors furnish an in-depth illustration of how these four frames can be employed to assess an ongoing change initiative. The model appears to be an analytic lens that can be used to enable the identified change agent to gain a deeper understanding of the department and its unique culture, and to analyze the change process throughout. These four frames are used during interview round one to go to a deeper level of understanding of the status quo and the variables of influences of ESD implementation at the AS Faculty of TU Delft. This understanding can, in turn, inform the direction of the systemic change effort.

4.2.4. Drivers, barriers and uncertainty factors

In order to comprehend how systemic change at an applied sciences HEEI can be initiated, this section seeks to synthesize the drivers, barriers, and uncertainty factors associated with systemic change in engineering education found in literature. Understanding and gaining insights into these pivotal elements is crucial for formulating effective strategies and overseeing the systemic change process to achieve intended objectives.

Drivers of systems change

The prior sections offer an initial understanding of systemic change strategies in H(E)EIs and certain potential *drivers*. According to the Royal Academy of Engineering (Graham, 2012), systemic change begins within an engineering education institution by exploring the *Why*, *What*, *Who* and *How*: Context for successful change, Strategies for successful change, Drivers of successful change and Mechanisms of successful change. These factors assist in structuring an action plan and prompting HEEIs to assess their current systems. Detailed preparatory work, planning, and implementation are vital for sustainable changes (Graham, 2012). Preparatory work includes evidence collection, collaboration with the Head of Department, and (informal) discussions with senior university management. Planning should encompass communication, curriculum design as a faculty-wide initiative, external consultations, impact evaluation, and selection of implementers for reform. Additionally, encouraging team teaching for new courses with regular meetings and resources is recommended.

Furthermore, effective change requires leadership support, particularly from the Head of Department and senior management. Their endorsement energizes faculty participation and maintains their confidence, even without explicit incentives. The Head of Department and another (top-)management figure play key roles in providing guidance and structuring change initiatives (Reinholz & Apkarian, 2018)(Graham, 2012). In many cases, the former offers guidance and impetus, while the latter translates the vision into a coherent curriculum structure. Graham (2012) additionally highlights the importance of exploring contextual change, educational design, and a sustainability focus throughout the whole institution.

Regarding sustaining momentum, this necessitates an ongoing dialogue between faculty and change agents. Monitoring impact data, engaging new faculty, and maintaining education as a priority post-implementation are crucial. Addressing potential issues, a noticeable enhancement in student enrollment and increased student motivation observed subsequent the reform likewise appear to be pivotal (Graham, 2012). Moreover, Olmstead et al. (2019) mention how project leaders unanimously concurred on the value of pedagogical training as a form of external engagement for team members in order for the momentum to be sustained. Examples are employee education through workshops, summer institutes, or guidance from education specialists. Likewise, project leaders appear to reach a consensus that team engagement with novel concepts (e.g., through interactions with other teams or via the aforementioned training) and receiving messages of encouragement from organizational leaders can be advantageous for teams. Effective team dynamics encompass regular meetings, open sharing of ideas, implementing changes and reviewing their outcomes, and honoring commitments to one another. In the same vein, favorable emergent team characteristics involve a collective alignment with and dedication to the task, a shared sense of responsibility for the task, and a belief in the team's ability to attain their objectives. However, the authors mention how comprehensive insights into the factors contributing to effective teams can only be gained through research tailored to specific contexts, emphasizing the necessity of the case-studies section of this research.

Finally, understanding the culture is pivotal for faculty engagement and cooperation across the faculty. Models like the four-frame model enhance change sustainability by addressing cultural facets. Additionally, understanding national support, institutional resources, and the teaching-research balance aids in comprehending the drivers and challenges in educational changes (Graham, 2012). Recognizing an institution's culture is paramount for the sustainable implementation of ESD and systemic change. Loorbach et al. (2017) propose employing a 'designing transition logic' for a profound cultural, spatial, and behavioral shift. This approach integrates six elements: 1) Urgency in moving away from fossil resource dependence 2) Commitment to a nature-positive, inclusive, just, and circular future 3) Embracing existing transition practices by various change-makers 4) Utilizing a transition-oriented framework involving system analysis and envisioning 5) Adopting a design-centered approach 6) Employing a cultural strategy involving broader public engagement. These elements could help craft a comprehensive vision and strategic plan for sustainable ESD implementation. They also serve as essential tools for communicating changes, continuous improvement, and advancements to stakeholders.

A summarized overview of drivers can be found in Figure 4.4. The drivers mentioned above are categorised by the researcher of this thesis under five themes: context and culture, direction of change, preparation and planning, design and implementation, and maintaining momentum and sustaining the change.

Barriers of systems change

In the realm of systems change, *barriers* denote hurdles, difficulties, or obstructions that impede or block the progress of bringing about substantial and trans-formative alterations within a complex system. These impediments may manifest in diverse ways, including resistance within institutions, resource deficiencies, entrenched cultural norms, policy restrictions, or other factors that generate opposition or inertia against desired transformations (Graham, 2012)(Reinholz & Apkarian, 2018). Recognizing and actively tackling these obstacles is vital for surmounting resistance and effectively guiding the process of systemic change towards the realization of intended results. Graham (2012) mentions how one key barrier for sustaining the transition is the absence of universally acknowledged indicators of success and evaluation instruments. Especially in engineering education, quantification of results is seen as highly important (local evidence gathering and bench marking). Without showing the progress and regress a program is making, it is difficult to keep everyone engaged. Other example barriers are a lack of resources, time and energy. Furthermore, can misalignment with the institution's culture and the absence of rewards procedures hinder a successful transition (Graham, 2012).

Uncertainty factors of systems change

As has been mentioned in section 4.1.4, *Uncertainty factors* are variables that cannot be categorised as a definite barrier or driver, of which it is unknown how they will influence the process of implementing significant changes within a complex system. These factors can bring along unforeseen consequences, unexpected developments, and external influences that can affect the outcome of the change effort. Under the right (or wrong) circumstances the variables can change into a driver or barrier. Managing uncertainty factors is crucial for effective planning and adaptability during system change (Reinholz & Apkarian, 2018). An example uncertainty factor is the first cohort of students that enters the new curriculum (Graham, 2012). These students are not only expected to receive the teaching that is given in their program, but also to give feedback and think along with the organisational structure of their courses. How these students will respond, and if they are able to provide the necessary feedback is uncertain. Another example is the situation where the faculty members that initiated the change decide to depart. If the change has not yet been grounded in both the educational and organisational structure of the institution, the innovation is typically lost (Fisher et al., 2003). The similar occurrence takes place when one individual continues to be responsible for the changes (Graham, 2012). This frequently happens when the new curriculum is not formally recognised (by top management) as the new norm. An overview of the barriers and uncertainty factors can be found in Figure 4.3.

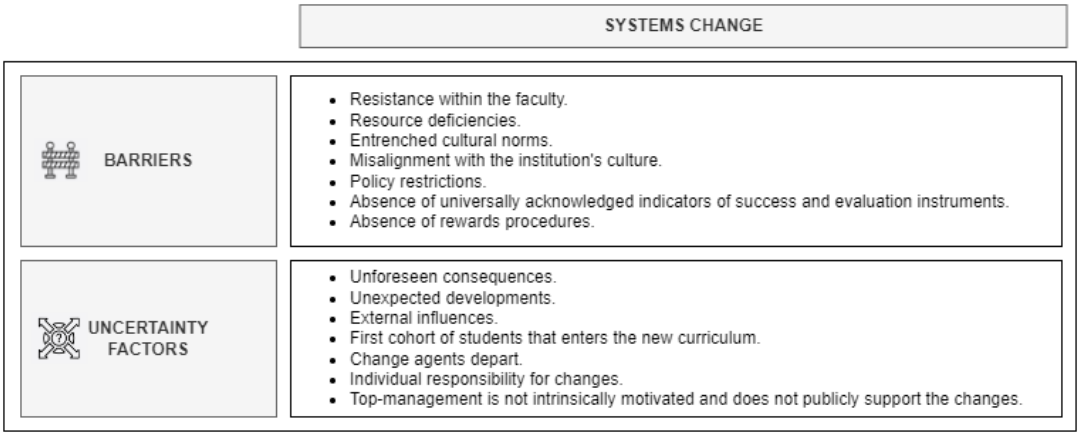

Figure 4.3: An overview of barriers and uncertainty factors influential in systemic change in HEEIs. Summarized from Graham (2012), Fisher et al. (2003), and Reinholz and Apkarian (2018).

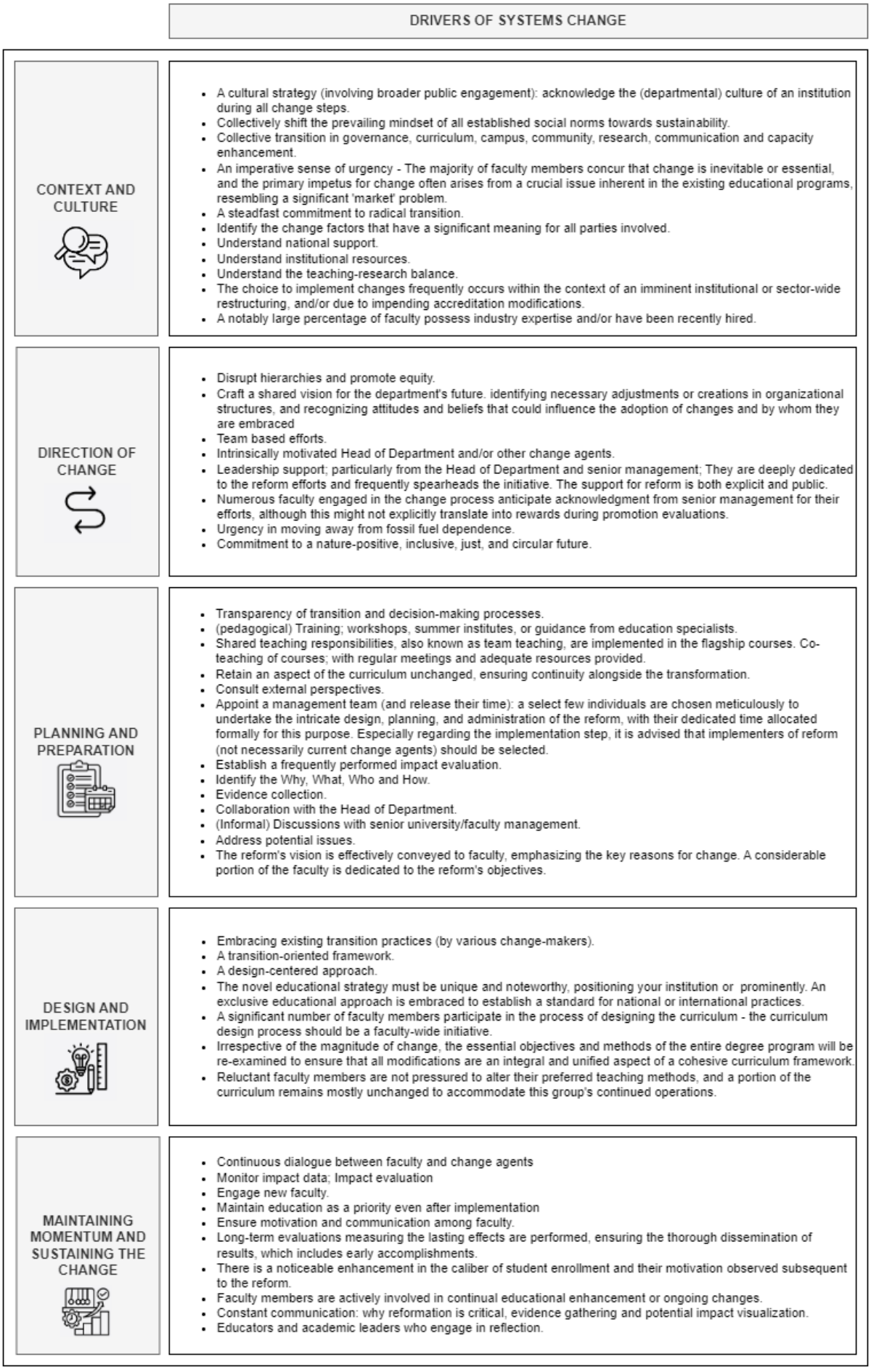

Figure 4.4: An overview of drivers influential in systemic change in HEEIs. Summarized from Fullan (2007a), Graham (2012), Holst (2023), Loorbach et al. (2017), Olmstead et al. (2019), and Reinholz and Apkarian (2018).

4.2.5. The complexity of systems change

Crucially, it's vital to understand that drivers of systems change can become barriers or sources of uncertainty if not executed effectively. Graham (2012) stresses the importance for institutions to identify hurdles to overcome and anticipate potential emerging obstacles. For instance, creating a collectively embraced vision during systems change holds significant value. A well-constructed vision can expedite the transition; conversely, attempting to initiate change without collective support can impede or halt systemic change (Kolmos et al., 2016). The complexity inherent in instigating systems change, as highlighted by Kolmos et al. (2016), underscores the critical need for active engagement across all organizational tiers. Individuals leading change, such as leaders, educators, and faculty developers, play pivotal roles throughout the entire change process, spanning from initial planning to continuous maintenance. These collaborative practices, essential for defining educational objectives, should extend into classrooms to fully engage students in their personalized learning experiences.

4.3. Systems change & education for sustainable development implementation

Institutional change approaches, whether perceived as "add-on", "integration" or "re-building", entail systemic perspectives encompassing leadership interventions and faculty development initiatives (Kolmos et al., 2016). Often, initiatives driven by individuals or small groups face challenges, leading to the restoration of the status quo post their departure. Research indicates that ESD implementation commonly follows top-down and/or bottom-up trajectories, but resource constraints and lack of top-level endorsement hinder sustainable initiatives. This mirrors the intertwined challenges faced by both ESD implementation and systemic change. Nevertheless, systemic change strategies can potentially address ESD challenges by focusing on thorough preparation, fostering collective vision, providing ample guidance while allowing room for interpretation, fostering a collaborative approach, conducting continuous evaluations, and offering evidence of effectiveness. While there is a consensus among researchers regarding the necessity of systemic change for ESD implementation, there are discrepancies in defining its scope and determining the methodologies for studying or influencing it. An initial step involves exploring and cataloging existing system dynamics, aligning relevant questions and tools with the appropriate stakeholders. Understanding a system is a prerequisite to transforming it. Thus, recognizing the distinct barriers, drivers, and uncertainty factors inherent in the context and culture of a HEEI significantly enhances the likelihood of successful systemic change and ESD implementation.

However, research on systemic ESD implementation at AS faculties is lacking. Understanding the cultural nuances of AS institutions, differentiating them from other engineering education paradigms, is necessary. Identifying effective implementation patterns tailored to this context, comprehending dominant drivers, barriers, and uncertainties, and discerning their interplay are vital. Therefore, the primary focus of this research, namely the AS Faculty of TU Delft, serves as both a contribution to existing literature and a subject for experimentation. TU Delft appears to have recognized the need for systemic change through the appointment of the Core Team of sustainability and their Local Sustainability Coordinators. The Core Team of Sustainability has given the AS Faculty the task to appoint a LSC. The AS Faculty has in turn responded with the creation of a Climate Action Team, acknowledging the need for change. The pivotal question lies not in the necessity of change but in the implementation strategy. The aforementioned drivers, barriers, uncertainty factors, and approaches acknowledge the complexity of ESD implementation and systems change. These insights can serve as a guide for undertaking an initial exploration and inventory of system dynamics within the AS Faculty. First of all, conducting extensive stakeholder interviews will unravel the status quo of ESD implementation at the AS faculty. Secondly, will it unravel the drivers, barriers, and uncertainties associated with ESD implementation in AS faculties, contributing significantly to this unexplored domain.

Drawing lessons from previous initiatives is crucial for discerning successful strategies and potential challenges. Chapter 5 initially emphasizes the importance of learning from other AS faculties that have undergone systemic ESD implementation, as well as their perceptions regarding barriers, drivers, and uncertainty factors. The objective is for the AS Faculty of TU Delft to derive insights from these experiences. Consequently, the subsequent section constructs case studies based on examples from NHL Stenden and HVHL universities of applied sciences. Furthermore, this thesis has the potential to serve as a catalyst by posing pertinent questions early in the ESD implementation process, conserving valuable resources.

5

Case Studies on universities of applied sciences: NHL Stenden and HVHL

This chapter will focus on answering sub-question 3:

- *SRQ3:* How are systemic change approaches used at applied sciences higher engineering education institutions to implement ESD?

To gain deeper insights into the systemic approach to implementing ESD, this chapter delves into two real-life case studies conducted at the NHL Stenden and Van Hall Larenstein universities of applied sciences, located in the Netherlands. Both case studies commenced with desk research followed by an interview with an influential stakeholder pivotal in shaping the pathway towards systemic ESD implementation within the HEEI. Acting as a link between the literature review and the primary focus of this study, namely the AS Faculty of TU Delft, this chapter provides valuable contextual groundwork. All acquired interview data is part of R1. In chapter 6, the relevance of the data to the AS Faculty of TU Delft is tested in R2.

5.1. Universities of applied Sciences' systemic education for sustainable development implementation

To explore how systems change approaches can be used to implement ESD and to answer SRQ3, two case-studies are performed. The two case-studies perform as a middle point between the literature and interviews with the AS Faculty stakeholders. The principal objective of this thesis is to furnish directly applicable recommendations for the AS Faculty of TU Delft. By integrating insights from literature with real-life case studies, the aim is to formulate practical recommendations that can be promptly implemented. The first case-study analysed in this research is the NHL Stenden university of Applied Sciences. The second case-study is on the HVHL university of Applied Sciences.

5.1.1. Desk research on NHL Stenden

NHL Stenden University, established in 2018 in the Netherlands, focuses on world-wise innovation, aiming to enhance personal growth and contribute to community development through top-tier education and research. NHL Stenden is a recently established international university with multiple campuses created as the result of a merger. Located in Leeuwarden Friesland, the university holds 22,000 students, 13% of whom are international, offering 70 bachelor's, 21 master's, 21 associate degree programs, and 249 minors. The Strategic Education Policy (2019-2024) highlights the role of students and teachers in shaping the world, emphasizing sustainability in their Design-Based Education (DBE) approach (Bakker & Sinia, 2019)("About NHL Stenden", n.d.).

Figure 5.1: The five aspects of Design Based Education created by (Bakker & Sinia, 2019) according to their visions, beliefs and ambitions. Starting top left and going clockwise direction: the five aspects are design thinking, multi-disciplinary collaborations, sustainable education, international and intercultural, and personal leadership.

DBE integrates sustainability into all study programs, fostering collaboration, real-world issue addressing, and impactful solutions for societal challenges (Figure 5.1). Sustainability has become a prominent focus across programs, with distinctive courses reflecting this ethos. The policy outlines a gradual, iterative process in formulating NHL's educational concept, incorporating insights from various disciplines and stakeholder consultations.

The implementation of DBE adopts a systemic change approach, endeavoring to harmonize all educational modalities with the DBE concept. The document addresses the 'why, what, who, and how' of their system, emphasizing a clear goal and roles of education consultants and team leaders. The 'how' involves a phased DBE implementation pathway, allowing flexibility for programs to shape structures and contribute to a common language. KPIs track progress, covering education, DBE implementation, visibility, and quality.

The policy envisions an easier DBE transition with appropriate communication methods, operational policies, manuals, and tools. Looking forward, the study suggests exploring NHL Stenden's progress post-2024 and understanding the drivers, barriers, and uncertainties in their Sustainable Education Policy. As NHL Stenden was only formed the way it is now in 2018, it should be taken into account that their approaches might not work at an HEEI that was founded in 1986 (Stoel & Smulders, 2021). However, the new plans of TU Delft to grow their community might give a window of opportunity to make radical changes.

5.1.2. R1 interview results on NHL Stenden

In the preliminary desk research phase, it became evident that the institution's DBE approach extends beyond the mere implementation and integration of ESD, permeating the entirety of the institution's operations. To gain deeper insights into the obstacles and effective strategies that facilitated the systemic transformation at NHL Stenden, an interview was arranged with an educational consultant involved in formulating the university of applied sciences' educational strategic policy.

The interviewee mentioned how their interpretation of ESD is defined according to five concepts:

1. A durable educational concept, that does not have to be updated every few years.
2. Continuous Feedback; throughout courses, feedback is constantly provided to students.
3. Bachelor and master end projects that have to contribute to a better society.
4. Sustainable Development Goals have to be included in courses.

5. Sustainable Research and Operations are connected to the educational program.

An overview of the discussed barriers, drivers and uncertainty factors is elaborated below.

Drivers of systemic education for sustainable development implementation

The biggest emphasis that was made during the interview was how the institution originated: as the institution was the result of a fusion, there was a big window of opportunity for the restructuring of the educational concept. The interviewee mentioned how ”The success of the fusion critically depended on the effective implementation of DBE. Our university aspires to emerge as a unified institution, moving away from a competitive stance to foster a more collaborative environment.” As shown in section 4.2.4, the design and implementation step of systemic change benefits from such a window of opportunity.

The driving force behind systemic change involved diverse stakeholders, not just the strategic plan writers. Early adopters among faculty, fueled by shared vision and intrinsic motivation, inspired widespread acceptance. Transparent communication and constant reinforcement of the vision were crucial for cultural change, presented visually offline and online by enthusiastic early adopters. Furthermore, a significant driver identified was the public support of top-management and collaboration across all levels of the faculty. The change endeavor necessitates an amalgamation of top-down and bottom-up approaches, ensuring that all stakeholders have a voice in the process.

Additionally, the interviewee emphasized the importance of a detailed strategic plan with a concrete action plan to give teaching staff guidance. However, it should be emphasized that all teachers should have freedom for interpretation and time for making the changes.

Another driver is the external assessment of the sustainability performance of HE(E)Is by institutions such as SHE and SustainaBul. The SustainaBul, organized annually by Studenten voor Morgen since 2012, is a ranking of Dutch Higher Education Institutions. Participating educational institutions are assessed through a questionnaire covering sustainability in research, education, operations, and integrated approaches (“SustainaBul”, n.d.). The interviewee mentioned how these assessments could create leverage or a means of enforcement to change.

The interviewee emphasized the necessity of simultaneously changing operations, education, community, and research to initiate cultural change and enhance ESD implementation.

Barriers of systemic education for sustainable development implementation

A barrier that was addressed during the interview was the broad interpretation of the word sustainability. Without clear guidance, some teachers do not understand what to do with this core objective. Furthermore, the interviewee did mention how in the initial steps of the process, sixty learning objectives were invented. However, such a high number of objectives led to a ’crossing-topics-off’ behavior, and risked the creation of a coherent green learning line. This number was then lowered to twenty objectives.

Furthermore, the interviewee highlighted that HEIs being primarily concerned with student enrollment figures might present a potential obstacle. The evolving mindset and altered course content might appeal to a different category of students, leading to a potential decline in enrollment figures. Consequently, this could prompt top management to reconsider their strategies to attract a larger student base.

Uncertainty factors of systemic education for sustainable development implementation

Regarding education and operations, the institution uses the Sustainable Development Goals (SDGs) as one of the guidelines. However, the interviewee mentioned how for some it is seen as a driver, while for others the SDGs can be a barrier. Although the utilization of a framework offers direction and unity, the necessity for a comprehensive elucidation and regular interactive sessions seems to be paramount.

A second uncertainty factor is student feedback. NHL Stenden lets students from different programs work together in multidisciplinary labs, where they address societal and environmental issues, often tackling the topic of sustainability and climate change. The interviewee stated: ”Multidisciplinary labs mix students from different fields to tackle significant issues. Initially focused on their disciplines, they later appreciate different perspectives, fostering empathy. While positive in the end, this understanding develops later in the program.” Initially, due to varying student motivations for enrollment that may not inherently align with sustainability-related matters, their initial feedback might veer negatively, thereby diverting the teaching staff’s focus from the subject matter.

A third uncertainty factor is the varied interpretation of the new educational concept. The interviewee stated: ”The uncertainties were, ’Will the educational concept be as intended, embracing the ideology? Can everyone adapt well to it without too many differences among programs?’ Ultimately, it appears that there are significant differences among programs.” The interviewee added how one should not forget that these changes are an ongoing journey and learning experiment.

Finally, there exists a perception among programs and educators that they are under continual pressure to adapt and change. This perception may adversely impact the successful implementation of ESD.

Overview

The interviewee ended with the statement: ”Well, it truly starts with an educational concept. Where statements are made, and then the program has to relate and get the space to shape it in their own way. But there is an overarching direction from the Executive Board that indicates how far the progress is, what is managed, what is difficult, and where help is needed. It’s really facilitated from the Executive Board.” Figure 5.2 shows a summary of the drivers, barriers and uncertainty factors mentioned above.

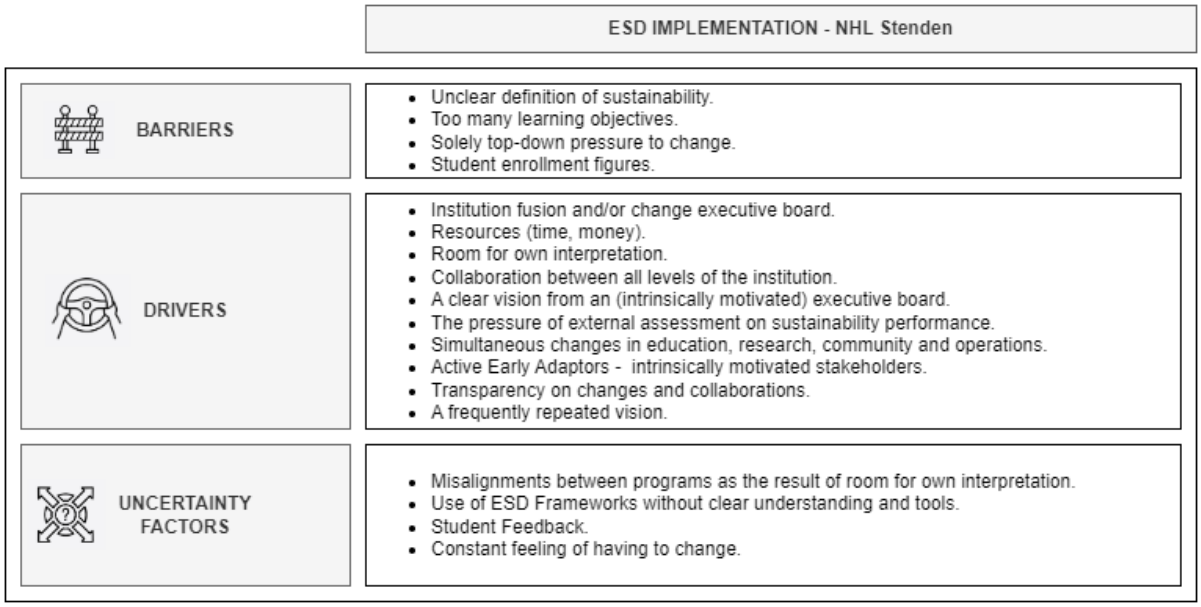

Figure 5.2: Overview of Barriers, Drivers and uncertainty factors for ESD implementation and systemic change at NHL Stenden.

5.1.3. Desk research on HVHL

The Van Hall Larenstein University of Applied Sciences (HVHL), with campuses in Leeuwarden and Velp, is a sustainable leader among Dutch Higher Education Institutions. Holding the SustainaBul title of the most sustainable HEI in the Netherlands for 2023, HVHL received a perfect score in Sustainability in Education, with all 13 bachelor studies earning three (AI)SHE stars (“Hogeschool van Hall Larenstein opnieuw ’duurzaamste hoger onderwijsinstelling van Nederland”’, n.d.)(“Van Hall Larenstein officieel de duurzaamste hogeschool van Nederland”, 2018). This means that all thirteen programs have included the SDGs and UNESCO objectives throughout their whole program and constantly evaluate the curriculum with sustainability in mind. The institution’s educational policy centers on four transitions: climate change, sustainable agriculture and food, sustainable water management, and biodiversity and (animal) welfare. This focus guides students and staff to create tangible impacts (“Dit is HVHL”, n.d.)(*Growing as experts in transition, institutional plan 2022-2025*, n.d.).

When comparing the HVHL institutional plan with the why, what, who and how of Graham (2012) and the NHL Stenden Educational plan, it can be observed that this document likewise starts with a clear statement on the vision, mission and core values of the HEI. *Growing as experts in transition, institutional plan 2022-2025* (n.d.) was not only created to guide the HVHL policy plans for 2022-2025, but also to manage

the annual evaluations. The HVHL institutional plan aligns with key elements of systemic transitions, emphasizing the importance of reporting and process evaluations. Collaboration at all levels and with partners shaped the plan, highlighting the role of individuals in initiating change. The strategy revolves around impact and the development of transition experts. The institution has set goals for 2025, including acknowledging the connection between education and transitions, promoting lifelong learning, aligning research with transition relevance, and using campuses as real-world test-beds for sustainability innovation.

The HVHL's ongoing process of implementing its policy plan involves continuous learning, collaboration, and transparency. The institution is developing an integral educational vision with a focus on transitions. The plan reflects a commitment to clear communication, constant monitoring, and periodic goal reassessment.

To gain insights into HVHL's vision agreement and implementation, it would be beneficial to explore how their culture of personal bonds and short lines within a small university may be applicable to TU Delft's AS Faculty.

The interview with a HVHL sustainability policy worker revealed a commitment to sustainability from a previous Executive Board, influencing curriculum changes and earning high (AI)SHE ratings. The transition from content-driven sustainability education to transition education aligns with the current Executive Board's emphasis. The interviewee highlighted key drivers, barriers, and uncertainty factors in integrating ESD at HVHL. These insights provide valuable considerations for shaping sustainable principles in education.

5.1.4. R1 interview results on HVHL

To obtain more profound understanding of the challenges and successful tactics that supported the systemic change and ESD implementation at HVHL, an interview was scheduled with a sustainability policy worker engaged in developing the (educational) strategic policy of the university of applied sciences. When the interviewee joined HVHL, a previous Executive Board highly prioritized sustainability, recognizing its critical importance for the future. Sustainability was a personal value for various staff members. As a policy officer, the interviewee decided together with a working group to adopt SHE principles. The group initially set goals of two out of five stars for programs, escalating to three stars the following year, and aiming for 50 percent achieving four stars within the next few years.

This commitment spurred curriculum changes, demonstrating rapid progress, indicating an effective integration of sustainability within each program's structure and ethos. Staff undertook significant efforts to rework all curricula, driven by their intrinsic motivation, resulting in smooth execution and pride in achieving set goals. The effort mainly focused on programs, coupled with a school-wide audit by Hobéon, assessing programs, facilities, and research for alignment with sustainability. Research-wise, lecturers were required to commit to at least one SDG and outline their contribution. Discussions arose, particularly regarding SDG Hunger and contentious topics like large-scale livestock farming. A compromise emerged: treating it as a compass, with Hunger at the core, while ensuring it doesn't negatively impact other SDGs. Following the recent change in the Executive Board leadership, emphasis shifted from sustainability to transition management, steering curricula towards transition education rather than content-driven sustainability education, impacting ongoing curriculum revisions.

In the pursuit of integrating ESD within HVHL, several key drivers, barriers and uncertainty factors were identified by the interviewee. These variables play a pivotal role in shaping and advancing sustainable principles across their educational landscapes. An overview is given in the sections below.

Drivers of systemic education for sustainable development implementation

The interviewee highlighted key drivers for successful ESD implementation at HVHL. Firstly, intrinsic motivation and clear leadership from the Executive Board significantly contribute to focused efforts, financial support, and progress tracking. The interviewee mentioned: "What really helps is simply that the Executive Board initiates and stands behind this. It helps in terms of money, it just helps in focus. It helps in the entire conversation cycle, so that translates completely into the fact that managers have to report it in a quarterly report."

Collaborative Working Groups, including policy advisors, facilitate collective decision-making and policy development, emphasizing the crucial connection of these groups with faculty hierarchy. Leveraging experienced staff as change leaders promotes stability and credibility in the transformation process. Additionally, collaborative endeavors among staff alleviate workloads and foster a supportive atmosphere,

promoting mental well-being and optimizing resource utilization. During the interview, the topic of LSCs and the Climate Action Teams at TU Delft was discussed. The interviewee mentioned: ”The connection with individuals of this kind [LSCs] with the regular hierarchy, the Dean and the Director of Education, is essential.” A positive relation of the LSC with all levels of the faculty, especially the decision makers, is an important aspect that should not be forgotten.

Convergence of vision among students and teaching staff, commitment to transparency, and maintaining a low environmental footprint enhance an institution’s credibility and intrinsic motivation. External assessments by accrediting bodies like SHE or Hobéon serve as benchmarks for compliance with sustainability standards. Institutional profiling and comparative analysis showcase unique sustainable initiatives, reinforcing the institution’s reputation within the academic sphere. Together, these drivers form the foundation for HVHL’s successful ESD implementations, guiding them toward a more sustainable educational paradigm.

Barriers of systemic education for sustainable development implementation

The interviewee mentioned how initially there was quite a lot of resistance from teaching staff: ”Initially, there was resistance because it simply took a lot of time. I was very involved in the process. For instance, we appointed external and internal coaches to assist programs in this regard. However, there was considerable enthusiasm regarding the content, which was really nice to see. Additionally, there were leaders within each program coordinating this effort—these were teachers who managed this coordination, so it wasn’t equally challenging for every teacher.” Even though there are multiple ways this barrier can be lowered, the amount of resources such a transition takes should not be underestimated.

The biggest barrier emphasized was the recent change in Executive Board, who have new goals and aspirations. Additionally, the misalignment of the sustainability focused vision and external funding caused a discussion on transparency and consistency. The interviewee mentioned: ”Good financial compensation from the business world is an obstacle. A company like Friesland Campina or Shell? If you conduct research for them, it’s financially quite attractive. That’s a real obstacle.” The interviewee further expounded that students frequently choose to work for the companies they had engaged with for research or projects. Collaborating with organizations aspiring to make a positive impact would be more aligned with HVHL’s vision.

Uncertainty factors of systemic education for sustainable development implementation

Similarly as with the NHL Stenden interview, the interviewee mentioned how the changes had an effect on student enrollment numbers. As HEIs are frequently focused on these numbers, the interviewee mentioned how this could be seen as an uncertainty factor ”In some programs, you might notice it in the intake, but overall, it will likely have little effect, as was evident in our case. Ultimately, I think it even may have resulted in higher intake figures. Yes, they simply made some clearer choices, and these [Executive Board] found it somewhat more stressful.”

Overview

All in all, the HVHL interviewee highlighted the importance of intrinsically motivated management and of bottom-up change agents. Furthermore, a sustainability coordinator that has been around for a long time, and available resources fasten the transition. The interviewee finally stated: ”Assign the role of coordinator to a teacher who has already been in the institution for a longer period of time. Partially free them up to work on this portfolio, and let them be supported by people who have more time, so you can hire someone for that or outsource it through central channels. I still think external monitoring is necessary. Having an external entity come by, it creates accountability.”

The interviewee emphasized the amalgamation of education, research, and facilities. According to the interviewee, it is imperative for these aspects to evolve in unison: ”The one influences the other, and that’s why it’s great when it happens in parallel; students receive a lesson on something, it simultaneously gets involved in research and it is noticeable in operations.” This shows how both case-study 1 and 2 suggest that institutional sustainability has an impact on ESD.

An overview of barriers, drivers and uncertainty factors can be seen in Figure 5.3.

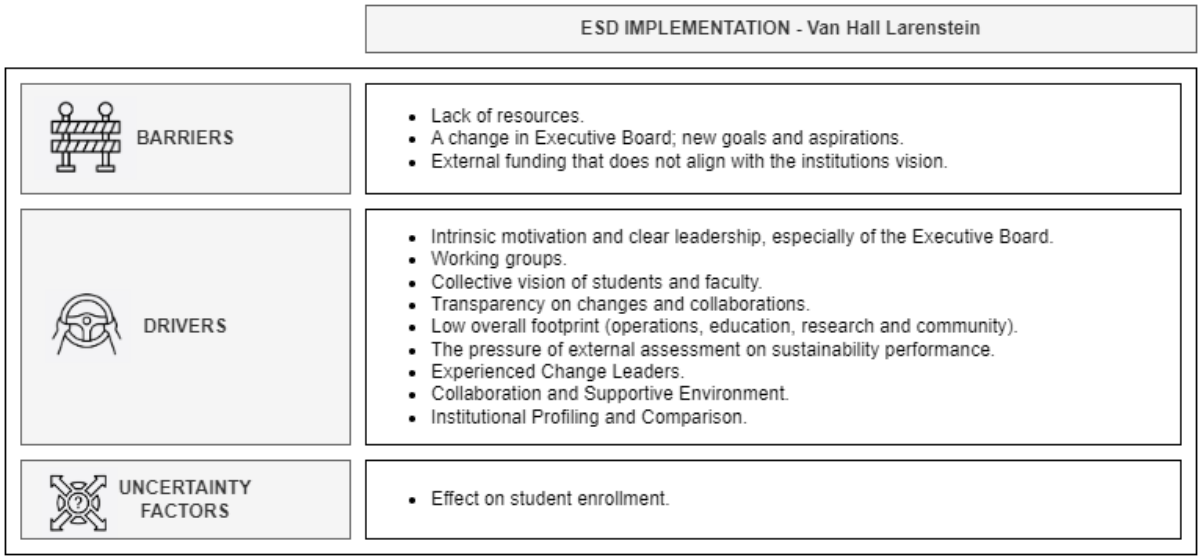

Figure 5.3: Overview of Barriers, Drivers and uncertainty factors for ESD implementation and systemic change at Van Hall Larenstein.

5.2. Take-aways & first comparison to the AS Faculty of TU Delft

Both case studies reveal robust visions for ESD implementation with long-term objectives, emphasizing collaboration and a commitment to global impact. Educational policy plans align with the *Why, What, Who*, and *How* of Graham (2012), stressing the importance of early preparation and planning. Guidance is provided while allowing room for individual interpretation.

Furthermore, synchronization among operations, education, research, and community initiatives appears to be crucial. Should one portfolio show stagnation, the momentum for change in the other areas diminishes. For a cultural shift to occur, fostering openness to new educational paradigms necessitates collective transformation across all facets of the institution.

Regarding the pressure of external assessments on sustainability related performances, such as SHE and the SustainaBul, its influence on the AS Faculty of TU Delft is questionable, as this appears to be more of an university-wide recommendation. TU Delft itself partakes yearly in the SustainaBul and currently has a member of the core-team of sustainability who works on an ESD framework. This framework can be seen as an assessment for all faculties.

Organizational differences between Universities of Applied Sciences and universities impact goal-setting processes. The former allows swifter top-down implementation, while the latter engages in in-depth discussions, resulting in a slower decision-making process. The HVHL interviewee mentioned: ”In universities of applied sciences, a more business-oriented structure prevails, facilitating hierarchical directives from the Board of Directors. Conversely, universities tend to engage in in-depth debates and discussions on proposed changes.” At TU Delft, the management of education involves collaboration between various stakeholders and operates through both top-down and bottom-up approaches. According to the TU Delft Executive and Management Regulations (EMR), the Dean of a Faculty, in consultation with the Executive Board, appoints a Director of Education. The Director of Education assumes primary responsibility for overseeing educational matters within the faculty, including curriculum management, quality assurance, and budget oversight. They provide leadership to program directors, contribute to strategic educational policymaking at the university level, and maintain external connections in the educational field. Additionally, they advise the dean on educational issues and are accountable as part of the faculty’s management team. Furthermore, the Dean appoints examination committees, program committees, and program directors for each program or group of programs within the faculty. These committees are tasked with reviewing and providing consent on education and examination regulations (provided by the faculty’s teaching staff), conducting annual evaluations of their implementation, offering advice on educational matters, and

discussing accreditation reports. Notably, half of the committee members are students enrolled in the respective program (“Executive and Management Regulations”, n.d.).

Student involvement, while beneficial, may be limited due to hierarchical structures in universities of applied sciences. According to both interviewees, students play a significant role in enrollment but are more inclined towards mobilization than central decision-making. One of the contributing factors to this scenario is the transient nature of student involvement in driving change; students who initiate these initiatives often depart after a certain period.

Students do play an important role when it comes down to student enrollment. According to the interviewees, both universities of applied sciences and universities face the pressure of competing for enrolment figures. This competitive environment often results in a cautious approach to avoid polarizing stands according to the HVHL Interviewee. The focus on these figures also fosters a tendency towards uniformity in approaches and curriculum.

Overall, while universities and universities of applied sciences have distinct operational methodologies, they share a common challenge of aligning operational strategies with societal needs amidst the constraints imposed by enrolment-driven financial dynamics. The recognition of the hierarchical and cultural difference emphasizes how in universities of applied sciences a more top-down focused approach can be taken while this would create solely resistance in universities such as TU Delft. While the barriers, drivers and uncertainty factors of both case-studies 1 and 2 align with the variables defined in the literature research (section 4.2.4), the role of students in ESD implementation is unclear. This should be further explored in R2.

Simultaneously, it should be questioned how institutional sustainability influences the success of ESD implementation at an AS Faculty of a university. It would be valuable to ascertain from experts employed at TU Delft how they see the differences and similarities between these two tiers of higher education when it concerns ESD implementation and the process of systemic change. This will likewise be further explored in R2.

6

The applied sciences faculty of TU Delft

This chapter will focus on answering sub-questions 4 and 5:

- *SRQ4:* What is the current situation of ESD implementation at the Applied Sciences Faculty of TU Delft?
- *SRQ5:* Which strategies can be used to implement ESD in a systemic manner at the AS Faculty of TU Delft?

To explore the current status quo of ESD implementation at the AS Faculty of TU Delft, and to answer sub-question 4, first a desk research is performed on AS Faculty ESD related initiatives that have taken place, are taking place and/or will take place. Secondly, diverse AS Faculty stakeholders are interviewed in the second part of R1. All TU Delft specific R1 data is coded as explained in section 3.4, with a main focus on the variables of Weiss et al. (2021).

This coded R1 data is then evaluated and validated in R2. Moreover, R2 incorporates data from both case studies and assesses its applicability to the AS Faculty of TU Delft. The outcomes of R2 comprise three refined and validated lists delineating the barriers, drivers, and uncertainty factors associated with (systemic) ESD implementation, pertinent to the AS Faculty of TU Delft.

In the final round (R3) the acquired and compiled data is analysed during a focus group, by performing a SWOT analysis. To answer sub-question 5, the researcher reflects on the drivers of systemic change found in section 4.2.4, and merges them with the outcomes of the SWOT analysis. The results yield five strategies suitable for implementing ESD in a systemic manner.

6.1. Desk research on (the applied sciences faculty of) TU Delft

Examining TU Delft, the university and its faculties have adopted multiple strategic visions since it originated. The first time TU Delft acknowledged the importance of sustainable development was in 1994, when the University Council did not only state their new commitment to development and offering of new SD courses, but also to the fact that engineers should have well developed social skills (TU Delft: Towards a new engagement, 1994). In 1998 the executive board of TU Delft set three new goals (Kamp, 2006):

1. Creating a foundational course titled ”Technology in Sustainable Development” to be a part of the curriculum for all Delft University of Technology students.
2. Integrating the principles of sustainable development into all standard disciplinary courses in a manner that aligns with the unique nature of each course.
3. Establishing an option for students to specialize in sustainable development as part of their degree program, allowing them to graduate with expertise in this field.

Kamp (2006) mentions how since then introductory and specialized courses have been developed university-wide. The introductory course is offered in various faculties, while specialized courses are open to all university students, with over 150 students choosing the sustainable development specialization. In four faculties, the Individual Interaction Approach was adopted to infuse sustainability into existing courses

and foster informal networks. This process entails conducting one-on-one interviews with instructors, encouraging them to brainstorm effective methods for incorporating sustainable development into their courses. This grassroots approach generated a wealth of enthusiastic ideas within the four faculties where it was implemented. However, a comprehensive evaluation of the extent to which these instructors have integrated sustainable development into their courses has yet to be conducted. The author states how for a lasting transformation towards sustainability in engineering education, the collaboration and support of leading academics, instructors, and the university administration at Delft University is essential.

Over the years, TU Delft has encountered various initiatives that represent attempts at implementing ESD. The GreenDatabase, a database constructed by GreenTU and the core team of sustainability of TUD in 2023, shows how 35 courses have included topics on SDGs and/or sustainability/climate change in general ("GreenDatabase", n.d.). Another initiative that should be mentioned is the Green Thread pilot that was initiated in 2019 by GreenTU and student body Lijst Bèta, performed by the GreenTeam of AS (GreenTeamAS) ("The Green Thread", n.d.). The objective was to support educators of the AS Faculty who are eager to create sustainable course materials, but lack time, energy or any other resources. The pilot involved actions such as modifying presentation slides, designing questions, and creating educational resources. At the heart of this procedure is the idea that course coordinators maintain authority over their courses, while minimizing the usual administrative challenges linked to implementing changes. GreenTU and GreenTeamAS collaborated to outline an actionable plan, followed by the selection of student assistants possessing the necessary skills, and they ensure that the requisite funding is secured. However, the current state of the courses that took part in this initiative is unknown. The Green Thread was discontinued at the outset of 2022 and remains pending for resumption.

In order to enhance comprehension of the current state of ESD implementation and to gain further insight into prior actions undertaken, the first part of the interviews will prioritize the discussion of specific inquiries pertaining to this subject matter at the Applied Sciences Faculty. Given that not all initiatives are comprehensively documented, the experiential knowledge of the interviewees is regarded as a notably valuable resource.

6.2. R1 interview results on the history & status quo of education for sustainable development implementation at the applied sciences faculty

For the AS Faculty of TU Delft, the stakeholders of the system involved in education are diverse and range from student to top management. This study considers multiple actors that are involved in educational processes and fulfill roles in top-down and/or bottom-up initiatives. The selection of interviewees for round one (R1) was based on the endeavor to obtain a comprehensive overview encompassing diverse levels of stakeholders. Quotes will be assigned to the job titles of the interviewees: top-management, student 1, assistant professor 1, assistant professor 2 and program director 1. A detailed selection process can be found in section 3.5.

In chapter 4 it was mentioned that to facilitate effective implementation of ESD and foster systemic change, it is imperative to discern prevailing obstacles and factors contributing to success and to understand the culture of an institution. An essential initial stride in this pursuit involves recognizing the existing implementation challenges encountered by the AS faculty. In the following discussion, the viewpoints of the TU Delft interviewees from the first interview round will be presented. This discussion aims to delineate scenarios wherein ESD implementation was experimented with, highlighting both impediments and achievements. It is important to note that this overview is not exhaustive and only encompasses the situations articulated by the interviewees.

As depicted in Appendix C.2, the recurrence of the *Status Quo* designation is conspicuous in its frequent association with the Weiss et al. (2021) variables. This phenomenon signifies the diverse nature of ESD within the faculty, indicating diverse stakeholders' engagement and commitment to this subject matter. The variables discussed in this section are *Top-Down*, *Bottom-up* and *Status Quo*.

6.2.1. Top-down initiatives

The initial instance of a top-down initiative highlighted was the establishment of a mandatory sustainability-focused course for all applied physics bachelor students two decades ago. Despite being stipulated by

the board of directors, the top-management interviewee explained how the course faced discontinuation due to students' dissatisfaction over its superficial treatment of the subject matter. An independent course focusing on rudimentary sustainability topics failed to resonate with applied physics' students academic preferences.

Throughout the interviews, it became evident that in both undergraduate and graduate programs, top management orchestrates a centralized curriculum, subsequently allocating specific courses to designated instructors. These educators then possess autonomy in structuring course content, provided it aligns with the defined learning objectives. Several interviewees underscored recent transformations initiated by the top management of the MSc of Chemical Engineering. At the end of 2023, the Chemical Engineering Master program was revised to now comprise of three specialized tracks: energy, circularity, and health. This change ensued following a shift in top management, presenting an opportune moment for reform. Although the decision was instituted top-down, collaborative working groups involving faculty members and researchers facilitated the execution of the plan. Assistant professors, top management, and the program director unanimously acknowledged that a change in leadership serves as an ideal juncture for initiating reforms. Nonetheless, they collectively agreed that exerting top-down pressure, if not executed adeptly, may evoke resistance.

An additional aspect meriting attention pertains to the mechanism governing university-wide and faculty-wide decisions. Within a discussion regarding the faculty's research funding affiliations, Assistant Professor 1 articulated, "The perennial issue at TU Delft revolves around whether it embodies a top-down approach disseminated uniformly or if individual faculties exercise autonomous decision-making. Our department's overarching stance is to articulate a clear standpoint to facilitate substantive dialogues at the faculty level." Evidently, TU-wide directives allow faculties leeway in their interpretation. An illustrative instance is the Vision, Ambition, Action Plan, which has cascaded down to the AS faculty, leading to the establishment of two Local Sustainability Coordinators (LSC) and the formulation of their bespoke Climate Action Road map, as delineated in Chapter 3. The directive from higher management mandated the AS Faculty's establishment of an LSC and the creation of a climate action road map. However, the absence of initial resources posed a considerable impediment to this endeavor.

6.2.2. Bottom-up initiatives

The GreenTeamAS initiative established in 2019 by four students initially focused on various portfolios but shifted primarily to education, creating the GreenThread pilot project. Funded by GreenTU and Lijst Beta, the GreenThread aimed to integrate sustainable development into course content. According to both assistant professor 1 and 2 and student 1, the responses varied among instructors, with some opposing and others showing enthusiasm, yet many did not respond. Despite a two-year pilot, the initiative lacked impact due to student constraints (time, incentives and expertise) and subsequent reversion of course changes. Student 1 mentioned how study associations and the Faculty Student Council have also prioritized sustainability, but with unclear results due to fluctuating interests when board years conclude.

In addition to this, Assistant professor 1 emphasized how at the GreenTeamAS level, it seems the university's and faculties' overarching ambitions have overshadowed the traditional role of student teams. The focus now appears to be on larger-scale changes, beyond what students can directly influence. There's ambiguity about the specific role of individual Green Teams, which traditionally mobilize and raise student awareness. The emphasis seems to lean more towards reducing the university or faculty's footprint rather than actively engaging and involving students. The top-management interviewee however emphasized how students should take more initiative and should start assisting teachers if they want ESD to be implemented. The interviewee mentioned: "I think it would be great if there were students who stood up and said to themselves, 'I'm going to engage actively with teachers'. Students cannot say they are not able to make exercises because they do not have the expertise. You're a TU Delft student, of course you understand it, and if not, make sure you get it." The question arises on how the issue can be seen more as a we-problem, and how an effective collaboration can be initiated that gives confidence and guidance to all stakeholders.

Meanwhile, individual educators integrate sustainability into courses autonomously, adapting to the pressing climate crisis, but these initiatives face discontinuity upon instructors' departures. Interviews with top-management and program director 1 highlighted increased sustainability content without explicit directives, but the Studiegids lacks updates, providing an unclear overview. Assistant professors 1 and 2 serve as direct examples, emphasizing the broader implications for students both within and beyond the faculty.

During the interviews it was emphasized how this integration adds to instructors' workload, resulting in increased stress.

6.2.3. Top-down and bottom-up collaborations

As previously indicated, the alterations in the Chemical Engineering master program were instigated through top-down directives, yet their effectiveness was contingent upon a fusion of top-down and bottom-up approaches. The program director worked in close collaboration with both teaching and research staff within a dedicated working group. However, during the interviews, it was noted that this working group was convened solely for the comprehensive restructuring of the master's program, indicating its one-time nature. The program director underscores the importance of ongoing assessment and feedback loops involving teaching staff and students, a practice that had not been previously instituted. Assistant Professor 1 highlighted the need for roles focused on program cohesion and student improvement, noting recent hires focusing on teaching innovation.

A next point of discussion was the evolving collaboration between the GreenTeam and the faculty, emphasizing the LSCs potential leadership in overseeing the GreenTeam initiative. Discussions are ongoing about a potential Task force unifying various green initiatives and LSC to consolidate collective impact.

Another significant aspect to consider is the close interconnection between education and research within the faculty. Throughout all five interviews, there was a consistent emphasis on how research takes precedence in shaping educational approaches at the AS faculty. There has been a gradual yet consistent transition within research activities, redirecting attention toward sustainable development-focused subjects. The program director noted students' intrinsic motivation in sustainability-focused projects. Concurrently, they mentioned external influences, including government subsidies and corporate engagements, that guide the faculty towards sustainability challenges, emphasizing the importance of framing inquiries within sustainability contexts to secure funding.

6.2.4. Windows of opportunity

There are diverse initiatives that have happened and are happening at the AS Faculty of TU Delft. Weiss et al. (2021) argue how institutions should compare their own systems with one of their six implementation patterns and should learn from the identified drivers and barriers. As the status quo of ESD implementation at the faculty shows signs of multiple patterns with so far none of them being most effective, it appears that a systemic strategy could benefit the AS Faculty. In order for a systemic strategy to work, first the barriers, drivers and uncertainty factors should be explored in more detail. In the next section, the interviews will be analyzed further to better understand the context and internal culture of the AS faculty. It will be further explored which variables can play a vital role in effective ESD implementation and can create a window of opportunity for a systemic change.

6.3. R1 interview results - drivers, barriers and uncertainty factors of education for sustainable development implementation

The results from the coding phase of the round 1 interviews regarding the drivers, barriers, and uncertainty factors impacting ESD implementation at TU Delft's AS faculty are summarized in Appendix C. The categorization was primarily based on interviewees' statements, occasionally applying labels to passages not explicitly mentioning 'barrier,' 'driver,' or 'uncertainty factor.' This classification was executed through an analysis of the context within which the statement was made, coupled with the researcher's expertise in the thesis topic and verified in the second round of interviews.

The twelve variables that appear to have a significant influence are: Implementation level, Integration approach, Resources, Communication, Internal Collaborative Culture, Faculty Support, Student support, Involvement internal stakeholders, Perception of sustainable development-faculty, Synergies between different areas, Internal culture AS and Perception of Own influence. These variables and their tendency for turning into a barrier, driver or uncertainty factor are discussed below.

6.3.1. Implementation Level

In section 6.2, the importance of setting an ambition from higher authorities while allowing enough autonomy to shape courses was emphasized. Both assistant professors mentioned how without a clear assignment,

strategic plan and/or vision, there will be no lasting change. Without a detailed plan and clear communication, employees will not know what to do or where to get the resources to make a change. Creating a Climate Action Road map, signed by the top-management of the faculty, could ensure available resources and faculty support. Furthermore, the creation of a Task force in which change agents work together could make sure actions are undertaken at all faculty levels and all people involved are heard. Especially the assistant professors agreed how an initiative such as the appointment of a LSC should be carried by multiple change agents, rather than by individualistic actions. They mentioned how resources should be set aside for these initiatives and how decision making processes should be clearly communicated to the rest of the faculty.

An uncertainty factor that should be taken into account is changes in top-management at both university and faculty-level. The top-management interviewee mentioned: ”Implementation takes a while, and then everyone forgets about it, and there’s a new board of directors, and they find something else important again.” Long term goals should be explored in order for changes to sustain. Furthermore, an uncertainty is the difference of implementation at university-level and faculty-level. Assistant professor 1 mentioned: ”When you’re looking at a university level, you care about different things than on a research or student level. It’s not talking about hard numbers such as a building’s energy reduction, we want our graduates and staff to be motivated, sustainable individuals. I think individual teachers are concerned about what type of people do we want to have graduating from our halls.” Open discussions with different types of stakeholders could explore how the faculty’s implementation approach should align with the implementation process of the university.

An overview of barriers, drivers and uncertainty factors can be found in figure 6.1. It should be emphasized how the barriers and drivers of the implementation level variable could turn into uncertainty factors when not performed right. An example of this is a sudden lack in resources, or a lacking communication in the middle of the process. These changes could cause the implementation level to stagnate, which could eventually lead to failure.

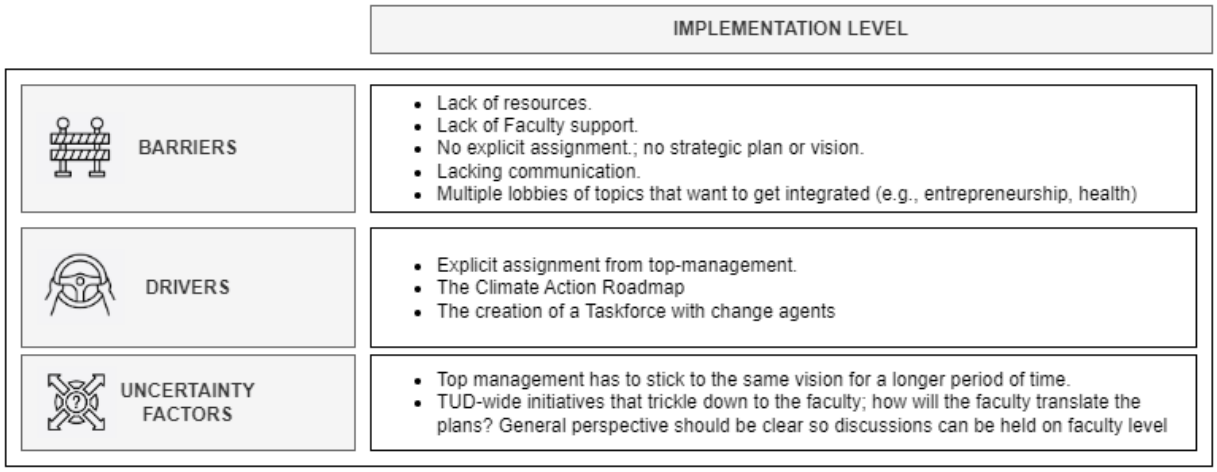

Figure 6.1: Overview of Barriers, Drivers and uncertainty factors relating to Implementation level at the AS Faculty of TU Delft.

6.3.2. Integration approach

Teaching staff repeatedly raised concerns about ESD integration, particularly regarding the potential challenges in knowledge transmission and curriculum overcrowding. Assistant professor 2 pointed out, ”A barrier could be that it complicates the transfer of specific knowledge as you might be mixing too many things together. There is an interplay between imparting awareness and wanting to impart the hardcore technical skills.” This quote underscores the importance of collaborating with teachers and how the initiation of ESD implementation should not exclusively be a top-down action but an ongoing conversation among all stakeholders involved in education.

Top-management emphasized that sustainability cannot ”*just be added*” to a course. The interviewee mentioned, ”We already have many courses explicitly focused on that [sustainable development], and in

addition, within regular courses, fundamental knowledge is almost always illustrated with practical examples. I'd also love to see students actively involved. Students shouldn't just point passively to teachers and say, 'Teach us about sustainability." This quote emphasizes again how bottom-up and top-down should work together closely. The assistant professors and the program director highlighted that educators need not be burdened with the sole responsibility of generating new course content. They emphasized the wealth of knowledge available online, indicating that many instances reliant on traditional subjects, such as oil refineries, can be effectively transformed to encompass themes revolving around green energy.

Assistant professor 2 further mentioned, "You have that one somewhat softer subject where you talk about sustainability, and then you have the rest, which is just hardcore technology where you delve back into oil refineries. And, I think that's the biggest disconnect that has always persisted. Similarly, you have ethics courses where you have one course for ethics and the rest." This quote sheds light on the perception of sustainability as a standalone subject.

The student interviewee stressed the importance of timing and reflection, proposing an end-project course for students to reflect on the broader impact of their knowledge. They suggested experimenting with when to provide context on sustainable development and climate change in the curriculum. The student interviewee proposed an idea akin to the introductory and concluding courses/projects at the commencement of bachelor's and master's programs, stating, "Giving students the assignment to zoom-out and reflect on the bigger picture could teach them more on the impact they can have with their work."

An uncertainty factor articulated by participants pertained to the habit of merely 'checking off' a subject, exacerbated by the existence of numerous competing interests in curricula, including but not confined to areas such as entrepreneurship and health. The complexities of balancing diverse interests were encapsulated by the top-management interviewee, who mentioned, "As there are multiple initiatives pushing for more time and other resources, it can become difficult to prioritize ESD."

Figure 6.2 provides an overview of barriers, drivers, and uncertainty factors related to the integration approach.

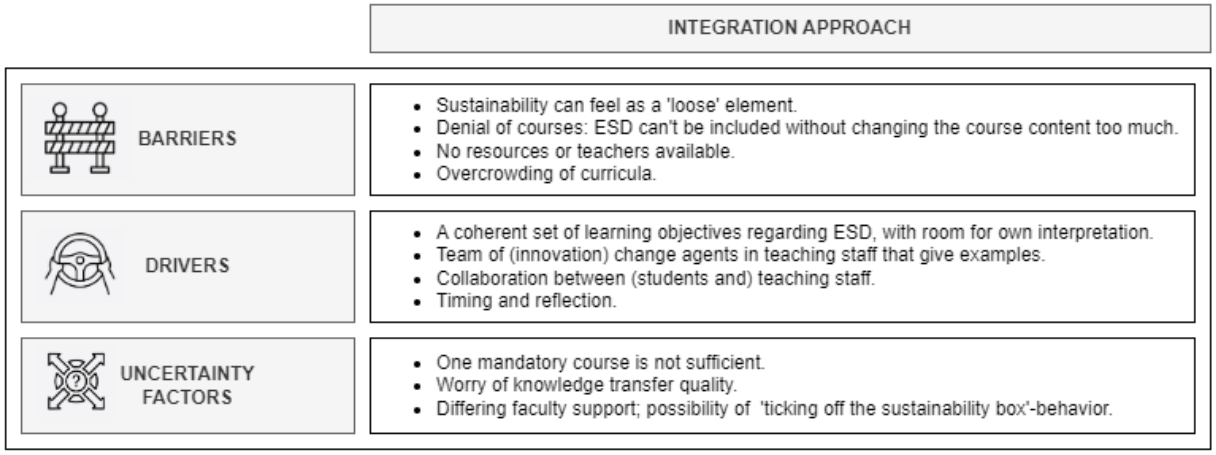

Figure 6.2: Overview of Barriers, Drivers and uncertainty factors relating to Integration Approach at the AS Faculty of TU Delft.

6.3.3. Resources and Communication

In the context of preparation or institutional environment, two prominent variables stand out: Resources and Communication. These variables have been previously addressed in discussions related to implementation levels and integration approaches. Throughout the interviews, it became evident that both variables are highly dynamic and susceptible to influence. Moreover, a frequently raised aspect revolved around the scarcity of resources. All five interviewees mentioned how if teaching staff expressed willingness to instigate changes, the constraints of time and energy remained persistent challenges. Both assistant professors mentioned how an enabler could be the appointment of personnel tasked with overseeing the integration and correlation between subjects. Given the multifaceted nature of sustainability and the

context-specific nature of subjects, each discipline necessitates an individual evaluation to determine how sustainability can be harmoniously integrated or elucidated as the fundamental basis for Sustainable Development. The top-management interviewee agreed and mentioned: ”Our education aligns with the current state of Engineering and research. Teachers, involved in practice about three-quarters of the time, contribute to the evolution of education, but this transformation lags due to the absorptive capacity, adaptability, and time constraints of teachers. Replacing long-standing examples with new ones is a time-consuming process, especially for thorough implementation.”

Another barrier on Resources that was mentioned by the program director is how certain course content is based on long-established knowledge (on for example fossil fuels). Some scientists might find the traditional science more reliable than recently published papers on green energy. Furthermore are the teaching tools based on the traditional sciences of high quality and already in place, which could be a huge barrier for the teaching staff. The program director mentioned how there is often a lack of (new) teachers that can teach these new topics. Resources can become a direct driver when time, money and energy are available. The program director mentioned how teachers become highly motivated by things that generate research funding and time saving.

Another significant driver might stem from both external and internal collaborations alongside research endeavors oriented towards sustainable development or the foundational aspects of climate change. In discussing final projects and internships, the program director highlighted the potentiality of collaborating with enterprises actively seeking sustainable advancements and solutions. Furthermore, new researcher staff should be attracted that focus on sustainable development. When new researchers transition into teaching roles, their intrinsic interest in addressing the climate crisis leads to an evolution in educational programs. Consequently, this transformative shift could potentially mitigate the resources required for programmatic changes. Encouraging collaboration and fostering creativity should be actively promoted within this context. An overview of the drivers, barriers and uncertainty factors regarding the resources variable can be found in figure 6.3.

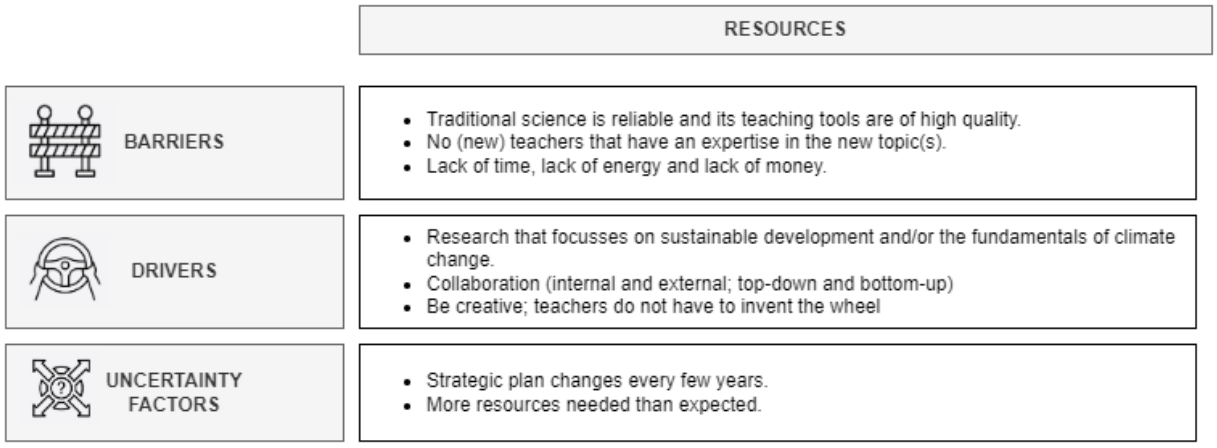

Figure 6.3: Overview of Barriers, Drivers and uncertainty factors relating to Resources at the AS Faculty of TU Delft.

Regarding the communication variable, a noteworthy observation across all five interviews was the absence of any interviewee who possessed comprehensive, up-to-date information concerning the assignment of the LSC and the completion of the climate action road map by the end of 2023. Assistant Professor 2 highlighted the incremental improvement in communication at both the faculty and university levels. The interviewee further mentioned however, how despite these advancements, decision-making processes remain unclear, and there is a prevailing sentiment among staff members of inadequate and infrequent updates.

One evident aspect derived from the interviews is the faculty’s tendency to operate as an independent entity within the campus, exhibiting minimal communication with other faculties. Furthermore, even within the faculty, there appears to be limited communication among different disciplines on individual principal

investigator (PI) level. Although communication of alterations within individual study programs has shown improvement, disseminating these changes to other programs remains a challenge due to time constraints mentioned assistant professor 1. Assistant Professor 2 suggested improving communication by instituting dedicated moments within annually or monthly organized events and meetings to focus on the advancement of the climate action road map. In terms of the education road map, the possibility of integrating structured Teaching Days was proposed as a potential option.

An uncertainty factor that was emphasized by assistant professor 1, was the misalignment of communication at university-level and faculty-level. ”The problem with TU Delft is always the question if it is a TU Delft approach how that then trickles down or is every faculty making their own decision. Our general perspective as a department is that we want to have our position clear so that we can have these discussions on a faculty level.” This misalignment can result in an unclear vision and overall understanding of the faculty’s plans and goals.

Furthermore, when it comes down to initiating communication endeavors, resources appear to be critical. Teaching assistants or even new teaching staff could be hired. Even a minor deficiency in communication-related-resources or communication could significantly jeopardize the success of a project and create resistance among the faculty’s community. An overview can be found in Figure 6.4.

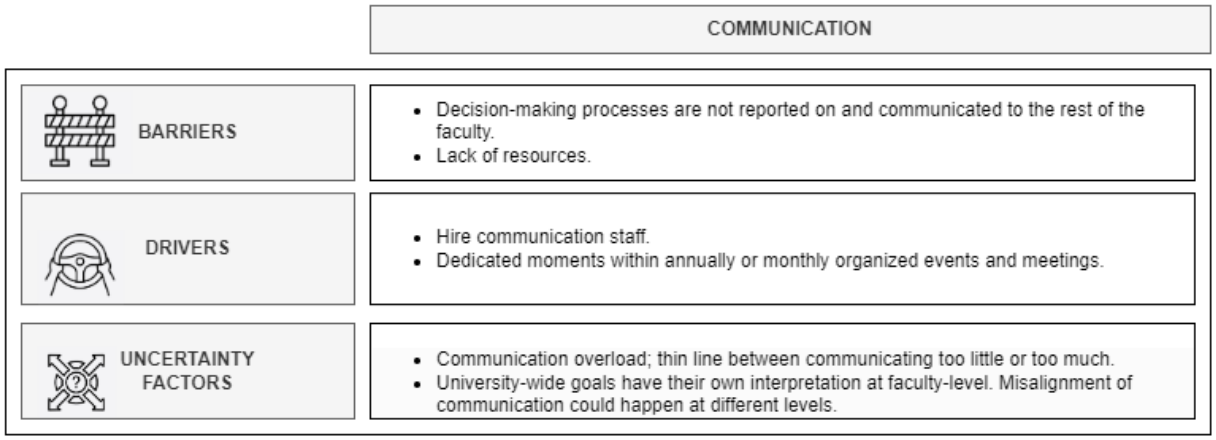

Figure 6.4: Overview of Barriers, Drivers and uncertainty factors relating to Communication at the AS Faculty of TU Delft.

6.3.4. Internal collaborative culture

As was mentioned in the earlier discussed variable sections, in order for ESD implementation to work there should be more collaboration between students and teaching staff, but also between teaching staff itself. Assistant professor 2 mentioned: ”A central curriculum is devised by the program director and coordinator, which then gets accredited. However, the specific content of courses comes down to tasks like ’you take this course, you take that course.’ Thus, one is limited in knowing how others shape their courses and how these align. Often, individuals like myself have to actively seek out this information.” The assistant professor acknowledged the potential of collaborative initiatives in reducing workload by consolidating courses addressing similar subjects across diverse study programs. However, they emphasized that initiating collaboration and establishing necessary tools and platforms require resources and willingness. The top-management interviewee mentioned how a reiterating barrier would be the multiple lobbies of topics that want to get integrated in the same manner as ESD. An overload of new tools, platforms and collaborations could create more resistance within the education community.

Assistant Professor 2 suggested that change agents could facilitate collaboration and demonstrate its direct impact. Change agents could be teaching staff already in place at the faculty, or newly hired employees that focus on interaction between courses as discussed in section 6.2.3. Furthermore, Assistant Professor 1 highlighted the potential of co-teaching courses as a strategy for educators to effect meaningful changes without requiring extensive resources. This strategy additionally serves to transform courses where teaching personnel exhibit considerable resistance towards the implementation ESD.

Moreover, the internal collaborative culture of the AS Faculty is shaped by its inherent, often individualistic characteristics, which will be thoroughly examined in the segment dedicated to the internal culture AS variable. Furthermore, when the internal collaborative culture came up during the interviews, the interviewees mentioned the differences between universities and universities of applied sciences. Universities have a more teacher-centred individualistic character, while universities of applied sciences have a more student-centred collaborative nature. These mentions emphasize the need for exploration on the resemblance and differences between both institutions when it comes down to systems change and ESD implementation. This will be further elaborated on in the NHL Stenden and van Hall Larenstein Universities of Applied Sciences sections of this research. In R2 an interview will be held with a stakeholder that has experiences at both types of institutions.

An overview of Barriers, Drivers and Uncertainty Factors can be found in Figure 6.5.

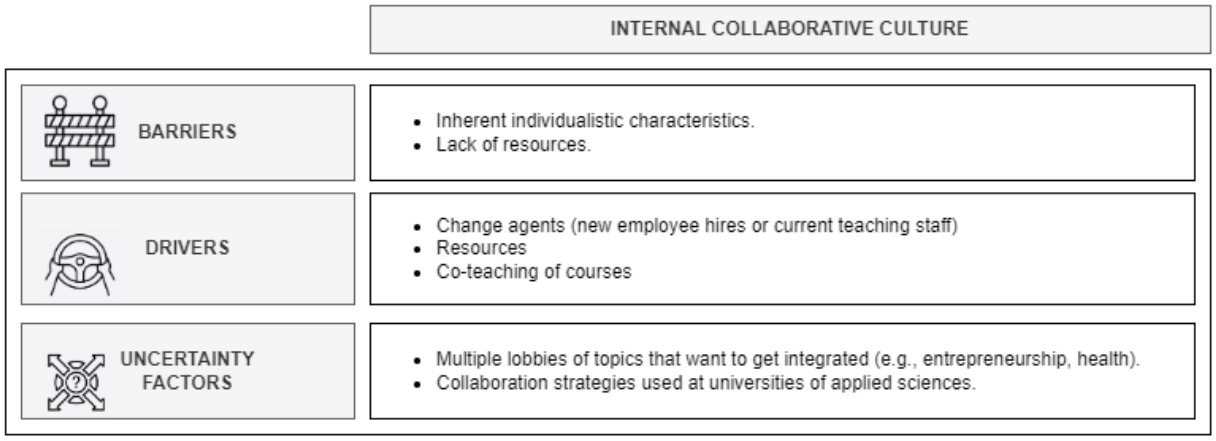

Figure 6.5: Overview of Barriers, Drivers and uncertainty factors relating to Internal Collaborative Culture at the AS Faculty of TU Delft.

6.3.5. Faculty support

According to the program director interviewee, the growing interest in climate change within the faculty is evident; however, limitations in time, energy, and financial resources hinder individuals from supporting changes in education. Besides resource constraints, a notable impediment to gaining faculty support is the absence of a clear vision from top management. Assistant Professor 1 articulated, ”It’s challenging to achieve consensus and allocate time without explicit directives and available resources.” The confluence of resources and authoritative directives appears pivotal. However, all five participants highlighted that solely adopting top-down approaches could generate resistance. Educators should retain autonomy in structuring course content and be invited to decision making processes.

Assistant professor 1 mentioned how the biggest barrier in any educational change is always the stubbornness of some teachers: ”At the end of the day, if someone just wants to teach a course the way they’ve been teaching it for 20 years, there’s very little that anyone can do to make that different. The biggest barrier is by far the fact that generally, in an academic environment, you can rarely force a PI to do anything. Which is one of the reasons why they love the job.” It was mentioned that to really enact change in regards to this type of teachers is by new teachers coming in or by having courses co-taught. These co-teachers could then push things towards more modern or more sustainable perspectives.

In all five interviews, the arrival of new staff members was seen as a fresh burst of energy and a chance for significant changes to happen more swiftly than usual. However, a concern that came up during the conversation on this potential driver is the departure of a (new) change agent, which might revert everything back to how it was before. But surprisingly, this could also present an opportunity. An example of this is the change of program director in the MSc Chemical Engineering, which directly initiated a change towards the implementation of ESD as described in section 6.2.1.

Furthermore, during the interviews the significance of resource availability and a clear directive aligned with a coherent vision was mentioned in relation to faculty support. The program director particularly

underscored the significance of securing funding for researchers if one wants to encourage them in a certain direction. Furthermore, both assistant professors and the program director emphasized the importance of visibility and acknowledgement of efforts of change agents. This acknowledgement could come from respective higher-level faculty members and/or from students. Something noteworthy is how interviewees mentioned how an increase in student support can result in an increase in faculty support. Especially the top-management interviewee stressed this direction of change. When students mobilize and express their needs for more ESD implementation, the teaching staff will turn as well mentioned to the interviewee. However, as student feedback can be ambiguous and inconsistent, it was discussed during the student interview how it can likewise be seen as an uncertainty factor.

Another aspect that interviewees mentioned regarding the faculty support variable is the character of the AS Faculty. Assistant Professor 2 mentioned how teaching staff can be conservative and often behave in an individualistic way. These internal culture characteristics will be further elaborated on below. Additionally, during all five interviews, there was a strong emphasis on the need for a shift in behavior among both the faculty and students. Interestingly, not one interviewee could quite pin down the exact approach to initiate this transformative change. An overview of the barriers, drivers and uncertainty factors regarding Faculty support is given in figure 6.6

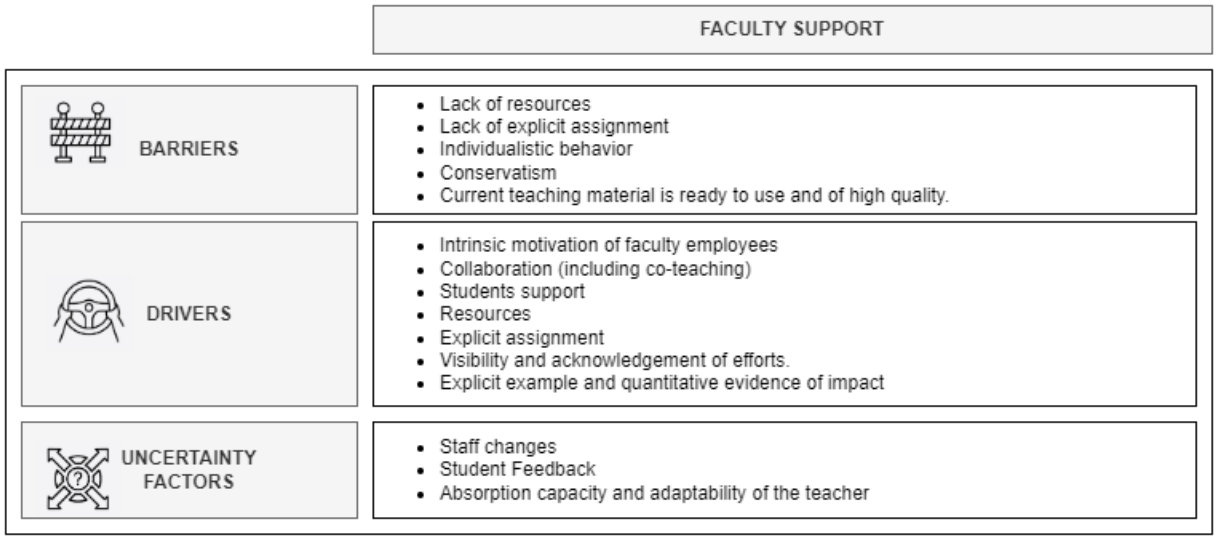

Figure 6.6: Overview of Barriers, Drivers and uncertainty factors relating to Faculty Support at the AS Faculty of TU Delft.

6.3.6. Student support

Regarding the involvement of students, there were divergent opinions among the participants regarding the significance of their role. As has been mentioned in the section on faculty support and in section 6.2.2 on bottom-up ESD initiatives, students could collaborate with teachers and create new exercises and other types of teaching content. However, Assistant professor 1 and 2 found that the expertise of students is less on the creation of specific course content, but should rather be used for student awareness and mobilization. Following the GreenTeam initiative, students wield considerable influence primarily through providing feedback to faculty members and collectively advocating for the integration of ESD. It was underscored that students hold the potential to acknowledge instructors who enact changes and engage in constructive discussions with those who do not.

However, as was addressed in section 6.2.2, assistant professor 1 addressed how the GreenTeam loses motivation and energy if they do not get room for their own interpretation and construction of a greenteam specific climate action plan. This is something that should be taken into account.

During the student interview, the participant pressed the importance of bottom-up initiatives as these undertakings show that there is support for change. When the GreenThread initiative was mentioned, the interviewee mentioned: ”A bottom-up approach garners more support for the change. By individually

consulting each teacher on how they would handle it, there might be less uniformity across the course, but it reduces the sense that any adjustments made in the curriculum will be temporary or obligatory. The risk is that if directives come directly from the management, specifying what needs to be included in the slides, it might create a situation where compliance becomes more procedural and less intrinsic."

The impediments encountered in bottom-up student initiatives appeared to revolve around a lack of expertise, influence, and confidence. Conversely, intrinsic motivation and the ability to inspire instructors to explore ESD implementation were identified as driving factors. An uncertainty factor highlighted during discussions was the continuous influx and outflow of students. This dynamic was seen as potentially leading students to focus on short-term gains rather than long-term benefit and causes student change agents to leave the faculty after they graduate. An overview is given in Figure 6.7

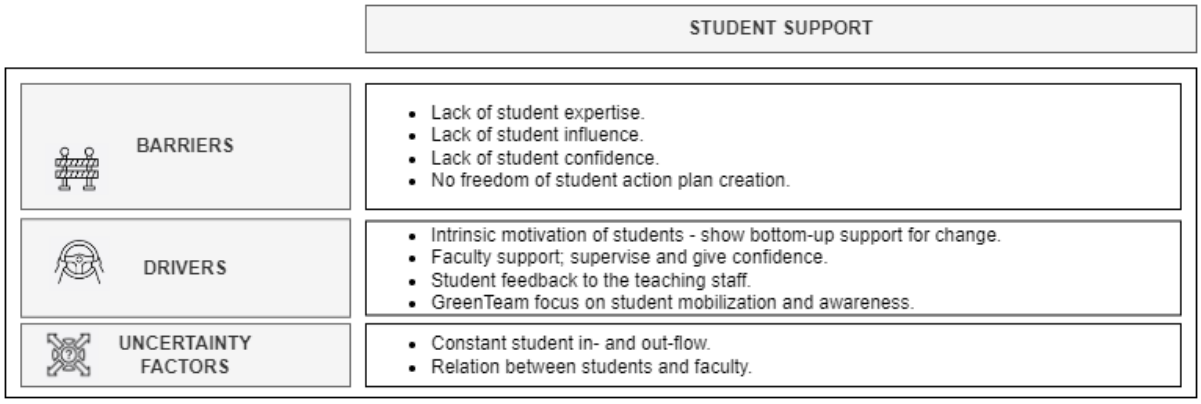

Figure 6.7: Overview of Barriers, Drivers and uncertainty factors relating to Student Support at the AS Faculty of TU Delft.

6.3.7. Involvement internal AS stakeholders

A diverse group of internal AS stakeholders have been involved in top-down initiatives such as the recent changes in Chemical Engineering, and bottom-up initiatives like the GreenTeam or teachers adapting their courses independently (section 6.2). Numerous initiatives aim to promote collaboration concerning ESD initiatives, but it seems that without a top-down directive, these initiatives struggle to gain momentum. Assistant professor 2 mentioned: "There will certainly be teachers who say, 'I'll make time for this and perhaps gather some funds here and there.' However, nothing structural will happen then. It will still be only one course in the curriculum that might suddenly pay more attention to sustainability. If you really want to make it a systematic integration into your program, it will have to come more from the program itself."

Once more, this underscores the efforts of grassroots stakeholders striving to effect change, yet without corresponding support from higher authorities, achieving substantial structural change remains unlikely. The proposed establishment of a Climate Action Team signifies a step in this direction. Nevertheless, as the LSC team already shoulders numerous responsibilities, the effectiveness of the intended change warrants additional resources and time allocated. The necessity of forming a collective (also called task force) led by the LSC to spearhead this transformation while encouraging the involvement of other change agents was mentioned by both assistant professors and the student. Emphasis should be placed on fostering collaboration and ensuring transparent communication, an aspect currently perceived to be deficient. As previously mentioned, collaborative efforts have the potential to mitigate work pressures and reduce resource demands. An illustrative case of a comprehensive faculty engagement in curriculum design is exemplified by the recent alteration in the MSc Chemical Engineering program. Here, the top-management initiated collaborative working groups encompassed all stakeholders involved in education to formulate the updated curriculum. An overview is visualized in Figure 6.8.

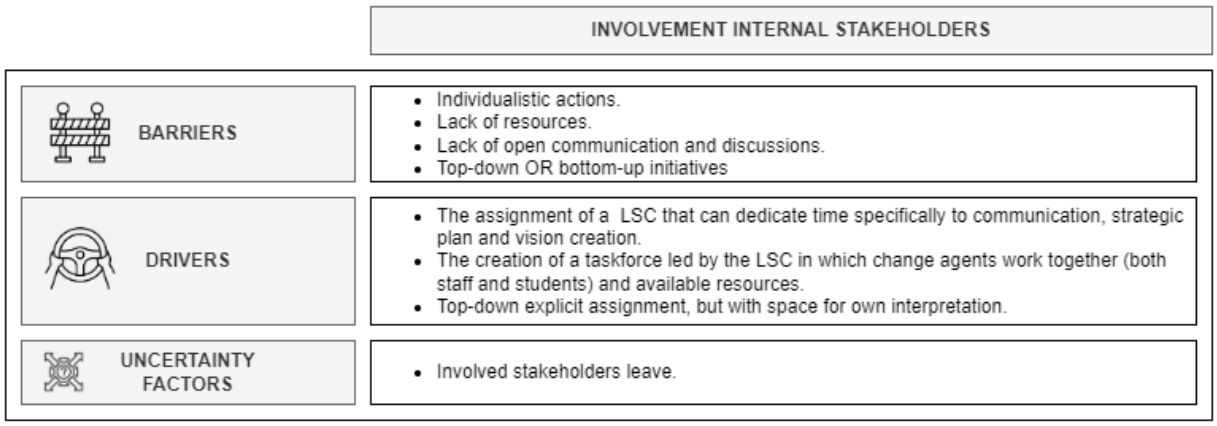

Figure 6.8: Overview of Barriers, Drivers and uncertainty factors relating to Involvement of Internal Stakeholders at the AS Faculty of TU Delft.

6.3.8. Perception of sustainable development-faculty

The first round of interviews delved into the perception of sustainability, highlighting its context-specific nature and the diverse perspectives existing within the faculty. When asked about the GreenDatabase and ESD related keywords, the program director interviewee highlighted: ”We make the keywords often more specific. Sustainability can mean everything. Take for example, circularity or energy. We have courses that involve recycling, bio-based plastics and more fundamental topics that use words not directly traceable to the terms sustainable and climate change.” Given the myriad interpretations of sustainability, establishing a clear educational green line becomes challenging. While some consider it a barrier, others perceive it as a driving force; the top-management interviewee mentioned for example how there is more ESD implementation happening in the faculty than what is available online.

The initial stride involves defining the specific implications of sustainable development within distinct courses and departments. Moreover, deliberations focused on exploring the potential applications of course content in fostering sustainable development or explaining various aspects of climate change. As was mentioned during the Integration approach section of this chapter, teaching staff have expressed concerns regarding the adequate transmission of desired knowledge to students, especially in cases where restructuring or the integration of sustainability concepts is envisioned. There is apprehension that incorporating sustainability might dilute or divert attention from the primary objectives or knowledge being imparted by these courses. During the interviews it was discussed that while teaching fundamental sciences, the emphasis could go more to explaining how to utilize this knowledge to contribute positively to the planet without compromising the core messages or knowledge that these courses aim to convey. Furthermore, Assistant Professor 1 highlighted the existence of a particular ’Technology-Fix’ mindset, emphasizing the complete reliance on technology to drive sustainable development. Further elaboration on this perspective will be provided in the forthcoming section addressing the internal culture of the AS faculty.

Furthermore, all five interviewees made a reference to the ongoing discussions concerning TU Delft’s associations with fossil fuel entities and how these discussions should proceed. Stakeholders within the faculty hold divergent views on whether the university (and consequently the faculty) should sever all connections. Some advocate for complete dissociation, while others underscore the significance of academic autonomy and the necessity of these affiliations to facilitate the advancement of sustainable energy initiatives. Notably, the AS Faculty maintains direct affiliations with fossil fuel industries through its research divisions focused on bio processes and green energy. However, through the interviews it appeared that there could be more transparency on these collaborations. Additionally, inclusive deliberations among a diverse spectrum of stakeholders was mentioned as a way of handling this specific situation. Figure 6.9 gives a short summary.

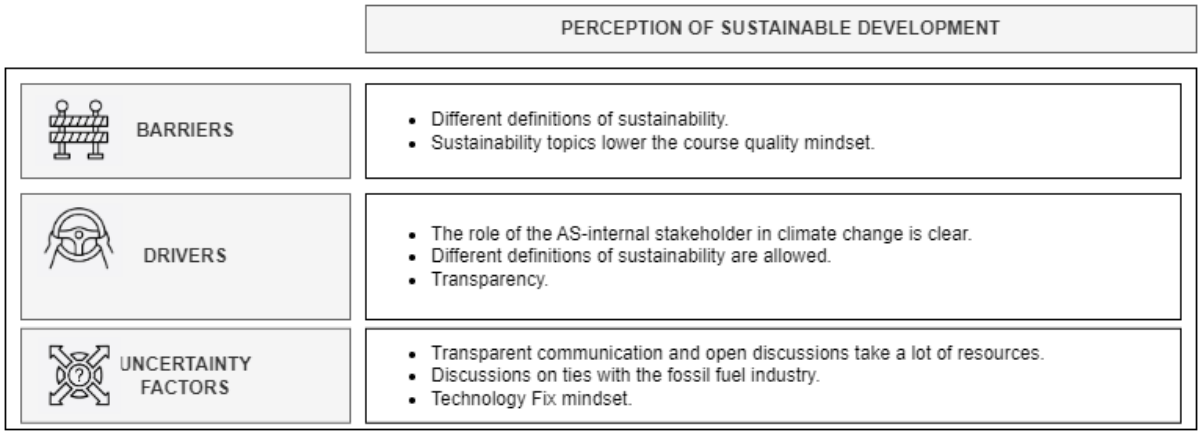

Figure 6.9: Overview of Barriers, Drivers and uncertainty factors relating to Perception of Sustainability at the AS Faculty of TU Delft.

6.3.9. Synergies between different areas

Throughout the interviews, the influence of research on education was a recurring topic. As was mentioned in section 6.2, the research that is done at the faculty reflects directly back on the education that is given. The top-management, both assistant professors and the program director all mentioned how the topic choices of the faculty's research projects are the result of funding applications, own interest and focusing on what is most innovative. As funding is often sought for outside of the faculty, choices are frequently influenced by governmental interests. The program director interviewee mentioned the important relation between funding, research and education: "[] a lot of research funding you also have to account for now when you apply for a grant. Questions arise as 'How does it align with the sustainability goals of the Dutch government', then when you conduct that research and then we also dare to provide that education, so that mechanism is already at play."

Regarding business relations, the Program Director mentioned how current collaborations with companies are mainly driven by the wish of companies for students to help them become more sustainable. Students have the choice to do their bachelor and/or master end projects at companies, which most of the time offer a research project that focuses on sustainability.

While the change in research results in a change in education, the top-management interviewee emphasized the importance of the connection of education to the operational side of the faculty. According to the interviewee, the current misalignment of sustainable operational alternatives and behavior is mainly the result of insufficient knowledge: "If you don't understand all aspects of sustainability and that the production of boiling water is a highly unsustainable process, and if you only think about cups filling up trash bins, then you're lacking the necessary knowledge and engaging in symbolic politics focused on symptoms." Additionally, the interviewee highlighted a prevailing inclination toward choosing convenience over sustainability. Furthermore, the interviewee addressed the role of the community and how they should initiate discussions in all aspects of their (university) life, including during their education and research endeavors. The relation between community, operations, research and education should be explored further. Recognizing the interconnections of operations, research, and education underscores the importance of a holistic approach. Disregarding one aspect could potentially undermine the credibility and effectiveness of the others. Therefore, fostering an environment that intertwines these elements is pivotal for the successful integration of ESD within the faculty. An overview of can be found in Figure 6.10.

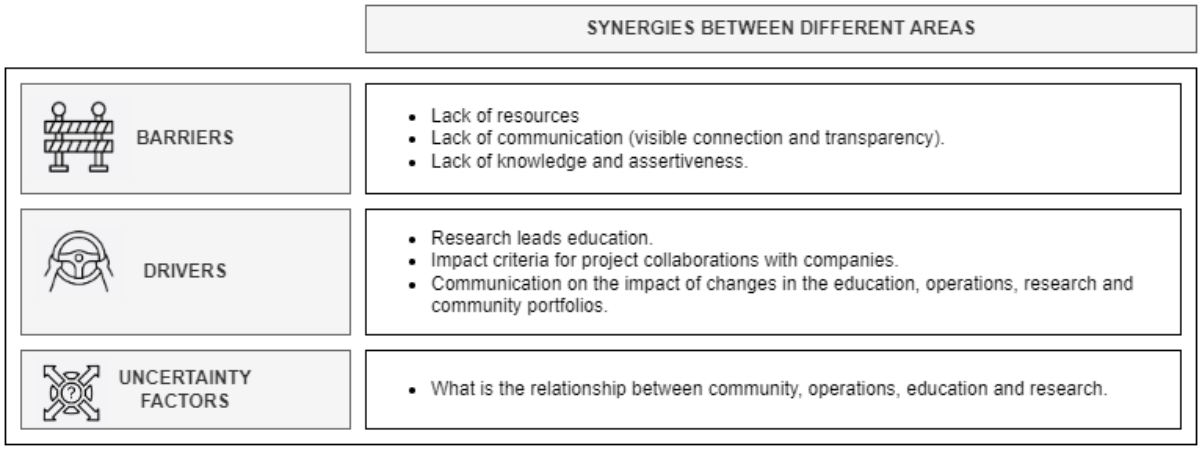

Figure 6.10: Overview of Barriers, Drivers and uncertainty factors relating to Synergies between different areas at the AS Faculty of TU Delft.

6.3.10. Internal culture AS

The implementation of ESD within the faculty is confronted with diverse stakeholder beliefs and attitudes that warrant careful consideration. According to Assistant Professor 2, a prevalent notion among several stakeholders within the faculty leans towards a technological fix to sustainability challenges. The interviewee mentioned that while not inherently detrimental, this perspective necessitates clearer elucidation and robust discussion to ensure comprehensive understanding and a nuanced approach: ”The presence of numerous Eco-modernists adds to the diverse spectrum of viewpoints. Their outlook often underscores the importance of technological advancements in solving sustainability issues. Engaging in constructive dialogues around this viewpoint can offer valuable insights and perspectives on integrating technology within the framework of sustainability.”

Another notable characteristic is the faculty’s ’nerdy’ disposition, wherein the mere addition of sustainability to existing courses is not perceived as adequate. Both student and top-management interviewee emphasized the need for specificity, expressing a desire to delve deeper into sustainability topics without compromising the core fundamentals of their disciplines. The incorporation of sustainability into the curriculum should enhance rather than detract from the core subject matter.

Moreover, the competitive nature of the AS faculty was discussed. Researchers face significant pressure to succeed in securing project approvals, often leading to limited autonomy in their research pursuits and dependency on institutional performance rankings. The top-management interviewee highlighted: ”In a highly competitive world, especially among the staff, an important cultural aspect is the level of competitiveness. Researchers often don’t get to conduct the research they desire. They’re highly dependent on excelling and ranking high on performance lists to get their projects approved, which puts immense pressure on them.”

Lastly, distinguishing between impact research and climate-focused initiatives highlights a broader need for behavioral change. Emphasizing the necessity for transformative changes extends beyond the subject matter and delves into how members of the faculty conduct themselves. The program director, both assistant professors and the top-management interviewee explained however how new hires can bring a change in interests and culture within the core of teachers. Every year 10-15 new teachers are hired from all around the world, who bring in new ideas, and thus rejuvenate the core of teachers. Figure 6.11 gives an overview of the characteristics of the AS Faculty, and how they influence ESD implementation.

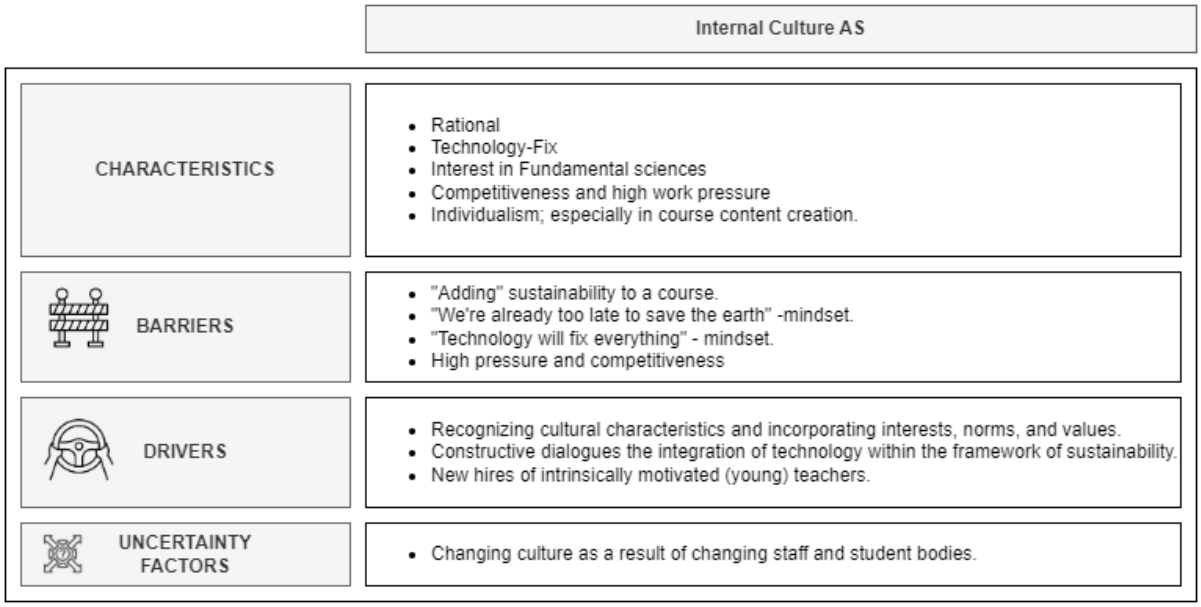

Figure 6.11: Overview of Barriers, Drivers and uncertainty factors relating to Internal Culture at the AS Faculty of TU Delft.

6.3.11. Perception of own influence

Additionally, conversations during the interviews centered around the necessity of elucidating the role and influence of individuals within the Applied Sciences field concerning sustainable development. The top-management interviewee addressed the connection between all areas of the AS Faculty and the importance of education: ”Individual and institutional efforts should prioritize sustainability in both personal lives and organizational practices. Emphasizing education is crucial, as future engineers have the potential to contribute significantly more to sustainability, extending their impact beyond personal endeavors. It is essential to encourage initiatives that not only promote a green campus but also focus on educating individuals to make a lasting impact beyond their immediate lives.” As was mentioned in the section on Synergies between different areas, there lays an important role in education on making students and staff understand the processes behind their choices and the effects of their actions.

When asked about the perception of own influence of students, Assistant Professor 2 answered: ”There has been a shift in mindset regarding career choices post-studies, with traditional top companies like Shell and Exxon seeing a decline in popularity among graduates. However, a significant number of individuals still adopt a pragmatic approach, contributing to these companies’ continued ability to attract staff. Although there is a growing awareness among the younger generation, it is yet to be fully reflected in their career decisions.” The top-management interviewee emphasized that when students explicitly express a reluctance to work for such companies, it can exert substantial influence, as these corporations rely heavily on new talent. The interviewee underscores the potential for significant industry change if the younger generation signals a preference for more sustainable employers.

Assistant Professor 1 emphasized that researchers should prioritize (and some already are prioritizing) collaborations that contribute positively to societal impact, favoring endeavors that are more future-oriented. However, the student interviewee noted a prevailing focus on the final objectives of research, suggesting a swift determination of the balance between research impact and environmental consequences. This dynamic prompts questions within the faculty about whether these aspects must be mutually exclusive. The integration of reflective instances in courses, especially those exploring broader perspectives, is seen as a potential way to enhance individual awareness and influence, as mentioned by the student interviewee.

Both Assistant Professors mentioned the role of teachers and researchers, and how they could give their students the confidence they can make a change. Current change agents within the teaching staff let students reflect on their impact, while also giving them hope. However, they also acknowledged how this also works the other way around. By providing teaching staff and researchers with feedback and

recognizing their work concerning sustainability and climate change, employees will be more motivated to explore to topic of influence. An overview of the mentioned barriers, drivers and uncertainty factors can be found in Figure 6.12.

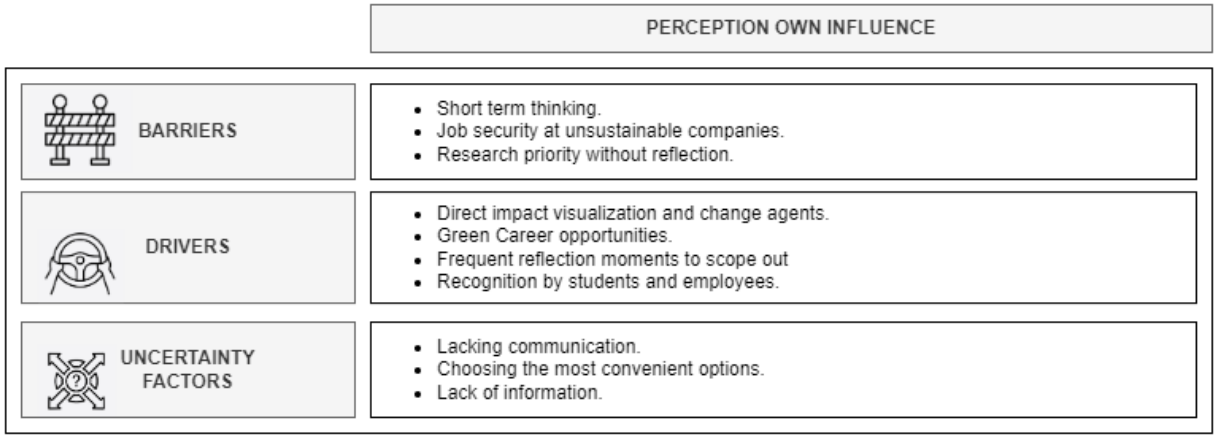

Figure 6.12: Overview of Barriers, Drivers and uncertainty factors relating to Perception of own influence at the AS Faculty of TU Delft.

6.3.12. Overview

The twelve variables of influence, decided in R1, are: Implementation level, Integration approach, Resources, Communication, Internal Collaborative Culture, Faculty Support, Student support, Involvement internal stakeholders, Perception of sustainable development-faculty, Synergies between different areas, Internal culture AS and Perception of Own influence. Ultimately, an Excel-based compilation was created, amalgamating all overlapping references. In total, a total of 30 barriers, 33 drivers, and 28 uncertainty factors were identified in R1 (Appendix C). During the R2 interviews, these themes are probed and extensively deliberated upon. Any absent perspectives or insights are subsequently incorporated into the comprehensive overview.

Upon reviewing Appendix C, it becomes evident that a considerable number of uncertainty factors prevail when compared to barriers and drivers. Often pieces of text were labeled as both a driver and uncertainty factor or as both a barrier and uncertainty factor as the shift from one label to the other was highly dependent on the context. This underscores the contextual specificity and the dynamic nature of the variables. The foregoing sections provide an exhaustive portrayal of the intricate nature of the AS system and delineate the variables pivotal in the implementation of ESD. Special emphasis is placed on examining the extent to which these variables appear to be contingent upon context or institutional factors.

It is noteworthy that numerous variables share commonalities in terms of drivers, barriers, and uncertainty factors. Given the research's primary aim of providing recommendations to the AS Faculty of TU Delft, a deliberate decision was made to portray the identified variables as either drivers or barriers when the variable had been labeled as both a driver/barrier and an uncertainty factor. Consequently, this decision resulted in a greater representation of drivers and barriers in the overview figures.

Frequently, the requisites for initiating ESD implementation encompass augmented resources, enhanced collaboration, the formulation of a long-term strategic plan, and the articulation of a clear vision. Additionally, the internal culture of the AS Faculty appears to wield significant influence over the implementation process and the latitude for change. Within the AS Faculty, there is a desire to witness the direct impact of changes and an ongoing discourse regarding the definition of sustainable development. Moreover, consensus among all five interviewees highlighted the imperative need for a shift in the behavioral perspective of stakeholders regarding their influence. There remains an ongoing discourse regarding the integration of operational, educational, and research-based transformations to facilitate the necessary behavioral adaptations and the specific role of students.

6.4. R2 interview results - Data validation and Comparative analysis

In the upcoming round two (R2) interviews, the twelve identified variables will undergo further exploration. This phase aims to validate the existing TU Delft specific R1 data and addresses any pertinent insights that might have been overlooked. Furthermore, R2 tests the data coming from the two case studies and its relevance to the AS Faculty of TU Delft. Considering the dynamic nature of most R1 variables, the inquiry will delve into whether these variables lean more towards being drivers or barriers. Moreover, this process aims to reduce the array of variables to identify those exerting the most significant influence. Subsequently, the finalized dataset will undergo analysis during a SWOT Analysis in round three (R3).

6.4.1. R2 analysis structure and participant selection

In contrast to the findings of R1, the R2 report exhibits a notable reduction in length. This can be attributed to the exploratory nature of the extensive R1 interviews and the thorough analysis undertaken in which the TU Delft specific data is compared to all 36 variables outlined by Weiss et al. (2021). The new R2 set of variables is analyzed by only four participants during an hour long focus group in R3 and had to be compatible with a swot analysis framework. Hence why the quantity of barriers, drivers, and uncertainty factors had to be streamlined. Only those specifically referenced in the R2 interviews were selected to be further deliberated upon in R3. While acknowledging the relevance of all identified drivers, barriers, and uncertainty factors, the goal was to distill this extensive list into a pragmatic set, comprising only the most impactful variables. This refined collection serves as the basis for formulating a definitive recommendation. Appendix 3.4 gives a detailed methodology behind the reduction and validation.

The interviewees of this round are: Assistant Professor 1 (R1), Assistant Professor 2 (R1), Student 2 (new) and Program Director 2 (new). The two assistant professors from R1 can be seen as change agents at the faculty. Both their R2 interviews mainly validated and evaluated the TU Delft specific R1 results. The new student participant was specifically queried about their involvement in student initiatives and their perceptions regarding bottom-up initiatives, as the seven interviewees in R1 had different perspectives on the exact role of students. Conversely, the new program director provided insights based on their experiences at universities of applied sciences, drawing comparisons with their tenure at TU Delft. The purpose of this new interview was to further scrutinize the case studies of NHL Stenden and Van Hall Larenstein, especially their systemic approaches. This examination aims to explore the potential feasibility of instigating similar systemic changes within the context of the current study on the AS Faculty of TU Delft.

As the final R2 interview (with Assistant Professor 1) was held a day before the focus group was organised, this interview additionally trialled the set-up of the focus group. The ultimate objective is to formulate a comprehensive set of recommendations aimed at structuring the educational road map within the AS Faculty's Climate Action Plan.

6.4.2. The role of students

The interviewee that was chosen for this interview had experience as GreenTeam Coordinator in the GreenOffice of TU Delft (GreenTU) and as GreenTeam member of the faculty of Mechanical, Maritime and Materials Engineering. During the GreenTU board year of the interviewee, they had frequent interaction with GreenTeamAS and they were highly involved in the education portfolio.

During the TU Delft interviews of R1, it appeared the opinions on the role of students in the process of ESD implementation were mixed. The top-management interviewee for example saw students as crucial for initiating change, while Assistant Professor 1 saw their role mainly in student mobilization and awareness. During R2 Student 2 mentioned how the Faculty frequently showed signs of how they were hesitant towards the importance and value of the GreenTeam. The interviewee agreed with the R1 statements made by Assistant professor 1, explaining that the faculty expected the GreenTeam to help courses in creating new assignments and topics, but the students often lacked expertise to cover all courses. The interviewee mentioned: "I've also seen it with others [GreenTeams] that they really want to approach teachers, and the teachers are generally willing. However, it doesn't lead to a structural change unless the teacher themselves really wants to contribute to it."

The interviewee highlighted the efficacy of GreenTeamAS during their tenure, attributing its success to payment, a team comprising critical-minded students, and notably, their substantial autonomy. However, a pivotal factor contributing to their effectiveness was the establishment of a dedicated presence within the faculty. The interviewee articulated: "A supervisor who holds a consistent role within the faculty, possibly

in connection with the Management Team or even involving someone from the Management Team. In essence, a senior figure within the faculty, associated with the team, requiring reports and monitoring progress. Such structural elements are paramount, given the team's student nature; seeking individuals with experience, while also considering it as a learning process necessitating proper guidance, which was not consistently available."

The interviewee underscored the significance of compensation as a crucial factor in instilling a sense of being taken seriously among student teams. Even a modest incentive can signify acknowledgment and validation for students, engendering a feeling of being valued as contributors: "But receiving recognition and feeling valued by the faculty for that small contribution was instrumental."

Additionally, the interviewee further highlighted the pivotal role of GreenTeams in fostering student mobilization, awareness, and monitoring efforts. GreenTeamAS could potentially serve as a catalyst for educational initiatives that experiment with modifications in courses, introduction of new electives, research themes, and more. Collaborating closely with study associations, the Faculty Student Council, and maintaining consistent dialogue with students could forge genuine grassroots support for the implementation of ESD and broader systemic change.

In summary, the principal barrier regarding Student support stems from the faculty's insistence on adhering strictly to their directives. Students prioritize the autonomy to create their action plans, recognizing its significance in sustaining their motivation and fostering a substantial learning experience. Moreover, the primary driver propelling student support was identified within the GreenTeam (or similar student initiatives), which concentrate on mobilizing students, raising awareness, and monitoring changes from a grassroots standpoint. However, the Team should be acknowledged by the faculty and receive incentives in the form of payment, study credits or a letter of recommendation. An associated uncertainty arises from the continual turnover of students, rendering it uncertain how effective these initiatives remain as new students assume roles each year. A solution for this could be supervision by someone such as the LSC, who has close contact with the Management Team and a fixed position in the faculty.

6.4.3. Comparative analysis case studies 1, 2 and 3

This section primarily aims to discern the distinct characteristics between universities of applied sciences like NHL Stenden and Van Hall Larenstein and TU Delft. The discussion centered on the institutional hierarchical structures and the potential of change to garner support instead of encountering resistance. The findings from this discussion will offer insights into the relevance of the barriers, drivers, and uncertainty factors delineated in Figures 5.2 and 5.3 within the AS Faculty of TU Delft.

According to program director 2, the comparison between a university of Applied Sciences and an university elucidates significant organizational differences. In a university of Applied Sciences, the Executive Board holds substantial hierarchical control, directly managing faculty and programs. Lecturers are hierarchically bound, as their salaries are determined by program authorities, constraining autonomy. Contrastingly, in a university setting, professors operate with greater autonomy, securing their funding and determining research directions. The hierarchical structure is less pronounced, granting professors more independence. Decisions made by the Executive Board hold substantial sway in an university of applied sciences, whereas university professors maintain more individual autonomy in their work, influencing their team and research direction. This distinction in organizational structure delineates the contrasting levels of hierarchical influence in decision-making processes between these educational institutions. At the same time, both types of institutions mentioned the need for a top-down support that can be publicly embraced by all tiers within the organization.

The interviewee mentioned: "I also think that it's detrimental to the quality of education to initiate a top-down change, because the knowledge and experience of education are not at the top, they are at the bottom." This highlights the necessity for a symbiotic collaboration between top-down and bottom-up approaches. The interviewee emphasized the significance of granting teaching staff the latitude to interpret and impart their expertise in their respective fields. They cautioned against excessive imposition from top management to alter course structures, citing the risk of demotivation among staff, potentially resulting in their departure: "That's how I've always seen it work in higher professional education. Ultimately, you want to tell your own story, share your own passion. Students want that lecturer down there in the lecture hall to tell their own story, because that's when passion and enthusiasm come alive. With a pre-written story, it becomes more of a theater performance and the lecturers become actors."

When the topic of cultural change was raised, the interviewee mentioned the importance of changes happening simultaneously in the operations, education, research and community portfolios of the faculty/university. The interviewee mentioned: ”A real cultural change simply involves establishing very clear fundamental rules and consistently adhering to them. You have to implement this in your research, education, and operational aspects. I don’t believe a university can convincingly offer sustainability-focused education while simultaneously continuing to use disposable plastic cups for coffee. I don’t think you have to conduct all research or education solely dedicated to that, but you only get somewhere when you start questioning your research from a sustainability perspective.”

In conclusion, the insights derived from case studies 1 and 2, as highlighted by the interviewee, underscore several key aspects. Firstly, a vital observation involves the interconnections between changes across operations, research, education, and community. It is evident that to induce a cultural shift, alterations in various domains should occur concurrently. Implementing alterations in one area alone may not suffice; a holistic approach encompassing multiple facets is imperative for initiating a comprehensive cultural transformation. Secondly, the interviewee stressed the significance of fostering collaboration between top-down and bottom-up approaches. Additionally, providing educators with the latitude for personal interpretation within their teaching roles emerged as a pivotal factor in facilitating effective change within educational settings.

6.4.4. Overview R2 drivers, barriers and uncertainty factors

Exploring deeper insights into the drivers, barriers, and uncertainty factors regarding the implementation of ESD revealed a multifaceted landscape at the implementation level. Notably, some aspects were absent in the first round of interviews.

One such aspect pertained to existing teaching days and teacher-focused afternoon sessions, which could potentially serve as a platform for integrating sustainable development (Assistant Professor 2). However, the effectiveness of these periods for implementing change appeared to be under scrutiny (Program Director 2). Concerns were raised that working groups, commonly employed for such endeavors, often proved time-consuming and inefficient. There was a consensus that systemic changes require explicit assignment and endorsement from top management to catalyze meaningful transformations within an institution.

Faculty support emerged as a crucial element for successful implementation. Recognizing and acknowledging efforts, along with providing adequate resources and support, were identified as pivotal components for engaging faculty in change initiatives. Assistant Professor 2 highlighted the significance of internal culture and the influence of incentives and feedback from top management and students in fostering faculty support.

The perception of sustainable development within the AS Faculty demonstrated a pronounced inclination towards quantitative approaches. There was an eagerness to incorporate sustainability through a quantitative lens, leveraging examples that scrutinize processes in terms of productivity, energy usage, and CO2 emissions. However, according to Assistant Professor 2 the challenge lay in comprehending the broader implications and philosophical considerations related to sustainability within the curriculum.

Furthermore, additional barriers and uncertainty factors were identified. It was noted by Program Director 2 that the focus on sustainability might push away students and staff who lack interest in the subject, potentially creating a divide within the institution. Additionally, the interviewee mentioned the uncertainty factor regarding the intrinsic motivation of teaching staff to discuss sustainability topics and effectively convey the message to their students.

Regarding additional drivers, all R2 interviewees agreed that waiting for all staff members to willingly embrace change was perceived as an endless endeavor and could be used as a reason to speed up the pace of change. It was emphasized not to delay initiatives until universal willingness among staff is achieved, recognizing that such a scenario might never materialize.

Despite acknowledging the potential of working groups, their feasibility was questioned due to time constraints. Suggestions were put forward for organizing workshops or seminars to cultivate interest and share best practices among faculty. A top-down approach emphasizing the importance of integrating sustainability into the curriculum was deemed instrumental. Additionally, the focus on the Climate Action

Team was identified as an area where change agents could strategically plan and demonstrate examples of change.

This information signifies a complex interplay of factors influencing the implementation of sustainable development within the AS Faculty. While some drivers, barriers, and uncertainties were evident, the absence of certain aspects in the initial interviews has shed light on critical areas requiring attention for successful systemic change. Continued exploration is essential to comprehensively understand and address these elements for effective implementation of sustainable development initiatives.

An overview of the new lists of drivers, barriers and uncertainty factors can be found in Figure 6.13. The three lists in this figure incorporate the additional variables identified in the R2 interviews while maintaining a coherent narrative on the factors influencing the implementation of sustainable development within the AS Faculty identified in R1. The drivers, barriers, and uncertainty factors from R1 that were not mentioned in R2 have been excluded.

DRIVERS

1. Explicit assignment from top-management.
2. A detailed climate action roadmap with a structured guideline and time for adjustment.
3. The creation of a taskforce with change agents (students and employees), creating clear examples and guidance on change efforts.
4. A coherent set of learning objectives, with room for own interpretation.
5. Collaboration between (students and) teaching staff.
6. Timing and increase of reflection moments (within courses, but also in staff evaluations and Teaching Days).
7. (more) Resources.
8. The Assignment of a LSC that can dedicate time specifically to communication, strategic plan and vision creation.
9. Impact validation and quantification: Frequent reporting on progress climate action roadmap and ESD implementation.
10. Intrinsic motivation of employees and student.
11. Student support (and feedback).
12. Visibility and acknowledgement of efforts; incentives and rewards structure (students and staff).
13. The role of the AS-internal stakeholder in the fight against climate change is clearly defined.
14. Different definitions of sustainability are allowed and constantly discussed and communicated.
15. Transparency on research ties (and other collaborations).
16. Green career opportunities (inside and outside the faculty).
17. Increase in Research that focuses on sustainable development and/or the fundamentals of climate change.
18. GreenTeam focuses on student mobilization (FSC, study associations, etc), awareness and monitoring of changes while being supervised by experienced faculty member(s).
19. Acknowledgement of cultural characteristics and embracing interests, norms and values.
20. New hires of intrisically motivated (young) teachers.
21. Simultaneous changes in education, research and operations.
22. Experienced change leaders.
23. Supportive environment.
24. Don't wait for all staff to be willing to change; then you can wait forever.

BARRIERS

1. Lack of resources (time, money, teachers).
2. Lack of faculty support.
3. No explicit assignment; no strategic plan or vision.
4. Lacking communication (and open discussions).
5. Multiple lobbies of topics that want to get integrated.
6. 'Ticking off the box behavior'; Sustainability can feel as a 'loose' element.
7. The mindset ESD implementation will change course content and quality (too much).
8. Full (overcrowded) curricula.
9. Inherent individualistic characteristics.
10. Change of staff (especially executive board): new goals and aspirations.
11. Conservatism.
12. Current teaching content is ready to use and of high quality.
13. Different views on what sustainability and climate change entails.
14. Research results as priority, without relection moments that focus on impact on the bigger system.
15. No freedom of action plan creation / interpretation.
16. Technology Fix mindset.
17. High pressure and competitivess.
18. Only Top-down initiatives.
19. Only Bottom-Up initiatives.
20. Push students and staff away that are not interested in sustainability and/or climate change.

UNCERTAINTY FACTORS

1. Involved staff and students leave.
2. Student feedback inconsistent.
3. Programs get the feeling they constantly have to change.
4. University-wide goals have their own interpretation at faculty-level. Misalignment of communication could happen at different levels.
5. Absorption capacity and adaptability of the teacher.
6. Connection between Climate Action Team/LSC and the regular hierarchy.
7. Relation between students and faculty.
8. What is the relationship between community, operations, education and research.
9. Transparant communication and open discussions take a lot of resources.
10. Technology fix mindset.
11. Strategic plan changes every few years.
12. More resources needed than expected.
13. One mandatory course is not sufficient.
14. Worry of knowledge transfer quality.
15. Differing faculty support; 'ticking off the box' behavior.
16. Multiple lobbies of topics that want to get integrated.
17. Not all applied physicists focus on sustainability and climate change; certain employees and students will leave if only focused on ESD.
18. Teaching staff needs to be intrinsically motivated to effectively cover a topic in their courses.

Figure 6.13: Through the assessment of the gathered data in R1 and its subsequent evaluation in R2, a condensed inventory of variables is derived. This figure shows an overview of the decreased list of drivers, barriers and uncertainty factors.

6.5. R3 focus group - a SWOT analysis

The main objective of this research is not to consolidate all drivers, barriers, and uncertainty factors under a singular theme or variable. The SWOT analysis performed in this chapter helps to structure strategies for the AS Faculty of TU Delft to overcome the barriers and/or uncertainty factors of ESD implementation and to use its drivers most effectively. In this section, the transcripts of the R3 focus group and the R2 interview with Assistant professor 1 are used.

First, the design process of the focus group is discussed. Secondly, the most influential barriers, drivers and uncertainty factors identified by the R3 participants and Assistant Professor 1 during step 2 are explained. Thirdly, the step 2 variables that are categorized as SWOTs by the R3 participants and Assistant Professor 1 are discussed. Lastly, the literature study results from section 4.2 are used to structure strategies for ESD implementation at the AS Faculty of TU Delft, in a systemic approach.

6.5.1. Focus group questions

The initial stage of this analysis involved introducing the participants to the research context and establishing fundamental guidelines. The participants of the focus group are Assistant Professor 3, Student 3, Student 4 and a core-team of sustainability member. Subsequently, in the second step of the focus group, participants were tasked with reviewing the list of variables derived from the R2 analysis. They were instructed to individually identify four significant barriers, four drivers, and four uncertainty factors they deemed most relevant to the implementation of ESD. After the completion of this individual task in step 2, the group engaged in a collective discussion to determine the variables to be incorporated into the SWOT Analysis matrix. The primary inquiries formulated to guide the focus group in step 3 are outlined and elucidated as follows.

Q1: What are the strengths of the AS Faculty when implementing ESD?

Q2: What are the weaknesses when the AS Faculty implements ESD?

Q3: What are the opportunities that the AS Faculty can exploit to implement ESD?

Q4: What are the threats that the AS faculty might face when implementing ESD?

The fourth step of the focus group focused on making the acquired information useful. The participants were asked how the identified strengths can be maximized, how the identified threats and weaknesses can be overcome, and how the opportunities can be taken advantage of. Further details on the methodology can be found in section 3.1 and Appendix D.

6.5.2. Step 2 results - a scorecard of most influential barriers, drivers and uncertainty factors

During Step 2 of the Focus Group (and the R2 interview with Assistant Professor 1), participants were tasked with identifying the most impactful barriers, drivers, and uncertainty factors, resulting in a comprehensive overview presented in Appendix D.

Regarding barriers, unanimous consensus was reached among all five participants, citing a lack of resources (time, funding, and faculty) as the most significant obstacle. Furthermore, 'No explicit assignment; no strategic plan or vision' and 'full (overcrowded) curricula' received four votes each. Notably, Assistant Professor 3 highlighted 'Only bottom-up initiatives,' whereas Assistant Professor 1 emphasized 'Only top-down initiatives,' underscoring the historical pattern of change initiatives at the faculty and highlighting the imperative collaboration between top-down and bottom-up approaches.

Concerning drivers, unanimous agreement emerged among all participants, emphasizing the intrinsic motivation of employees and students as the foremost driving force. Subsequently, 'A detailed climate action road map with a structured guideline and time for adjustment' was identified as the secondary driver. These drivers stress the need for change agents, who often put in their own time and energy to reach goals that have not been assigned resources (yet). Furthermore, there appears to be a need for a detailed action plan that can give stakeholders not only guidance, but gives them reasons to change.

Regarding uncertainty factors, opinions somewhat varied compared to the more aligned views on barriers and drivers, indicating the intricate complexity and multitude of variables influencing ESD implementation. Notably, the two most influential variables, receiving four votes each, were 'A detailed Climate Action

road map with a structured guideline and time for adjustment' and 'Teaching staff needs to be intrinsically motivated to effectively cover a topic in their courses.' These observations underscore the importance of well-prepared and executed actions to prevent potential resistance to change. Similarly, these variables are also the most influential drivers identified. This emphasizes the fluidity of drivers, barriers and uncertainty factors.

6.5.3. Step 3 results - strengths, weaknesses, opportunities and threats of education for sustainable development implementation

Subsequently, participants were tasked with collectively categorizing these identified barriers, drivers, and uncertainty factors as Strengths, Weaknesses, Opportunities, and Threats (SWOTs). Conducting a SWOT analysis facilitates a comprehension of the circumstances that the AS faculty might encounter while endeavoring to implement ESD. During this step, it could be observed that additional variables than chosen in step 2 rose up during the discussion and were picked as a SWOT. This emphasizes the different definitions of barriers, drivers, uncertainty factors and SWOTs. An overview can be found in Figure 6.14. The sections below elaborate on the outcomes of step 3 of the focus group.

6.5.4. Strengths

During step 3, strengths were defined as 'positive tangible and intangible attributes, internal to an organisation and within the organisation's control'.

S1: Explicit assignment from (top-)management.

As previously mentioned during the literature review and the case-studies from R1 and R2, an explicit assignment from (top-)management has repeatedly been mentioned as critical for successful ESD implementation. An example was given by Assistant Professor 3 how regarding the structuring of yearly schedules for research, explicit assignments from the university's executive board push departments to set goals and to brainstorm on integration/implementation approaches. On this ground, an explicit assignment from (top-)management is a strength for ESD implementation at the faculty. Noteworthy, the focus group participants agreed how it would bring along less resistance if these assignments came from the dean of the faculty rather than the executive board.

S2: A coherent set of learning objectives, with room for own interpretation.

Throughout the interviews R1, R2 and the focus group, there was a widespread consensus that a cohesive collection of learning objectives is imperative to direct the teaching faculty toward the necessary adjustments. Nevertheless, all participants stressed the significance of allowing room for individual interpretation. This facet will guarantee the stakeholders' personal drive and foster their creativity. Additionally, it will facilitate a shift in mindset for the stakeholders. Granting the teaching staff the freedom to independently explore and discover their intrinsic motivation is crucial.

S3: Intrinsic motivation of employees and students.

Of all strengths, intrinsic motivation appeared to be most important. Intrinsic motivation inspires other stakeholders and effectively helps to sustain changes. Assistant Professor 1 especially emphasized the importance of the intrinsic motivation of program managers, department heads and the faculty management team. An example is the earlier mentioned change in the Chemical Engineering master, where the assignment of a new program manager resulted in ambitious endeavors to reform the program. Assistant Professor 1 mentioned the diligent efforts and persistent engagement with various stakeholders. Assistant Professor 1: "Their dedication has the potential to cascade down and influence others within the institution. This action holds promise for effectuating the most significant impact and fostering a cultural shift, potentially yielding substantial cultural transformative effects." Continuous communication and setting the example for others appear to be pivotal factors that come with this variable.

S4: Planning, Preparation and KPIs; learn from research approach.

In order for changes to sustain and to be effective, the importance of planning, preparation and the creation of KPIs was mentioned. As was mentioned above, Assistant Professor 3 explained the yearly goal-setting approach of research departments: *'For research, I see that the Executive Board says, 'We have these goals for 2025 regarding a department's research.' Then we have a department-level meeting, and we discuss what we're going to do in the next two years to focus our research more on CO2 reduction. Then*

we make plans, and the Principal Investigators are actually very involved in this planning. However, this precisely doesn't happen for education.'

S1 helps to initiate the changes, while S4 additionally helps to sustain the transition process. The focus group participants agreed on the importance of giving stakeholders a concrete plan; collaboratively setting goals, evaluating and impact visualization. Additionally, Assistant Professor 1 stressed the importance of deliberating on focal points, considering that not all initiatives can be simultaneously undertaken: "Therefore, prioritization is crucial. Identifying areas of focus at the program level—issues that programs and individuals are genuinely invested in and willing to allocate their valuable resources and time toward—is paramount."

6.5.5. Weaknesses

During step 3, weaknesses were defined as 'internal factors within an organisation's control that detract from the organisation's ability to attain the desired goal. Which areas might the organisation improve?'

W1: Lacking communication (and open discussions).

Concurrently with the identification of S2, delineating a cohesive framework of learning objectives with space for individual interpretation, one of the acknowledged barriers surfaced: a deficit in communication and open discourse. Assistant Professor 3 highlighted the frequent absence of coherence, attributing it to inadequate communication prevailing among the diverse stakeholders involved in this task.

Emphasizing that while not mandating uniform learning objectives across every faculty or stakeholder, there exists an underlying commonality that can be identified when defining a specified set of learning objectives. In this regard, a collaborative sit-down, ensuring comprehensive communication to delineate the collective vision and subsequently outline the learning objectives, becomes imperative. Thus, despite the apparent association between the driver and barrier, the actualization of this synergy remains elusive. The participant often witnesses a recurring cycle where individuals struggle to definitively articulate learning objectives in specific contexts.

W2: Lack of resources (time, money, teachers).

All five interviewees unanimously concurred on the profound significance of resource scarcity, identifying it as a critical and pressing concern. To initiate and sustain trans formative changes, a sufficiency in temporal, financial, and instructional assets is imperative. Assistant Professor 1 detailed encountering this limitation in their routine activities. They cited an illustrative example related to monthly faculty meetings, focusing on discussions encompassing new faculty recruitment, educational focal points, or the department's strategic orientation. Assistant Professor 1 articulated, "Usually 50% of people show up and about like 40% of those people are the people who show up to every meeting and the other 10% are kind of revolving around the remaining staff. So if it's a department meeting so if you really wanted to get everyone together to change something and not everyone is there, that's quite a problem."

W3: Lack of intrinsic motivation of employees and students.

While intrinsic motivation of employees and students can be a strength, it simultaneously can act as a weakness. As the faculty has various stakeholders, with various norms, values and mindsets, there is not one reasoning that aligns with all and sparks everyone's intrinsic motivation. Assistant Professor 1 stressed how attempting to instigate changes among stakeholders who lack intrinsic motivation and/or resources may yield resistance or hinder the dissemination of essential messages.

W4: Only Top-down or Bottom-up initiatives.

Through the R1/R2 interviews and the focus group session, it was discerned that exclusive reliance on either top-down or bottom-up approaches for the implementation of ESD poses considerable risks. This was particularly evident when directives solely emanate from the Executive Board of the university. Assistant Professor 3 remarked, "If the Executive Board begins mandating highly specific educational directives, as an educator, I perceive a coherent set of learning objectives with individual interpretation as a far more pivotal goal than receiving explicit instructions from top management regarding precise educational content." This is a similar remark as Program Director 2 made in R2.

Assistant Professor 1 amalgamated W3 and W4, emphasizing how directives from the university administration lacking intrinsic motivation could thwart initiatives. The interviewee articulated, "When someone mandates action, the best way to deter it is by top-down dictating what must be done." Furthermore, both

students highlighted the predominant focus on bottom-up initiatives and the persistent issue of not being accorded sufficient credibility or seriousness. Without support from top-management, bottom-up initiatives eventually cease to exist.

W5: Interest in Fundamental Sciences behaves as a hurdle for further ESD implementation.
Assistant Professor 1 delved into the prevalent inclination towards fundamental sciences within certain research departments. Emphasizing the profound involvement in fundamental sciences, these departments often allocate minimal space for supplementary contextual elements or diverse subject matters (e.g., the Q-Tech department). The interviewee expounded upon this perspective, stating, ”In the context of teaching-related activities, ESD might be regarded as distinct. There exists a delineation between its incorporation and the research pursuits. Conversely, in my research area, we engage in sustainability-related research. Hence, when I engage in teaching, my interests intrinsically align with sustainability. However, for disciplines like Q-Tech and areas within Nanobiology, there may be instances where the enthusiasm for sustainability, as well as the drive to impart it, is largely disconnected from their research endeavors. While feasible, this presents a separate avenue for engagement.”

W6: Internal culture around course reflection and course quality improvement moments; neglect to incorporate sustainability elements.
Attaining an adequate resource allocation demands a cultural shift. Educators remain preoccupied with enhancing their courses through the introduction of novel learning objectives, activities, and assessment methodologies. If a fraction, 10-20%, of the annual time invested in course improvement is allocated to matters pertaining to sustainability, it would mark a substantial achievement. However, according to Assistant Professor 3 this allocation seldom materializes. Assistant Professor 3 underscored this predicament by acknowledging personal experiences, stating, ”At times, my focus is primarily directed towards adjusting certain aspects, only later contemplating on how to genuinely integrate sustainability elements into them.”

The core-team member highlighted the delicate equilibrium between research and education time management, available resources and teachers’ adaptability to change, stating, ”I believe this balance hinges on individual instructors, but I assert that the fundamental qualification in education aids educators in adopting an improvement-oriented approach. Furthermore, the availability of time plays a pivotal role; it dictates the feasibility of such endeavors. For instance, if one is inundated with research commitments and overlooked the documentation of desired teaching enhancements from the prior year, the preparation phase becomes challenging. Hence, it’s a variable scenario.”

6.5.6. Threats

During step 3, threats were defined as ’Factors beyond the organisation’s control which could place the organisation mission or operation at risk. The organisation may benefit by having contingency plans to address them should they occur. Try to identify their severity and probability of occurrence’.

T1: Different views on what sustainability and climate change entails; Polarisation within staff and students.
During the discussion on the definition of sustainable development, it became evident that the participants are scared for polarisation within staff and students concerning this topic. Student 4 mentioned: ”There are so many different factors to consider. And different perspectives too. I think there are various truths. Perhaps a danger for polarization.” Assistant Professor 3 agreed by saying: ”This is a danger if, when we sit at a table and at the end of the discussion, we leave the room with highly polarized opinions. We need to realize there are just different opinions to contribute here. Every form is very important.”

T2: Full (overcrowded) curricula.
Both Assistant Professors articulated the current inclination among multiple educators to introduce significant sustainability-related aspects into their courses. However, they acknowledged the emerging challenge in finding suitable room for integration. Assistant Professor 3 highlighted, ”I believe that if I want to add something, considering the amount of time I have for a certain teaching activity, something else has to be removed. That’s how it is. When it comes to fundamental aspects, I don’t want to discard the fundamental elements from a course.” Assistant Professor 3 articulates the significance of maintaining essential subjects within courses as their paramount concern, ensuring they remain a priority.

The pressing concern of an overcrowded curriculum was deemed a threat rather than a weakness, significantly impeding teaching staff. The educators expressed their reluctance to engage in superficial changes. Integrating additional topics would broaden the curriculum's scope but would compromise its depth, potentially disadvantaging both teachers and students in the long run.

T3: Individualistic character; lack of collaboration and communication.
In addition to the identified weakness of lacking communication and open discussions (W1), the individualistic nature of the Applied Sciences was perceived as a threat. Individualistic character traits, partly caused by the prevalent competitive atmosphere, within the discipline pose potential obstacles to the successful implementation of ESD and may even precipitate the failure of the transition process. Assistant Professor 1 highlighted that Threat T3 diminishes the likelihood of collaborative efforts and communication initiatives to achieve success.

T4: University-wide goals have their own interpretation at faculty-level. Misalignment of communication could happen at different levels.
Both Assistant Professor 1 and Student 4 highlighted the potential misalignment between university-wide and faculty-specific action plans. They emphasized the importance of a harmonious collaboration between the faculty's objectives and the expectations set forth by university management. To develop an efficient action plan, this aspect necessitates careful consideration. An illustrative instance involves the GreenTeam initiative, who's role differs per faculty, causing confusion between stakeholders. Similarly, in the context of ESD implementation, discrepancies in approaches across various faculties could cause confusion among teaching staff. This issue extends further within the AS faculty, encompassing distinct study programs that may exhibit analogous disparities.

T5: Current teaching content is ready to use and of high quality.
Assistant Professors 1 and 3 concur on the significance of utilizing pre-existing high-quality teaching content, recognizing its capacity to conserve time and energy—two frequently scarce resources in academic settings. Moreover, there's a prevalent apprehension among certain teaching staff members regarding the potential inferiority of new teaching content and tools compared to the current materials in use. Such concerns could potentially impede the transition toward ESD implementation.

6.5.7. Opportunities

During step 3, opportunities were defined as 'Attractive factors that represent the reason for an organisation to exist and develop. What opportunities exist in the environment, which will propel the organisation and facilitate identified learning outcomes?'

O1: Different definitions of sustainability are allowed and constantly discussed and communicated.
As outlined in the section concerning T1, emphasizing the discussion surrounding the definition of sustainable development is pivotal. The unanimous agreement among all participants underscores that a continuous discourse on this subject has the potential to mitigate polarization and positively impact the successful implementation of ESD (minimizing W1). This opportunity could increase the intrinsic motivation (S3) of a variety of stakeholders and result in the transition seen as a challenge carried by all.

O2: A detailed climate action road map with a structured guideline and time for adjustment.
In line with the task from the core team of sustainability to assign LSCs at the faculty, and the necessity of the creation of a climate action road map, it was mentioned how this plan should have a structured guideline. Furthermore, was it emphasized how it is critical to give stakeholders time to adjust to the new objectives.

Student 4 stressed the need for a faculty-specific action plan highlighting the distinctive nature of programs within the faculty, underscoring the requisite contextual specificity imperative for ESD integration. The interviewee emphasized the need for disparate approaches between programs such as civil and mechanical engineering in contrast to biology-centred programs like Nanobiology. There was recognition that not all courses within a faculty are homogeneous; nonetheless, commonalities in learning objectives might exist across various programs at the AS Faculty. It was emphasized that the definition of these objectives need not be tethered to a particular course title or subject but should rather focus on conceptual coherence. Effective communication and collaborative efforts were underscored as pivotal for refining and aligning these learning objectives across diverse educational elements.

O3: The creation of a task force with change agents (students and employees), creating clear examples and guidance on change efforts.
In conjunction with the climate action road map, discussions highlighted the necessity for change agents to collaborate and inspire not only fellow faculty members but also each other. Assistant Professor 3 articulated the need for an initial identification of stakeholders followed by collective deliberation to delineate overarching goals and specific objectives for individual courses.

Moreover, discussions during the focus group underscored the necessity for cultural change, which according to Assistant Professor 3 often commences with one individual. It was emphasized that a single teacher, if positively inclined, could initiate conversations and interactions with enthusiastic individuals within the faculty, potentially forming a collective group. Assistant Professor 3 suggested that approximately 10 to 30 individuals in the faculty might share similar enthusiasm for this cause, thereby proposing the formation of a collaborative unit responsible for defining learning objectives and designing corresponding activities. The importance of top-level support to catalyze these discussions and bring like-minded individuals together was highlighted.

O4: Collaboration between (students and) teaching staff within the faculty and over the whole campus.
Assistant Professor 3 mentioned how the climate action road map can be the opportunity for the faculty to work in a more collaborative manner: ”I think climate action is actually an opportunity, a chance for various faculties within the TU to collaborate. Only when we sit down together to discuss this, we realize that there are actually many points of intersection. It’s not the case that for every faculty, concerning education, we have to come up with completely different things. I can give an example. I teach the course ”Physical Transport Phenomena” for the MST program, and only two years after I started teaching the course did I realize that almost all faculties at the TU offer a similar course. Perhaps the name is different, maybe the format is different, but essentially, this is a course where you can define certain learning objectives related to climate action very well. It’s mostly an opportunity to look at what is possible.”

All interviewees agreed that an increase of collaboration between teaching staff (including students) could lower the amount of resources (W2) needed for change. However, Student 3 and 4 did mention the threat of partial responsibility. As long as there is a structured guideline with end responsible stakeholders, this variable can be seen as an opportunity. Furthermore, Student 3 highlighted the influence of collaboration on the intrinsic motivation of the AS stakeholders (S3 and W3), stating ”I think it’s about motivating people and really pushing for actual action. Getting those people to collaborate. Getting everyone excited from the bottom-up and also having a bit of a push from the top-down. There should be clear agreements so that people can actively start doing something about it.” By combining a top-down and bottom-up approach, it might be possible to systemically change the culture of the faculty.

O5: Don't wait for all staff to be willing to change; then you can wait forever.
Assistant Professor 1 and the core-team member emphasized the prospect of not awaiting the unanimous consensus of all stakeholders regarding the prospect of change. Assistant Professor 1 remarked, ”I sometimes harbor pessimistic views regarding existing individuals who, if they have been part of the institution for over 20 years, have shown no inclination toward change.” The sentiment conveyed a skepticism about the readiness of long-tenured individuals to embrace transformation.

The assistant professor suggested the consideration of a more strategic allocation of time and effort, highlighting the importance of directing efforts towards individuals displaying willingness and enthusiasm to effect changes. They underscored the concept of concentrating efforts on those inclined towards change, albeit acknowledging that this approach might demand greater investment from fewer individuals due to a lack of evenly distributed effort. Consequently, this approach might necessitate a careful balance with their other responsibilities.

O6: Rational characteristic enhancement to intrinsically motivate stakeholders.
The rational nature of the AS faculty presents an opportunity when articulating the arguments for ESD in a clear and detailed manner. Assistant Professor 1 highlighted the importance of elucidating the necessity for change and consistently communicating the ongoing transition and decision-making processes. Leveraging this rational characteristic could prove advantageous. It was suggested that substantiating the impact and visually demonstrating the changes can be crucial in appealing to the mindset of the rational stakeholders within the AS Faculty.

O7: A collaborative effort to create a coherent set of learning objectives, room for own interpretation and sharing of the new objectives.
During the focus group discussion, a suggestion emerged that a new set of coherent learning objectives need not necessarily be universally integrated into all individual courses. Assistant Professor 3 drew a connection between S2 (pertaining to a coherent set of learning objectives allowing for individual interpretation) and W1 (pertaining to lacking communication and open discussions). At this juncture, the core-team member raised an inquiry: "Would it be beneficial to allocate sustainability topics across various courses? This way, discussions can determine the allocation without duplicating content?" The Assistant Professor wholeheartedly concurred, stressing the importance of establishing comprehensive agreements and ensuring that all stakeholders are precisely aligned to pursue such an approach.

This strategy affords more reticent stakeholders the opportunity to adapt gradually and develop their own understanding of ESD. It is imperative to grant teaching staff the latitude to explore and identify their intrinsic motivations autonomously.

O8: Transparency on collaboration with fossil fuel industry.
In parallel with the ongoing discussions regarding the definition of sustainable development, the faculty's affiliations with the fossil fuel industry surfaced as a relevant concern. Given the dispersed opinions within the faculty on this matter, it becomes imperative to maintain a continuous discourse on this topic while simultaneously enhancing transparency concerning collaborative engagements.

O9: New hires of intrinsically motivated teachers and/or appointment of motivated program managers.
This opportunity was primarily articulated by Student 3, Student 4 and Assistant Professor 1. Despite this proposition not implying an incapability among the current teaching faculty to adapt or act as agents of change, both students and Assistant Professor 1 underscored the favorable impact resulting from the induction of new faculty members. Assistant Professor 1 stated, "I've witnessed numerous instances wherein new faculty exhibit an enthusiastic inclination towards implementing substantial alterations, unhampered by adherence to the former system's norms."

Nevertheless, Assistant Professor 3 and the core-team member emphasized that this aspect is intricately linked to the mindset and adaptability of the educators, emphasizing the importance of the teacher's readiness to adopt innovative approaches.

6.5.8. Relations of SWOTs

As outlined in the preceding sections, initial linkages were established among various SWOT factors. Opportunities aim to capitalize on Strengths, and conversely, Threats and Weaknesses hinder and impede the progress, potentially causing a slowdown or halt in the transition. While certain connections were not explicitly defined during the session, they emerged organically from the course of the discussion and the sequential order of topics explored.

An illustrative example exists in the dual characterization of (lack of) intrinsic motivation among employees and students, which can be perceived both as a Strength (S3) and a Weakness (W3). The assignment of this variable as both a strength and a weakness underscores its significance in ESD implementation and emphasizes the necessity for deliberate discussions on this subject by those instigating change. These variables are influenced by for example W5: 'Interest in Fundamental Sciences,' as identified by Assistant Professor 1, suggesting a potential reduction in intrinsic motivation. Concurrently, O1: 'Different definitions of sustainability are allowed and constantly discussed and communicated' contributes to an elevation in intrinsically motivated stakeholders.

The identified weakness (W3) lies in the challenge of identifying unifying intrinsic motivators (S3) capable of engaging all key stakeholders involved in this transition or allocating dedicated time for teaching staff involved in this process (addressing W2).

Another example is the influence of W2: 'Lack of resources' and how it minimizes the chances of success of five out of nine opportunities (O2-4, O7 and O9). This Weakness can be lowered by S1: 'explicit assignment from (top-)management and S4: 'Planning, preparation and KPIs; learn from research approach'.

Figure 6.15 provides an initial overview of the connections deliberated during the focus group.

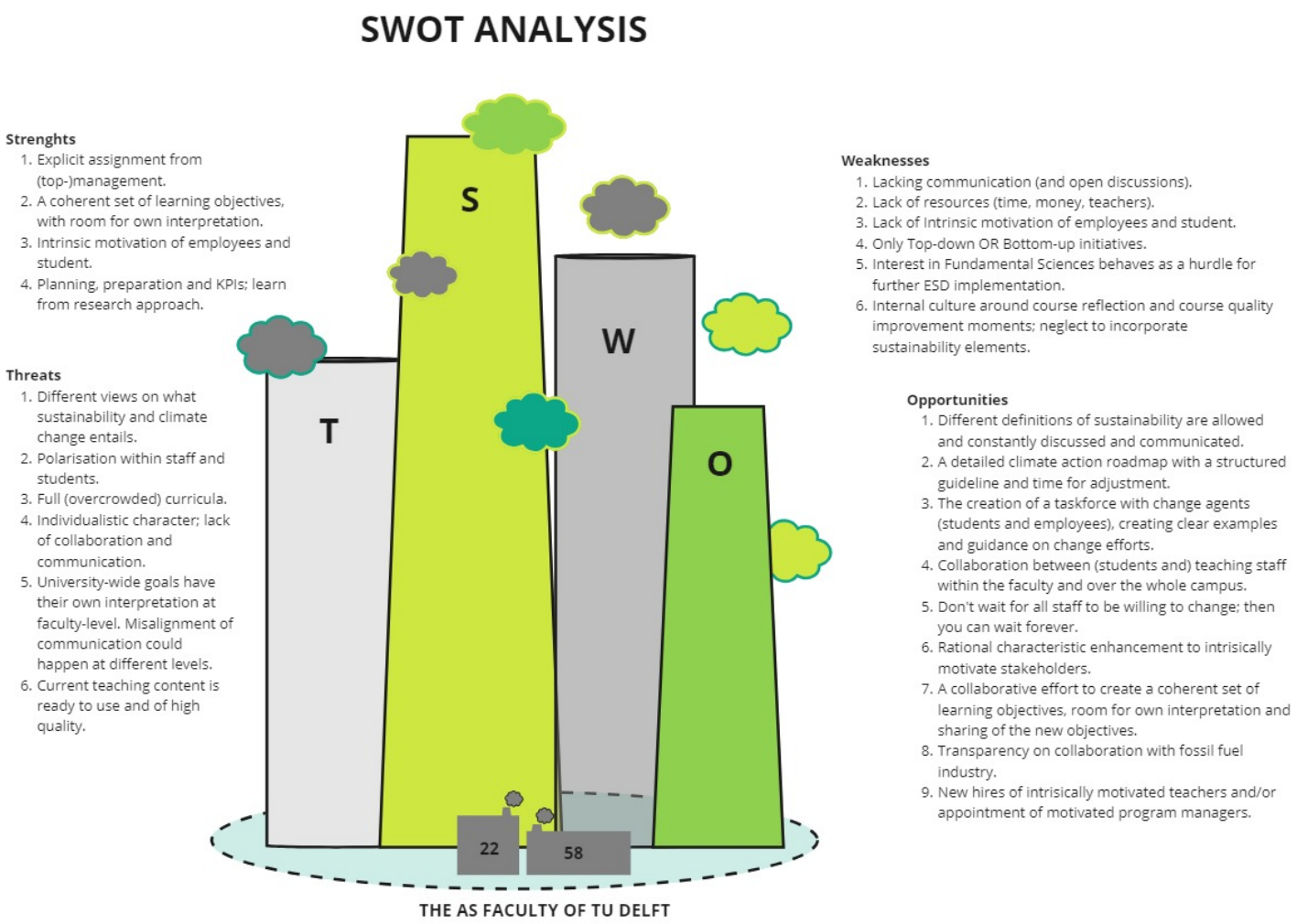

Figure 6.14: Results of the SWOT Analysis performed with five stakeholders from the AS Faculty of TU Delft.

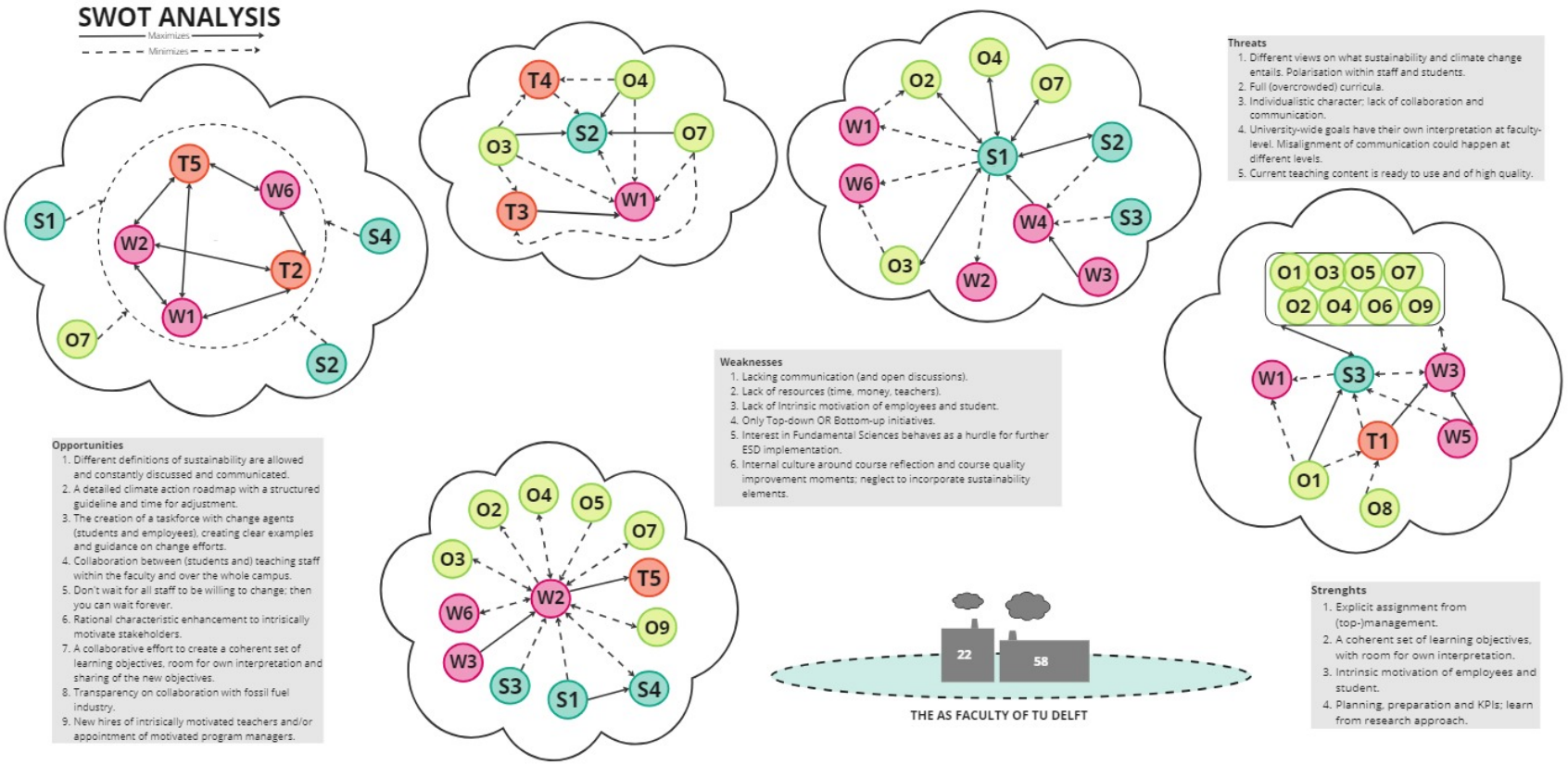

Figure 6.15: An initial overview of the SWOT connections deliberated during the focus group.

6.6. Strategies for systemically promoting and implementing ESD

In step 4 of the focus group the participants discussed strategies for achieving a cultural change within the faculty, emphasizing the need for collaboration, concrete plans, and systematic change. Assistant Professor 3 highlighted the importance of individual commitment, while Student 4 suggested concretization through written plans and goal-setting. Student 3 emphasized the motivation of individuals and the need for both bottom-up enthusiasm and top-down pressure. The core-team of sustainability member suggested creating a special interest group to bring teachers together, acknowledging the broader spectrum of student interests beyond sustainability. The participants expressed optimism and a shared commitment to making positive changes within the faculty.

Together with the final thoughts of step 4, the literature research on systemic change approaches (specifically the Drivers from Figure 4.4), and the expertise of the researcher, critical strategies for ESD implementation at the AS Faculty of TU Delft can be proposed accordingly. Moreover, considering the extensive literature available on ESD implementation and systems change, an analytical approach will be employed to seek fresh perspectives and distinctive facets that differentiate applied sciences engineering education from other forms of engineering. The goal is to leverage strengths and opportunities to their fullest potential, to convert weaknesses into strengths, and to mitigate threats.

The five proposed strategies are: ST1 -Direction of Change, ST2 -Context and Culture, ST3 -Planning and Preparation, ST4 -Design and Implementation, and ST5 - Maintaining Momentum and Sustaining the Change. All five strategies are imperative considerations in formulating the education portfolio of the climate action plan. ST1, ST2, and ST3 assume significant roles in the initial phases of the action plan, followed by the implementation of ST4. Ultimately, the emphasis should be placed on ST5. Throughout the progress of the climate action plan, all five strategies should be revised. The particular strategies suggested will be elaborated upon in the subsequent sections.

6.6.1. ST1: Direction of change.

To drive substantial change towards a more sustainable future within the AS faculty, an integrated approach opening up existing hierarchies and fostering equality is imperative. The SWOT analysis underscores the pivotal role played by the Climate Action Team in the faculty. A systemic change approach recommends the team's establishment of working groups focusing on various ESD related topics, thereby surrounding themselves with individuals committed to instigating change. Together, the change agents should create a vision that can be carried by the whole faculty and is continuously repeated.

Next to the Climate Action Team, formulating a task force comprising representatives from diverse faculty levels is suggested, aimed at ensuring inclusivity and mitigating potential polarization. This envisioned task force would encompass student representatives from bodies such as the FSC, the GreenTeam, and study associations, but also be open to students that have not yet joined a student body. Other task force positions should be filled by program directors from all academic programs, leading assistant professors advocating for change, the director of education, and members of the Climate Action Team itself.

While not mandating the presence of all stakeholders in every meeting, regular gatherings are proposed, several times annually, to conduct impact evaluations and assess progress. This structured approach is designed to ensure comprehensive representation and effective evaluation mechanisms within the task force. It is recommended that the Climate Action team chairs these meetings and monitors the progress in order for partial responsibility to work effectively.

Furthermore, leadership support, especially from the management team of both the faculty and of the different study programs, plays a pivotal role. Their dedicated commitment to spearheading reform is evident in explicit, public support for these endeavors, and additionally the allocation of resources.

Lastly, the section on Direction of Change in Figure 4.4 touches upon the urgency to move away from fossil fuel dependencies. During the focus group, it was discussed how regarding the AS Faculty an initial stride would be to be completely transparent on the collaborations. Most participants of this study held the opinion that completely cutting the ties would would cause even more harm than good.

Looking back at the earlier defined SWOTs, ST1 needs explicit assignment from (top-)management (S1) and intrinsic motivation of employees and students (S3). ST1 tries to resolve lacking communication (and open discussions) (W1) while counteracting lack of resources (W2) and lack of intrinsic motivation of

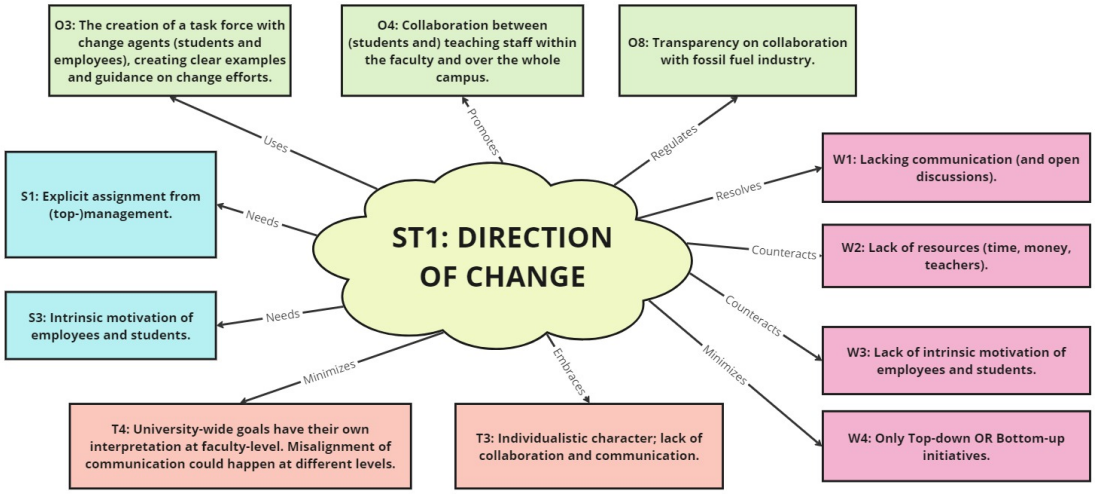

Figure 6.16: An overview of the relation between Strategy 1 (ST1) 'Direction of Change' and the SWOTs identified in Step 3.

employees and students (W3). Additionally, ST1 encourages collaboration between top-down and bottom-up, minimizing the chance of only top-down OR bottom-up initiatives (W4) taking place. Furthermore, ST1 uses the creation of a task force with change agents, creating clear examples and guidance on change efforts (O3). ST1 likewise promotes collaboration between (students and) teaching staff within the faculty and over the whole campus (O4), and regulates transparency on collaboration with fossil fuel industry (O8). Lastly, ST1 minimizes the chance of misalignment of communication between different university and faculty levels (T4) and embraces the faculty's individualistic character (T3). An overview is found in Figure 6.16.

6.6.2. ST2: Context and culture.

During R1, R2 and R3 it was found that the AS faculty exhibits distinct characteristics, notably an individualistic, rational, and competitive nature, alongside a profound interest in fundamental sciences and often a Technology-Fix mindset. Recognizing these factors is imperative in implementing changes that resonate with the stakeholders. Moreover, there exists a diversity of opinions regarding the definition of sustainable development within the faculty. To minimize the chance of polarization, different definitions of sustainable development should be allowed and openly discussed.

A strategic approach is proposed to address these aspects through the organization of monthly (or quarterly) open discussions on contentious sustainable development-related topics for both employees and students. These discussions, such as those concerning ties with the fossil fuel industry, aim to provide a platform for comprehensive dialogue and understanding. Inclusivity is key, necessitating the involvement of all faculty layers, not solely as spectators but as active participants in these deliberations.

However, previous instances have highlighted low turnout rates in such gatherings. Leveraging existing events (e.g., Teaching Day) and facilitating dedicated time for teaching staff to engage in these discussions could significantly enhance attendance and involvement in these critical conversations. Similar to the recommendations in ST1, this requires public support from the management team of the faculty.

An additional cultural facet that warrants discussion is the intricate equilibrium between teaching and research obligations within the faculty. Interviews have consistently revealed that research typically holds precedence over other commitments. However, for an effective implementation of ESD, it is imperative to synchronize both educational and research endeavors with sustainability objectives.

Ensuring this alignment necessitates full transparency concerning institutional collaborations and the allocation of resources (specifically collaboration with the fossil fuel industry). Moreover, understanding the support mechanisms provided at the national level is equally crucial in fostering a cohesive approach towards integrating sustainability across educational and research frameworks.

Broadening the scope, the Climate Action Team should facilitate a comprehensive system-wide transition, embedding sustainability principles in governance, curriculum, campus practices, community engagement, research initiatives, communication strategies, and capacity building. The progress on all portfolios should be well communicated. The team should leverage the consensus among faculty members regarding the inevitability and urgency of change, using existing issues in educational programs as catalysts for transformation. It is recommended that resources are freed up for the structuring of said communication plan. Initiate a collective shift in entrenched social norms, fostering a pervasive mindset focused on sustainability across all facets of the faculty. Simultaneously, it is recommended to capitalize on faculty expertise and new hires' fresh perspectives to drive impactful sustainability initiatives effectively.

Furthermore, the departmental culture at the faculty should likewise be acknowledged for this strategy. The head of the department plays an important role in influencing the intrinsic motivation of others. Open discussions between the Climate Action Team, with support of top-management, and heads of departments should ensure alignment of institutional values with sustainability goals.

Reflecting on the previously identified SWOTs, ST2 needs explicit assignment from (top-)management (S1) and intrinsic motivation from employees and students (S3). ST2 acknowledges the faculty's interest in fundamental sciences (W5), and counteracts lacking communication (and open discussions) (W1) and lack of intrinsic motivation of employees and students (W3). ST2 acknowledges the importance of different definitions of sustainability and constant discussions and communication (O1). Moreover, the strategy acknowledges the faculty's rational characteristic (O6) and promotes transparency on collaboration with the fossil fuel industry (O8). Lastly, ST2 acknowledges the faculty's individualistic character (T3) and the different views on what sustainability and climate change entails, minimizing the chance on polarization (T1). An overview can be found in Figure 6.17.

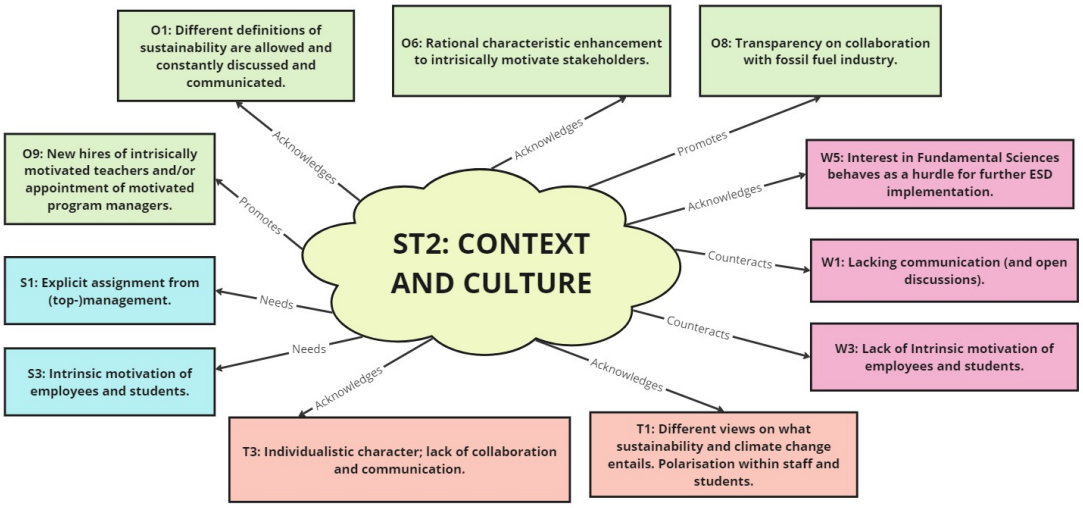

Figure 6.17: An overview of the relation between Strategy 2 (ST2) 'Context and Culture' and the SWOTs identified in Step 3.

6.6.3. ST3: Planning and preparation.

To spearhead this intricate transformation, the appointment of a dedicated management team, strategically chosen to oversee the design, planning, and execution of reforms, is crucial. At the AS Faculty, this initiative has already commenced through the formation of the Climate Action Team. However, allocating formal time to this team is essential, emphasizing the recurring nature of impact evaluation as a fundamental process. To bolster this effort, pedagogical training in the form of workshops or guided sessions led by education specialists is recommended for both the Climate Action Team and the ST1 proposed task force. Regarding the AS teaching staff, embracing shared teaching responsibilities — such as team teaching in courses — accompanied by regular meetings and adequate resources, facilitates a seamless transformation while ensuring continuity in the curriculum.

Moreover, during the literature research it was shown that external perspectives and consultations bring

valuable insights into the reform process. Given that most of the TU Delft faculties and services now possess assigned LSCs and the task of creating a Climate Action Plan, collaboration between the AS Climate Action Team and other LSCs in crafting their road maps is advisable. This approach reduces resource requirements and ensures alignment with university-wide objectives. Moreover, fostering collaboration with other faculties of applied sciences outside of Delft, which was highlighted as lacking during R1 and R2, presents an opportunity for accelerated transition by learning from other institutions.

In the Planning and Preparation phase of the Climate action road map, it is prudent to review the identified drivers, barriers, and uncertainty factors from this research. Furthermore, understanding the dynamic nature of these variables and their interdependence is crucial. Engaging in reflective moments and adopting a systemic perspective to comprehend the broader picture are vital.

Activities such as evidence collection, collaboration with the Head of Education, and informal discussions with senior university/faculty management strengthen the foundations of the reform. Addressing potential issues proactively and effectively conveying the vision of the reform to the faculty underline the steadfast commitment to this trans formative endeavor. Ultimately, ensuring transparency in the transition and decision-making processes remains imperative, fostering an environment conducive to meaningful change.

Reviewing the SWOTs, ST3 needs planning, preparation and KPIs (S4) and increases intrinsic motivation of employees and students (S3). Conversely, ST3 resolves lacking communication (and open discussions) (W1). Likewise, ST3 counteracts lack of resources (W2), only top-down OR bottom-up initiatives (W4) and the internal culture around course reflection and course quality improvement moments (W6). Moreover, ST3 creates a detailed climate action road map with a structured guideline and time for adjustment (O2). The strategy needs the creation of a task force (O3) and promotes collaboration within the faculty and over the whole campus (O4). Finally, ST3 counteracts individualistic behavior (T3) and ensures that no communication misalignments happen (T4). An overview is pictured in Figure 6.18.

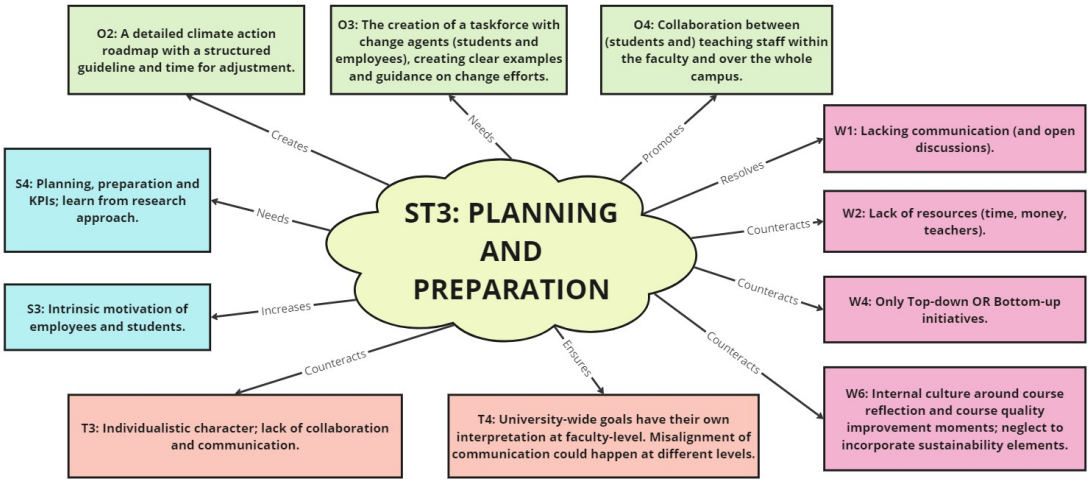

Figure 6.18: An overview of the relation between Strategy 3 (ST3) 'Planning and Preparation' and the SWOTs identified in Step 3.

6.6.4. ST4: Design and implementation.

Encouraging the active involvement of a substantial number of faculty members in curriculum design, making it a faculty-wide initiative, fosters inclusivity and diverse perspectives. The Climate Action Team could create a call for change agents and opponents of ESD to help structure the educational strategy. Despite the magnitude of change, revisiting the fundamental objectives and methods of the entire degree program ensures that modifications are seamlessly integrated into a cohesive curriculum framework. In accommodating reluctant faculty members, there's a deliberate choice to avoid pressuring them to alter their preferred teaching methods. A portion of the curriculum could remain largely unchanged, allowing for the continuation of established teaching practices within a unified curriculum structure. This will lower the resistance caused by T3 and T6.

Moreover, as outlined in O7, it is acknowledged that change within the AS Faculty requires considerable time and space for individual interpretation. The proposal for new learning objectives not to be universally mandated across all individual courses, but for new objectives to be shared, may foster collaboration and facilitate ongoing communication. This approach aims to minimize content overlap among different courses and reinforces the systemic perspective of ESD.

Examining the SWOTs, ST4 needs a coherent set of learning objectives (with room for own interpretation) (S2) and planning, preparation and KPIs (S4). ST4 tries to resolve lacking communication (and open discussions) (W1). Additionally, ST4 counteracts lack of resources (W2), lack of intrinsic motivation of employees and students (W2) and the internal culture around course reflection and course quality improvement moments (W6). Conversely, ST4 promotes different definitions of sustainability to be allowed, discussed and communicated (O1). Likewise, ST4 promotes the creation of a task force, clear examples and guidance (O3) and collaboration between all types of stakeholders (O4). Furthermore, ST4 promotes initiating change without all stakeholders to be on board (O5) and the collaborative effort of creating a coherent set of learning objectives with room for own interpretation and sharing of new objectives (O7). Lastly, ST4 tries to minimize the influence of full overcrowded curricula (T2) and the threat of current teaching content being ready to use and of high quality (T5). An overview is found in Figure 6.19.

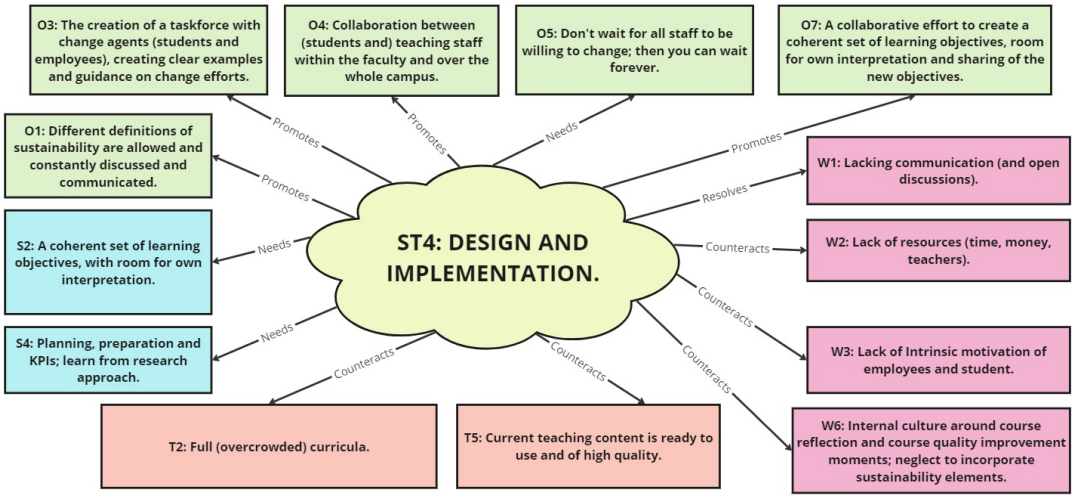

Figure 6.19: An overview of the relation between Strategy 4 (ST4) 'Design and Implementation' and the SWOTs identified in Step 3.

6.6.5. ST5: Maintaining momentum and sustaining the change.

Continuous dialogue between faculty members and change agents acts as a catalyst for sustained progress. Faculty members should actively participate in continual educational enhancement, fostering an environment of ongoing changes and improvements. Furthermore, monitoring impact data through systematic impact evaluations allows for ongoing assessment and improvements. To ensure faculty motivation and cohesive communication, long-term evaluations should be conducted to gauge the lasting effects of the reform. These evaluations focus on disseminating results, highlighting early achievements, and measuring the increased caliber of student enrollment and motivation. The Climate Action Plan ought not to be confined to a mere five-year time-frame; rather, it should encompass enduring reforms with a long-lasting impact.

Consistent communication underscores the critical importance of reformation, evidence gathering, and potential impact visualization. Educators and academic leaders should engage in reflective practices, encouraging introspection and continuous learning in the educational reform process. Additionally, engaging new faculty members in the reform process is crucial to maintain momentum.

Something noteworthy is that even after implementation, prioritizing education is essential for the enduring success of the transformation.

Analyzing the SWOTs, ST5 increases intrinsic motivation of employees and students (S3) while requiring meticulous planning, preparation and KPIs (S4). ST5 resolves lacking communication (and open discussions) (W1) and counteracts lack of intrinsic motivation (W3). Simultaneously, it counteracts the internal culture around course reflection and course quality improvement moments (W6). Concurrently, necessitating the creation of a task force, clear examples and guidance (O3). Moreover, ST5 needs collaboration (O4) and it necessitates taking progress steps without all stakeholders being on board with the change (O5). Lastly, ST5 minimizes individualistic characteristics (T3) and misalignments between university-wide goals and faculty-level interpretations (T4). An overview can be found in Figure 6.20.

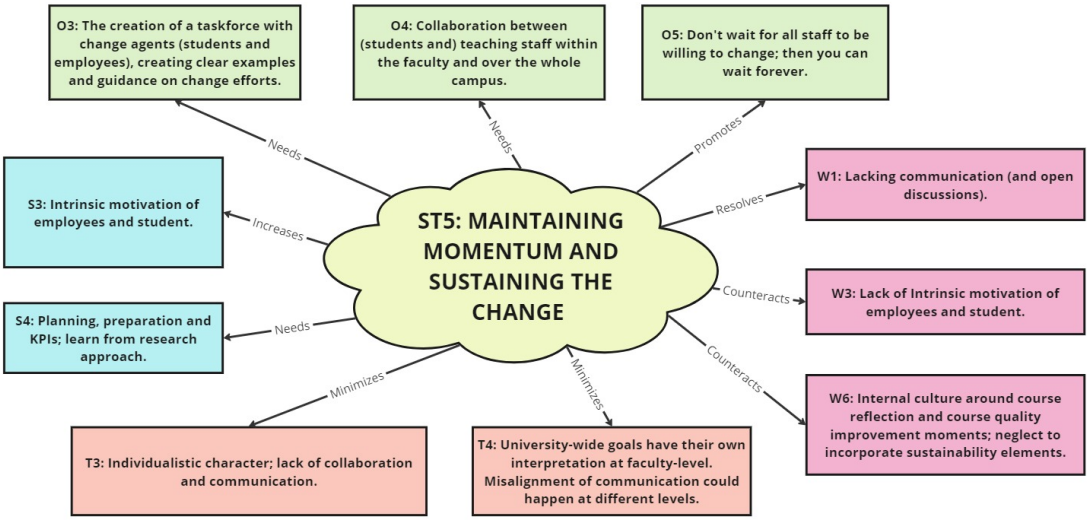

Figure 6.20: An overview of the relation between Strategy 5 (ST5) 'Maintaining Momentum and Sustaining the Change' and the SWOTs identified in Step 3.

7

Discussion

In this chapter, the discussion demonstrates the key findings and interpretations extracted from the results. Moreover, the academic contribution and the primary constraints of this study are acknowledged. Lastly, recommendations for prospective research are delineated.

7.1. Reflection on findings

7.1.1. The importance of dissemination of knowledge and experiences

Upon reflection, it becomes apparent that initially the literature regarding the Applied Sciences Faculty lacked comprehensive coverage. It is now evident that substantial efforts and advancements are taking place within the institution, albeit undocumented in academic literature. This observation underscores a prevalent phenomenon across various educational institutions, wherein significant progress made during classroom sessions and meetings often goes unreported in scholarly publications. While this discrepancy may seem evident, it highlights a critical gap between the reality of educational endeavors and the existing body of literature. Bridging this divide is imperative, and there exists an opportunity to encourage practitioners to share their insights and experiences through scholarly dissemination. While it may be commonplace for educators to privately document their progress, the absence of such publications restricts the dissemination of valuable knowledge within the academic community. Consequently, fostering a culture of publication and knowledge sharing within educational spheres is crucial for enhancing the collective understanding of effective teaching practices.

7.1.2. Context-specificity & the value of institutional culture

It should be acknowledged that the large focus on context-specificity, might be seen as a reason not to initiate change or to lengthen the transition period. As was emphasized in the literature study, Wiek and Lang (2016) suggest that institutions should cease the pursuit of an ideal model and take immediate action. H(E)EIs need not to reinvent the wheel but can readily adopt existing frameworks, tailoring them to their own systems, needs, and values, and commence experimentation without delay. Even though this research has emphasized the need to understand an institution's culture when implementing change, the most influential barriers, drivers and uncertainty factors are not far off from those of other institutions implementing ESD (Weiss et al., 2021). Institutions could learn more from cases not specific to their field, than is implied.

However, this research emphasizes the importance of culture not only in sustaining systemic change, but in sustaining ESD implementation. During the literature study, it already appeared that understanding and working with an institutions culture is highly important (Reinholz & Apkarian, 2018)(Graham, 2012)(Holst, 2023)(Weiss et al., 2021). Emphasizing again the importance of including and understanding institutional cultures gives stakeholders more acknowledgement and helps in increasing intrinsic motivation rather than changes being seen as a burden.

7.1.3. Variable categorization and the term Uncertainty Factors

Something noteworthy is the categorization of variables in this research. Categorizing variables as barriers, drivers and uncertainty factors, or into one of the four SWOT quadrants, presents its own set of challenges. Strengths that are not adequately maintained may evolve into weaknesses over time. Similarly, opportunities that are overlooked but subsequently seized upon by competitors can transform into threats. This fluidity and context-specificity was observed in R1, R2 and R3. The classification of a variable is contingent upon the specific objectives of the analysis and the interpretation of the interviewees and focus group participants. The complexity of the classification of variables and the influence of culture should be taken into account. This also brings in the discussion on the term uncertainty factors.

Upon reflecting this research's addition of the term *uncertainty factors*, it became apparent that there is considerable overlap with the *barriers* term. It may be argued that the term uncertainty factors is unnecessary in this context. However, it was decided that solely categorizing variables as barriers and drivers does not adequately emphasize the complexity of the topic. While uncertainty factors may seem redundant, they serve to prompt readers to also consider variables that are not directly seen as a driver or barrier and could potentially influence the outcome, thus adding an additional layer to the barrier/driver categories. Additionally, the scope of the thesis was refined by employing a restricted set of three categorization terms during both the literature review and the interview rounds, rather than including the same amount of terms as Weiss et al. (2021).

Moreover, the term can help structure the creation of the action plan's KPIs as it illustrates potential hurdles (or catalysts). It enables the Climate Action Team to explore various scenarios that could result from different decisions. This approach encourages thorough consideration and strategic planning, enhancing the effectiveness of decision-making processes. A potential next step could involve assigning weights to the variables to better capture their significance.

7.1.4. SWOT & additional tools of analysis

This thesis proposes integrating the SWOT matrix with literature and a stakeholder supported scorecard of the most influential barriers, drivers and uncertainty factors to create a systematic and comprehensive strategic management plan. It acknowledges that the SWOT analysis provides a structured approach for establishing the foundation of the balanced scorecard, rather than relying solely on intuition or brainstorming to identify the most influential variables. The terms barriers, drivers and uncertainty factors may not comprehensively capture all facets of the variables under consideration. By contextualizing them within the framework of the SWOT analysis, participants were prompted to reassess their definitions of these variables and contemplate their implications on the implementation of ESD. Moreover, this approach provided a more holistic perspective on both internal and external variables, thereby identifying elements that could be addressed by the Climate Action Team or (top-)management, as well as those requiring attention from the university or external stakeholders.

Although a SWOT analysis is effective in profiling and listing issues, it does not offer concrete strategies for capitalizing on opportunities or maximizing strengths. Hence why in the final stages of this research, the SWOT outcomes were synthesized with systems change drivers found in literature. SWOT analyses can be seen as vague and simplistic (Helms & Nixon, 2010). However, by adding two additional layers, the rounds of interviews and a final synthesis with literature, these limitations are counteracted and a resource-based SWOT is constructed (Figure 7.1). Furthermore, the quality and timeliness of information utilized in crafting the SWOT analysis are crucial, as is the diversity and reliability of the viewpoints considered. The participants were engaged in evaluating the accuracy of the data as they interpreted the provided information. Scrutinizing and subjecting the findings to literature was necessary to ensure clarity and appropriateness in both the information and the interpretation of the SWOT evidence. These procedures mitigated some of the subjective elements inherent in SWOT analysis. A next step could be the bench marking of stakeholders outside the HEEI for a more robust external analysis.

The SWOT analysis was rapidly assembled and leveraged diverse perspectives through collaborative brainstorming. However, it was concluded that without the previous rounds of interviews and data analysis of R1 and R2, the SWOT analysis would have lacked depth and usefulness. Nevertheless, the SWOT analysis contributed a novel perspective to the findings of both R1 and R2, and vice versa. It is concluded that the SWOT analysis is a sufficient tool to 'kick-start' the strategic planning phase, as was similarly stated by Helms and Nixon (2010).

7.1.5. Universities versus universities of applied sciences

The amalgamation of the three case studies delineates a notable discrepancy in hierarchical structure between the two categories of institutions. An institution such as TU Delft requires a dual approach, encompassing both bottom-up and top-down methodologies, whereas the NHL Stenden and HVHL universities of applied sciences can thrive under a more top-down focused change initiation. Considering the principal focus of this study on a university setting, it might have been advantageous to conduct case studies on technical universities, given their alignment with the primary research subject.

Nevertheless, as expounded upon in the context-specificity section, such distinctions should not impede mutual learning and communication among these institutions. Intrinsic motivation at all echelons emerges as pivotal, and effecting cultural change proves to be a profoundly intricate endeavor. The recommendation to concurrently reform operations, education, research, and community engagement for example constitutes a pivotal consideration in formulating the climate action plan. To ensure the longevity of educational reforms, a cultural shift becomes imperative. The examples of NHL Stenden and HVHL show how systemic ESD implementation is possible and can be sustained with the energy and time of intrinsically motivated stakeholders.

7.2. Academic contribution

Weiss et al. (2021) mentioned how case studies should delve deeper into specific contexts, including traditions, organizational cultures, and national backgrounds, among other factors. Additionally, the authors argued that studies should clarify coping strategies for overcoming barriers to foster shared experiences among HEIs. This research precisely undertook such an endeavor for the AS Faculty of TU Delft. This research holds substantial significance due to the acquisition of empirical data via interviews and insights from the focus group. This empirical data contributes to the broader understanding of the field of applied sciences engineering education, the diverse stakeholders within this sector, systemic change and ESD implementation, the interaction between the faculty and (educational) changes, cultural traits, as well as the identification of drivers, barriers and uncertainty factors of influence in both ESD implementation and systemic change.

Cultural aspects as delineated in the literature study (Reinholz & Apkarian, 2018)(Graham, 2012)(Holst, 2023)(Weiss et al., 2021), have been proven by this research to play an important role in ESD implementation, especially when implemented in a systemic approach. A cultural change is necessary to make the changes durable, emphasizing the importance of the AS Faculty's found characteristics. Acknowledging the rational, high interest in fundamental sciences, individualistic, technology fix mindset and competitive character, and the recognition of different definitions of sustainability allows for open discussions and hinders polarization from happening within applied sciences institutions.

Moreover, the study agrees with the findings of Helms and Nixon (2010) and further illustrates the applicability of the SWOT analysis methodology within educational environments, showcasing its integration with other qualitative methods such as interview-based preparatory steps and strategies outlined in existing literature. By crafting a (strategic) profile of the HEEI, this approach aims to enhance the accuracy of the SWOT analysis, thus increasing the likelihood of successful strategy implementation. It is recommended to develop a knowledge-driven overview to assist focus group participants in conducting the SWOT analysis effectively. Moreover, the synthesis of SWOT outcomes with strategies (drivers) extracted from literature is proposed. The methodology overview presented in Figure 7.1 is not only pertinent within educational settings but also offers value across diverse sectors endeavoring to devise strategies for effecting (systemic) change.

The knowledge gap addressed in this research concerns the interplay between ESD implementation at Applied Sciences Faculties and systemic change approaches. Strategies aiming for systemic change hold potential in addressing ESD challenges through meticulous preparation, fostering a shared vision, offering clear guidance while allowing flexibility, promoting collaboration, ongoing assessments, and demonstrating effectiveness. In the realm of Industrial Ecology, research frequently focuses on significant or revolutionary shifts of systems aiming for increased sustainability. This research aligns with this idea, proposing how in order for ESD implementation to be effective at the AS faculty, a systemic change has to be initiated and sustained.

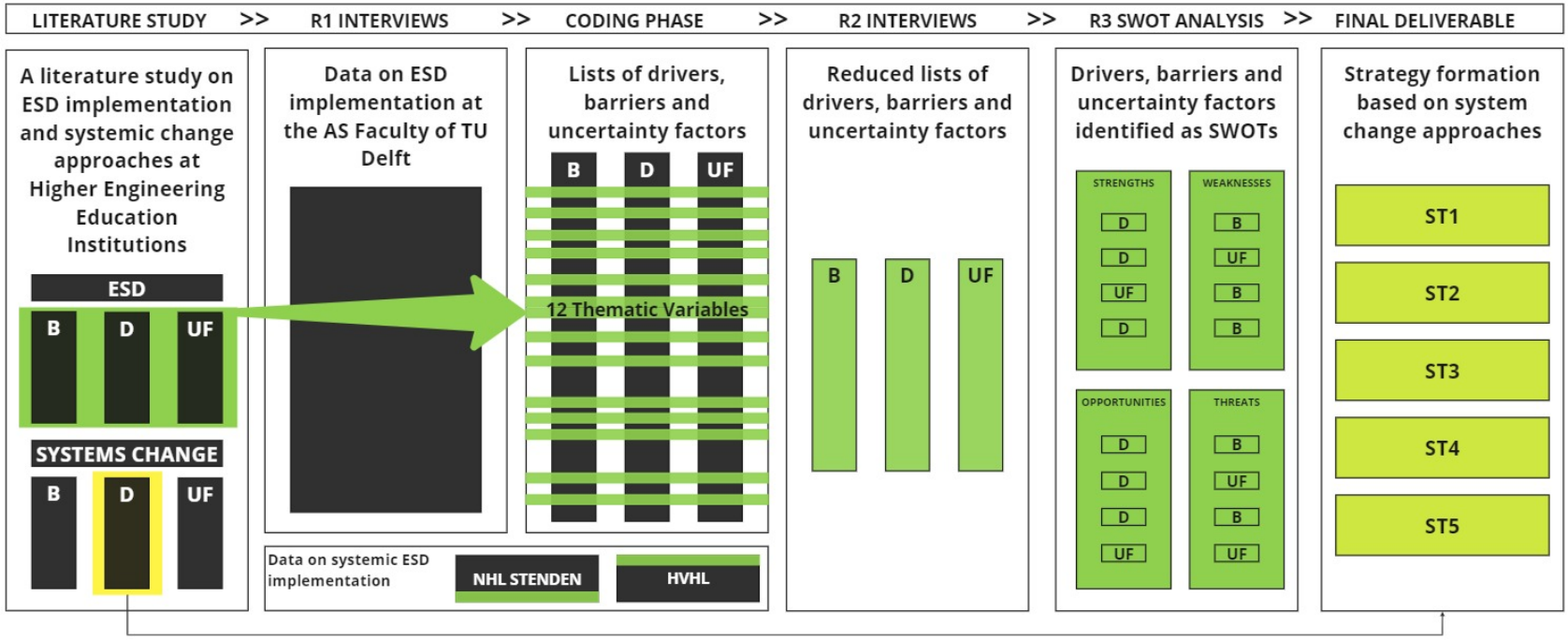

Figure 7.1: Final Variable Reduction and Strategy Formation Methodology. Drivers are labeled as 'D', Barriers as 'B' and Uncertainty Factors as 'UF'. The five proposed final strategies are labeled ST1 to ST5. The final strategies are a synthesis of the drivers found in the literature study on systems change (first block) and the outcomes of the R3 SWOT analysis, which is based on the literature study and the two rounds of interviews (R1 and R2).

7.3. Limitations of study

Recognizing limitations within this study is crucial. Like many similar projects, constraints on the researcher's time and resources are inevitable, inevitably impacting the study's scope. Given more time or additional resources, this research could have delved further into insights, uncovered more detailed findings, or offered a more expansive coverage of the context. The following paragraphs outline specific limitations encountered within this study.

7.3.1. Literature research

The literature research, relying on both desk research and the author's network, presents valuable insights into the thesis topic. However, due to time constraints, the examination is somewhat limited. Despite efforts to minimize oversights through literature studies, there is a noteworthy possibility that certain strategies and variables may not have been included in this research. This limitation arises from the scarcity of research on applied sciences HEEIs and the relatively limited number of case studies investigated. The emphasis on context-specificity in many research studies may result in variables that lack generalization and may not be universally applicable to other institutions. Consequently, the list of variables may be incomplete. Nevertheless, the research has successfully identified a comprehensive set of variables that covers a substantial portion of HEEIs.

7.3.2. Semi-structured interviews & participant selection

Due to time constraints, it was only possible to organise 11 interviews and one focus group of four participants. The choice of interviewees might not comprehensively represent the entirety of the field of study and of the whole AS Faculty of TU Delft. Practical limitations prevented the inclusion of all stakeholder types present at the faculty in the interviews. Additionally, among each stakeholder category, various individuals might have provided diverse perspectives and insights.

Moreover, for case-studies 1 and 2 universities of applied sciences were chosen. As there is a difference between the two types of H(E)EIs in the Netherlands, the value of these case-studies might not have been as valuable as initially thought.

7.3.3. Coding & variable reduction

Because of the subjective aspect inherent in the selected coding method, the author's biases and comprehension of the subject influenced both the created codes and the depth of analysis. Despite efforts made by the author, such as mainly using the code framework of Weiss et al. (2021), personal biases persisted in the analysis. Consequently, the findings might mirror these biases.

Furthermore, a subset of the identified variables underwent further examination in R2, aiming to encompass the most influential variables concerning ESD implementation at the AS Faculty of TU Delft. It is conceivable that some essential drivers, barriers and uncertainty factors may have been unintentionally omitted. Nevertheless, feedback on this variable selection in R3 indicated that no crucial variables were missing, allowing the study to offer a general overview since the selected variables cover various topics.

7.3.4. SWOT analysis

Although the participants in R3 and Assistant Professor 1 from R2 acknowledged the well-structured nature of the focus group, certain limitations should be considered. Primarily, step 4 of the focus group encountered time constraints, preventing the completion of the final step. Additionally, enhanced impact could have been achieved by organizing the session with a representative from the Climate Action Team or higher management. This would have provided the focus group with increased depth concerning credibility and feasibility.

Furthermore, performing a SWOT analysis focus group in a virtual environment presents certain challenges. First, the lack of non-verbal cues in online platforms may hinder the nuanced understanding of participants' reactions. Additionally, maintaining engagement and attention over virtual channels is a concern, potentially impacting the depth of discussions. The virtual setting might limit spontaneity and informal interactions, affecting the richness of insights. Group dynamics may be altered, with participants possibly being more reserved in expressing opinions compared to face-to-face interactions. Furthermore, the absence of physical presence can diminish the sense of connection and shared experience among participants. Despite these challenges, leveraging virtual platforms provides opportunities for accessibility and cost

reduction, making it essential to address these limitations for a successful SWOT analysis in a virtual focus group.

7.4. Recommendations & future prospects

7.4.1. Recommended next steps for the AS Faculty of TU Delft

Examination of the current status of ESD at the AS faculty of TU Delft shows that substantial initiatives are already in progress, surpassing the initial scope revealed by the thesis' desk research. To augment these initiatives, careful consideration should be given to a comprehensive communication plan, inclusive of updates to the Studiegids and the Greendatabase. This strategic communication approach is poised to positively influence the intrinsic motivation of stakeholders, cultivating a deeper appreciation for the faculty's ongoing climate action initiatives.

Moreover, it is advisable to concentrate on the five thematic strategies when formulating the education portfolio of the Climate Action Plan, and to implement ESD with a systemic approach. Additionally, in the detailed construction of the plan and its strategies, it is essential to take into account the various variables identified in R1 and R2. Analyzing the associated barriers, drivers, and uncertainty factors provides valuable insights for constructing the education portfolio of the Climate Action Plan. Moreover, understanding the identified strengths, weaknesses, opportunities, and threats (and their interconnections) contributes to a more profound comprehension of the system within which the Climate Action Team operates. In navigating challenges, a revisit to this research can identify relevant variables that could aid in overcoming obstacles and recognizing achievements that should be celebrated.

To guide this journey further, a structured approach to KPIs is paramount, ensuring effective measurement of the success of sustainability endeavors. The transition from broad recommendations to a detailed guideline is essential, providing comprehensive steps for the seamless implementation of sustainability initiatives. In the pursuit of holistic engagement, a more detailed stakeholder analysis is warranted. This entails identifying and involving all pertinent stakeholders to enhance the impact and inclusivity of sustainability efforts. An additional focus should go to the identification of change agents, starting with some of the participants identified in this study. To refine the five strategies and draw conclusive insights, focused discussions, particularly with the Management Team and the Climate Action Team, should be prioritized. Additionally, initiatives such as the GreenThread and MSc Chemical Engineering changes warrant in-depth exploration to understand their implementation intricacies and outcomes.

Looking forward, a follow-up study could further delve into the dynamics and (quantitative) outcomes of the education portfolio of the Climate Action Plan, building on the foundational insights gained from the initial research. The effectiveness of the strategies could be tested by monitoring and reporting on the Climate Action team and the proposed task force and working groups. The exploration of frameworks offers another intriguing avenue, or implementation strategy and transition of the framework offered by the core team of sustainability of TU Delft. By combining the insights from this study with the prospective core-team framework, ESD implementation might happen more efficiently. To gauge the direct impact of changes, a focused analysis of a specific educational AS program is recommended. This involves examining shifts in students' and employees' perspectives on climate change, sustainable development, and their envisioned future careers before and after the implementation of ESD related measures.

Furthermore, the strategies suggested in Step 4 of the SWOT Analysis are based on the drivers found in systems change approaches. Next steps could go into more detail on the barriers and uncertainty factors that accompany this transition. These barriers and uncertainty factors are already explained in the literature research of this study, but are still to be connected to the critical strategies proposed.

7.4.2. Recommendations for further research

Future research stands to gain significant value from adopting the methodology devised in this study. The comprehensive literature review provides an in-depth understanding of ESD implementation and systemic change, furnishing ample background knowledge for other institutions to seamlessly initiate the interviewing phase. By adhering to the prescribed two specific rounds in conjunction with the code framework proposed by Weiss (2021), institutions can swiftly ascertain an initial comprehension of the influential variables and critical cultural characteristics within their own context. Subsequently, the SWOT analysis framework can be employed to convene pertinent stakeholders involved in ESD implementation for a focused discussion aimed at identifying internal and external variables of influence. Synthesizing these outcomes with the drivers, barriers, and uncertainty factors of systems change delineated in this study enables the formulation of strategic approaches.

Particularly, applied sciences institutions can derive notable benefits from the cultural characteristics described in this research; these variables provide valuable insights into understanding the origins of obstacles and successes and elucidate the aspects of change warranting attention. For instance, consider the ongoing discourse surrounding the definition of sustainability; this variable merits significant consideration during the initiation of a climate action plan. Inadequate exploration of this aspect could cause substantial resistance during the plan's execution phase.

Broadening the research scope, additional case studies on applied sciences HEEIs (in the Netherlands) should be conducted to generalize findings, contributing to a broader understanding of sustainability in diverse educational settings. An aspect that could be explored further in future research is the difference between universities and universities of applied sciences, specifically regarding their (systemic) ESD implementation strategies. This study has made an initial comparison between the two types of HEIs, but further exploration could be beneficial. This would help certain institutions pick the right frameworks and/or initiate systemic change with the right approach and with the right stakeholders. This ongoing commitment to exploration and refinement is crucial for the enduring success of education related sustainability transformations within HEEIs.

Furthermore, the research utilized qualitative data to explore patterns in (systemically) implementing ESD. Future studies should considering more thoroughly exploring the relationships of variables and giving values to the variables to show their level of influence. For a more comprehensive understanding of the dynamics at play, the application of system dynamics modeling is proposed. This approach will illuminate the intricate relationships between barriers, drivers, and uncertainty factors, unveiling feedback loops that shape the outcomes of sustainability initiatives. A similar approach could be taken for the identified SWOTs and strategies.

8

Conclusion

This section provides responses to the sub-inquiries and consequently addresses the primary research query:

How can the Applied Sciences Faculty at TU Delft adopt a systemic change approach to incorporate education for sustainable development throughout its entire academic program?

The sub-questions following from the main research question were:

1. What are the key factors, strategies, uncertainty factors and barriers of a successful implementation of education for sustainable development (ESD) in engineering education?
2. What are the key factors, strategies, uncertainty factors and barriers of systems change in engineering education?
3. How are systemic change approaches used at applied sciences higher engineering education institutions to implement ESD?
4. What is the current situation of ESD implementation at the Applied Sciences Faculty of TU Delft?
5. Which strategies can be used to implement ESD in a systemic manner at the AS Faculty of TU Delft?

As described in the research outline in chapter 2: 'research content', sub-research questions 1 and 2 are answered in chapter 4: 'Literature Review'. Sub-research question 3 is answered in chapter 5: 'Case-studies'. Chapter 6: 'The AS Faculty of TU Delft' answers sub-questions 4 and 5. The main research question is answered through the synthesis of all three chapters.

8.1. Research questions

The upcoming section revisits and tackles the research questions, elucidating the contributions that this study brings to the field. It will commence by addressing the sub-research questions, culminating in the response to the main research question.

8.1.1. Sub-question 1

To answer sub-question one: *What are the key factors, strategies, uncertainty factors and barriers of a successful implementation of education for sustainable development (ESD) in engineering education?* a research study took place.

Pivotal revelations emerged from the research conducted by Weiss et al. (2021), which entailed a comprehensive comparative analysis of 131 case studies focusing on HEIs striving to incorporate ESD into their educational agendas. They identified six implementation patterns: 1) Collaborative paradigm change pattern 2) Bottom-up, evolving institutional change pattern 3) Top-down, mandated institutional change pattern 4) Externally driven initiatives pattern 5) Isolated initiatives pattern 6) Limited institutional change pattern. While specific patterns appear to facilitate more thorough and sustainable implementation, achieving full integration involves a combination of bottom-up and top-down approaches. At the curriculum change level, three conventional teaching incorporation approaches are recognized: vertical (add-on),

horizontal (integration), and redesign (rebuild). These strategies entail different approaches for altering curricula and behavior. Engineering schools predominantly employ the add-on and integration strategies due to the challenges associated with overhauling their curriculum entirely. According to Kolmos et al. (2016), institutions may employ all three strategies at different stages or within various departments of the change process. However, there is a growing advocacy for systemic change, requiring institutions to develop comprehensive curriculum responses that encompass incorporation of new subjects, adoption of new values, and, at the most intricate stage, alteration of the epistemological foundation and fundamental identity of H(E)EIs. Moreover, the use of frameworks appeared to play a pivotal role in ESD implementation at HEIs, providing a structured approach to curriculum development. However, the effectiveness of these frameworks hinges on their alignment with institutional priorities and contextual nuances. Institutions are encouraged to adopt existing frameworks and customize them to suit their unique systems, needs, and values, frequently promoting a systemic approach to ESD implementation (Wiek et al., 2011).

Weiss et al. (2021) identified a wide range of drivers and barriers involving internal and external stakeholders with diverse motivations for all six implementation patterns. These perspectives reflect varied attitudes toward sustainability, change, and ESD assumptions, alongside the utilization of different organizational tools. Moreover, these factors are influenced by institutional and educational cultures. Variables were categorized per implementation pattern, with descriptions of possible *drivers* and *barriers*, and further classified as medium, other, or not described, highlighting the need for an additional term: *uncertainty factor*. In this thesis, uncertainty factors denote unpredictable variables that cannot be definitively classified as drivers or barriers but are highly context-dependent.

Among the drivers, establishing a consistent vision statement and engaging all stakeholders actively fosters ownership and long-term impact. Collaboration among various ESD initiatives and stakeholders facilitates knowledge and resource exchange. Effective informal communication can offset the lack of formal leadership support. Meticulous planning, detailed strategy formulation, and equitable distribution of responsibilities aid in comprehensive ESD implementation. Recognizing the contributions of individual change agents within H(E)EIs is crucial. Moreover, involving more stakeholders aligns with the overarching vision for change and enhances favorable outcomes, emphasizing the importance of a systemic approach.

Conversely, barriers to ESD implementation include the absence of a strategic plan, lack of faculty support, and weak leadership. Factors such as lack of awareness, institutional structure, and insufficient resources also pose significant challenges. Overcoming these barriers requires constant consideration of human factors and cultural context within institutions. The interplay between variables can lead to fluctuations in the integration process, impacting motivation and sustainability efforts. While initial commitments may secure funding and foster synergy, resource depletion and shifting priorities can hinder progress. The fluidity and context-specific nature of these variables highlight the need for nuanced approaches to ESD implementation. Understanding these drivers, barriers, and uncertainty factors can inform the development of ESD action plans and frameworks tailored to specific institutional contexts. Recognizing the interconnectedness and dynamics of these factors underscores the importance of contextual considerations and cultural observations in implementing sustainable development initiatives.

8.1.2. Sub-question 2

Similarly to sub-question one, sub-question two: *"What are the key factors, strategies, uncertainty factors and barriers of systems change in engineering education?"* was answered by performing a literature study.

Weiss et al. (2021) highlighted the challenges in sustaining change across different implementation patterns, emphasizing collaborative endeavors and contextual understanding within HEIs. Similarly, Kolmos et al. (2016) delineate various methods for curriculum and behavioral alterations, emphasizing the indispensability of systemic approaches for enduring changes. Scholars like Fullan (2007b) advocate for a systemic perspective, emphasizing that educational change extends beyond altering student learning to enhancing organizational capabilities and needs continuous reflection and engagement. Holst (2023) proposes Whole Institution Approaches (WIAs), emphasizing principles like consistency, ongoing learning, and involvement, along with various domains of activity and the importance of organizational culture. WIAs underscore the interconnectedness of education with other areas of activity.

Efforts to drive systemic change may adopt various approaches, such as top-down, bottom-up, or a combination of both. Regardless of the strategy chosen, it's crucial for change initiators to actively involve others early in the process, ensuring meaningful engagement to maximize results. Reinholz and Apkarian

(2018) highlight how existing hierarchies in academia can marginalize certain groups, but assert that change agents can strategically disrupt these hierarchies to promote equity. The process of change begins with crafting a shared vision for the department's future, identifying necessary structural adjustments, and recognizing attitudes that may influence the adoption of changes. Change efforts are increasingly being conducted by teams rather than individuals, as seen in TU Delft's establishment of its sustainability core team in 2019. Change leadership must address both individual and organizational levels, focusing on curriculum and cultural aspects alike. By understanding (cultural) dynamics, change agents can inform the direction of systemic change efforts effectively.

Chapter 4 outlines key drivers for systemic change in H(E)EIs, drawing from insights provided by the Royal Academy of Engineering and other scholarly works (Graham, 2012). Overall, the drivers for systemic change are categorized into five themes: context and culture, direction of change, preparation and planning, design and implementation, and maintaining momentum and sustaining change. As an illustration, preparatory work, planning, and effective leadership support are highlighted as vital components for sustainable change. Leadership endorsement, particularly from department heads and senior management, is crucial in energizing faculty participation and maintaining confidence throughout the process. Likewise, drivers for sustaining momentum involve ongoing dialogue, monitoring impact data, and engaging new faculty to ensure education remains a priority post-implementation. Pedagogical training and fostering effective team dynamics are emphasized as essential for maintaining momentum and enhancing the efficacy of change efforts. Understanding institutional culture and national support, along with balancing teaching and research priorities, are identified as crucial factors for driving and sustaining educational changes. Additionally, recognizing the need for a profound cultural shift, Loorbach et al. (2017) proposes a 'designing transition logic' involving six key elements to facilitate sustainable ESD implementation. These elements encompass urgency in transitioning away from fossil fuel dependence, commitment to a nature-positive and inclusive future, embracing existing transition practices, adopting a transition-oriented framework, employing a design-centered approach, and utilizing a cultural strategy involving broader public engagement.

Barriers may include institutional resistance, resource shortages, entrenched cultural norms, policy constraints, or other factors that generate opposition or inertia against desired changes. Recognizing and addressing these barriers is essential for overcoming resistance and effectively guiding the process of systemic change towards achieving intended outcomes. One key barrier identified is the absence of universally acknowledged indicators of success and evaluation instruments, which hinders the ability to quantify progress and maintain engagement. Other barriers include resource constraints, time limitations, misalignment with institutional culture, and the absence of reward mechanisms.

Uncertainty factors are variables that cannot be definitively categorized as barriers or drivers, as their influence on the change process is unpredictable. These factors can lead to unforeseen consequences, unexpected developments, and external influences that affect the outcome of change efforts. Managing uncertainty factors is crucial for effective planning and adaptability during system change. Examples of uncertainty factors include the response of the first cohort of students to a new curriculum and the departure of faculty members who initiated the change. If not properly managed, these uncertainties can undermine the sustainability of the change effort.

Overall, recognizing and addressing drivers, barriers and uncertainty factors are essential for successfully navigating the complexities of systemic change in H(E)EIs. These factors highlight the need for comprehensive planning, adaptability, and alignment with institutional culture to ensure the sustainability of change efforts.

8.1.3. Sub-question 3

In chapter 5, sub-question three: *How are systemic change approaches used at applied sciences higher engineering education institutions to implement ESD?* was used as a bridge between the literature study and the main focus of this research, the AS Faculty of TU Delft. Two case-studies were performed on the NHL Stenden and Van Hall Larenstein (HVHL) universities of applied sciences, based in the Netherlands.

The analysis, comprising desk research and two interviews during interview round one (R1), provided an in-depth examination of the systemic approach employed by NHL Stenden and HVHL in implementing ESD. At NHL Stenden, the primary impetus for change stemmed from the merger of two institutions, NHL and Stenden, resulting in a shift in executive leadership. The systemic approach adopted was bolstered by several factors, including the availability of resources, collaborative efforts across all organizational

levels, a well-defined vision articulated by an intrinsically motivated executive board, and flexibility in interpreting educational objectives. Additionally, key drivers of change included the proactive engagement of intrinsically motivated early adopters, transparency in decision-making processes, and simultaneous initiatives targeting education, research, community engagement, and operational practices.

However, the implementation process encountered barriers, such as the ambiguity surrounding the definition of sustainability, the proliferation of (new) learning objectives, excessive top-down pressure, and stagnating student enrollment figures. Moreover, uncertainty factors emerged during the change process, including program misalignment, challenges in gathering and incorporating student feedback, a pervasive sense of constant change, and difficulties in comprehending and applying new frameworks and tools. These factors underscore the complexity and multifaceted nature of systemic change endeavors within educational institutions.

The HVHL study showed likewise the criticality of a motivated executive board and of bottom-up change agents. Similarly to NHL Stenden, HVHL emphasized how synchronization among various institutional facets such as education, research, and community initiatives is deemed crucial, as stagnation in one area can impede momentum for change in others. Achieving a cultural shift requires collective transformation across all aspects of the institution. Furthermore, the HVHL study added the barrier of external funding that does not align with the institutions vision, and the driver of experienced change leaders and institutional profiling. Both case studies emphasized the creation of robust visions for ESD implementation with long-term objectives, emphasizing collaboration and a commitment to global impact. Both mentioned how the pressure of external assessments, such as SHE and the SustainaBul, was seen as effective to create accountability within an institution. Both educational policy plans align with the principles of preparation and planning outlined by Graham (2012), providing guidance while allowing for individual interpretation.

Additionally, Chapter 5 touched upon a first comparison to the AS Faculty of TU Delft. First of all, the direct influence of external assessments' pressure on sustainability-related performances of the AS Faculty of TU Delft was questioned, given their university-wide nature. Secondly, it was observed how organizational differences between Universities of Applied Sciences and universities impact goal-setting processes. While the former allows for swifter top-down implementation, the latter engages more regularly in in-depth discussions, resulting in a slower decision-making process. At TU Delft, constant collaboration between various stakeholders and a blend of top-down and bottom-up approaches characterize educational management. Moreover, it was observed during the case-studies that student involvement in driving change is significant but may be limited by hierarchical structures, particularly in universities of applied sciences.

Despite differences, both types of institutions share the common challenge of aligning strategies with societal needs amidst enrollment-driven financial dynamics. Both types of institutions face pressure to compete for enrollment figures, fostering a cautious approach and a tendency towards uniformity in curriculum. While barriers, drivers, and uncertainty factors align with existing literature, the role of students and top-down pressure in ESD implementation warranted further exploration in chapter 6.

8.1.4. Sub-question 4

The next five interviews of R1 tried to answer sub-question 4: *What is the current situation of ESD implementation at the Applied Sciences Faculty of TU Delft?*

Firstly, the status quo of ESD implementation and its history at the AS Faculty of TU Delft were explored. The sustainability implementation at the AS Faculty of TU Delft involves a dynamic interplay of top-down and bottom-up initiatives. In terms of top-down efforts, a mandatory sustainability-focused course for applied physics students faced discontinuation due to student dissatisfaction, indicating challenges in aligning curricular changes with student preferences. Additionally, recent transformations in the Chemical Engineering Master program were initiated as the result of a shift in program director, showcasing how changes in (top) management can create opportune moments for reform. However, the effectiveness of top-down decisions is contingent upon collaborative working groups involving faculty members and researchers. The Chemical Engineering master program changes, despite being initiated top-down, required close collaboration between management, teaching staff, researchers and students. Collaboration between top-down and bottom-up approaches appears to be pivotal.

Bottom-up initiatives, exemplified by the GreenTeamAS initiative and individual educators integrating sustainability into courses autonomously, aim to instigate change from the grassroots level. The Green-

Thread pilot project, part of the GreenTeamAS initiative, faced challenges such as student constraints and subsequent reversion of course changes, highlighting the complexities associated with sustained impact. Additionally, individual educators contribute to sustainability integration but encounter discontinuity when instructors depart. Ongoing discussions about a potential Task force and the leadership role of the Local Sustainability Coordinators (LSC) in overseeing the GreenTeam initiative exemplify efforts to consolidate collective impact through collaborative initiatives.

The interviews underscored the challenges inherent in ESD implementation, including resource constraints, student and employee constraints, and the need for ongoing collaboration and feedback loops. The evolving interconnection between education and research emphasizes a gradual shift toward sustainability-focused subjects influenced by external factors like government subsidies. The intricate dynamics between top-down directives, bottom-up initiatives, and collaborative efforts are crucial considerations in navigating the path towards ESD implementation at the AS Faculty.

Subsequently, the drivers, barriers and uncertainty factors of ESD implementation were explored. Twelve influential variables were identified, including Implementation Level, Integration Approach, Resources, Communication, Internal Collaborative Culture, Faculty Support, Student Support, Involvement of Internal AS Stakeholders, Perception of Sustainable Development-Faculty, Synergies between Different Areas, Internal Culture AS, and Perception of Own Influence. A comprehensive compilation of these variables was created, resulting in the identification of 30 barriers, 33 drivers, and 28 uncertainty factors. R2 further probed and deliberated on these themes, ensuring a thorough overview and reducing the number of variables.

Several prerequisites for initiating ESD implementation were identified, including increased resources, enhanced collaboration, the development of a long-term strategic plan, and the articulation of a clear vision. The internal culture of the AS Faculty emerged as a significant influence in the implementation process. The desire for a direct impact quantification of changes, ongoing discussions about the definition of sustainable development, and the consensus on the necessity of a behavioral shift among stakeholders were noteworthy findings. Additionally, there was a recurring discourse on integrating operational, educational, and research-based transformations to facilitate behavioral adaptations. It appears that with the assignment of the Climate Action Team, the faculty has made the initial steps needed for a systemic change. However, the exact approach the faculty and the Climate Action Team would like to take is still unclear. A suggestion is given in the next two sections.

8.1.5. Sub-question 5

The results of the analysis of R1 and the variable reduction and validation in round two (R2) were then used to answer sub-question 5: *Which strategies can be used to implement ESD in a systemic manner at the AS Faculty of TU Delft?* by performing a SWOT analysis in the format of a focus group in round three (R3). The SWOT results were then synthesized with the literature research findings from Chapter 4 on systems change drivers, to eventually create five critical strategies that can be recommended to the Climate Action Team of the AS Faculty of TU Delft (Figure 7.1). These findings may also be useful references for other (applied sciences) engineering education institutions. Five critical strategies (ST) for systemic ESD implementation at the AS Faculty of TU Delft were identified: ST1 - Direction of change, ST2 - Context and Culture, ST3 - Planning and Preparation, ST4 - Design and Implementation, and ST5 - Maintaining Momentum and Sustaining the Change. The influence of intrinsic motivation and the acknowledgement of cultural characteristics is highlighted through all of the strategies.

ST1 - *Direction of change* focuses on the implementation of change within the faculty, which necessitates engagement across all organizational levels, with continuous reaffirmation of support from top management. More specifically the change should take form of a task force, additional to the Climate Action Team, that meets routinely, enables participants from various levels to be somewhat equally regarded and with public support of top-management.

ST2 - *Context and Culture* aims to establish a cohesive, concerted effort to make sustainability an inherent aspect of the faculty's ethos, practices, and educational offerings. The AS faculty, characterized by individualism, competition, a technology-fix mindset, rationality and a focus on fundamental sciences, requires a strategic approach for sustainable development implementation. Open discussions, inclusivity, and public support are vital to address diverse opinions on the meaning of sustainable development and climate change and to avoid polarization from happening. Furthermore, balancing teaching and

research obligations, ensuring transparency, and fostering a system-wide transition led by the Climate Action Team are key recommendations. Additionally, leveraging faculty consensus, allocating resources for communication, and aligning departmental culture with sustainability goals are essential for impactful changes.

ST3 - *Planning and Preparation* explains how the establishment of a dedicated management team, exemplified by the Climate Action Team, was and is crucial. Formal time allocation, recurring impact evaluations, and pedagogical training for the team and the proposed task force are essential. Regarding Faculty support, shared teaching responsibilities and collaboration with external perspectives and other university entities enhance the transformation. Additionally, collaborative efforts with other faculties (specifically their LSCs) and continuous engagement with this research's identified variables during planning and preparation are recommended. Activities like evidence collection, collaboration, and transparency in decision-making reinforce the commitment to the transformative endeavor.

ST4 - *Design and Implementation* mentions the importance of active involvement of faculty members in curriculum design, as a faculty-wide initiative. The Climate Action Team can engage change agents and opponents to structure the educational strategy. Revisiting fundamental degree program objectives ensures seamless integration of modifications. To accommodate reluctant faculty, there's a deliberate choice not to pressure substantial changes in preferred teaching methods, allowing a portion of the curriculum to remain unchanged. Acknowledging the need for time and space, the proposal to avoid universal mandates for new learning objectives, but for new objectives to be shared, fosters collaboration and minimizes content overlap, reinforcing the systemic perspective of ESD.

ST5 - *Maintaining Momentum and Sustaining the Change* emphasizes how continuous dialogue between faculty and change agents catalyzes sustained progress. Systematic impact evaluations, coupled with monitoring impact data, enable ongoing assessment and improvements. Long-term evaluations are vital for gauging the reform's lasting effects on faculty motivation, communication, and student enrollment. Active faculty participation in continual educational enhancement fosters an environment of ongoing improvements. Consistent communication emphasizes the importance of reformation, evidence gathering, and potential impact visualization. Reflective practices for educators and academic leaders encourage continuous learning in the reform process. Engaging new faculty is crucial for maintaining momentum. Lastly, prioritizing education post-implementation is essential for enduring transformation success.

ST1, ST2, and ST3 play crucial roles in the initial stages of the action plan, succeeded by the execution of ST4. Ultimately, special attention should be directed towards ST5. As the climate action plan advances, it's important to continuously review all five strategies. Additionally, it is recommended that the identified drivers, barriers, uncertainty factors and SWOTs are revisited.

8.1.6. Main research question

The main research question this thesis investigated is: *How can the Applied Sciences Faculty at TU Delft adopt a systemic change approach to incorporate education for sustainable development throughout its entire academic program?* To answer this question, the study first performed a literature study on ESD implementation and systemic change at HEEIs. The findings highlighted specific strategies, barriers, drivers and uncertainty factors, specifically emphasizing the importance of context and culture. The literature research on ESD implementation in engineering education helped understand the system, while the literature research on systems change helped build strategies for a cultural, institutional change.

After the literature study, two case-studies were performed to bridge the literature to the AS Faculty of TU Delft, and show real-life cases and their obstacles/successes. Subsequently, the AS Faculty of TU Delft was explored, by organising interviews with a multitude of stakeholders relevant to ESD implementation (management to student). It was found that the AS Faculty has had experiences with (collaborative) top-down and bottom-up initiatives, such as the changes in the Master program in Chemical Engineering and the Green Thread initiative. Furthermore, after instruction from the university's core-team of sustainability the faculty appointed a Climate Action Team, consisting of two local sustainability coordinators. This team is currently creating a Climate Action plan including an education portfolio, which can benefit from the research performed in this study.

During R1 and R2, twelve influential thematic variables and their barriers, drivers and uncertainty factors were found: Implementation Level, Integration Approach, Resources, Communication, Internal Collaborative Culture, Faculty Support, Student Support, Involvement of Internal AS Stakeholders, Perception of

Sustainable Development-Faculty, Synergies between Different Areas, Internal Culture AS, and Perception of Own Influence. The found variables were further explored during a focus group SWOT analysis, which delved into internal and external influences. The final SWOT outcomes were then synthesized with the drivers of systemic change found in literature, to eventually come up with five strategies (ST1 to ST5) that can help structure the education portfolio of the Climate Action Plan, and so the systemic change approach of the faculty to incorporate ESD throughout its entire academic plan.

ST1, ST2, and ST3 are pivotal in the early phases of the creation of the Climate Action Plan of the AS Faculty, followed by the implementation of ST4. Priority should be given to ST5 in the long run. As the climate action plan progresses, it's essential to regularly assess all five strategies. Furthermore, it's advisable to revisit the identified drivers, barriers, uncertainty factors, and SWOT analysis periodically, especially when obstacles form.

ST1, focusing on the *Direction of change*, underscores the importance of engaging all organizational levels and securing ongoing support from top management. It suggests the formation of a task force alongside the Climate Action Team to ensure diverse participation and public backing from higher-ups. ST2, centered on *Context and Culture*, aims to integrate sustainability into the faculty's ethos and practices, addressing the individualistic, competitive, and technology-oriented culture of the AS faculty. Open discussions, inclusivity, and transparency are highlighted as crucial for navigating diverse opinions on sustainability and climate change. ST3, relating to *Planning and Preparation*, emphasizes the establishment of a dedicated management team, time allocation for impact evaluations, and pedagogical training. Collaboration with external perspectives, other faculties, and continuous engagement with identified variables are recommended. ST4, regarding *Design and Implementation*, stresses active faculty involvement in curriculum design, accommodating varying teaching methods, and revisiting program objectives for seamless integration of changes. It proposes a collaborative approach to minimize resistance and content overlap. ST5, focusing on *Maintaining Momentum and Sustaining the Change*, highlights the importance of continuous dialogue, systematic impact evaluations, and ongoing faculty participation in educational enhancement. It underscores the need for consistent communication, reflective practices, and engaging new faculty post-implementation.

The five strategies are meticulously organized, taking into consideration the identified strengths, weaknesses, opportunities, threats, their interconnections, and the drivers associated with systemic change approaches. The delineation of interconnections underscores the intricate nature of the transition, emphasizing the necessity of systems dynamic thinking in effecting changes. Moreover, the abundance of opportunities identified during the SWOT analysis underscores the fervor and inherent drive observed in the change agents who were interviewed and participated in the focus group. Within the context of the focus group discussions, there was a sense of momentum at TU Delft, gradually permeating individual faculties, contingent upon the acknowledgment and comprehension of the sentiments of the change-initiating stakeholders.

The study highlights the pivotal role of the Climate Action Team and the creation of a task force, advocating for allocated resources and continuous endorsement from the faculty's top management. Team-based initiatives, particularly those involving change agents among students and staff, are identified as advantageous for facilitating the transition. Moreover, the study underscores the intricate nature of ESD implementation, underscoring the necessity for support at all organizational levels. The recognition and exploration of cultural aspects within the institution emerge as critical factors. The faculty's distinctive individualistic, rational, competitive character, coupled with a keen interest in fundamental sciences and a Technology-Fix mindset, necessitates ongoing discussions on the societal impact of AS stakeholders and a nuanced understanding of sustainability and climate change. The fundamental understanding of one's impact and the necessity of continuous impact quantification (and communication), are identified as a potential catalyst for cultural transformation, emphasizing the importance of open discussions and transparent communication to mitigate resistance. Furthermore, providing employees with the autonomy to interpret new objectives and share insights across different courses in the curricula further contributes to a conducive environment.

This study has shown that ESD implementation at the AS faculty of TU Delft can benefit from systemic change strategies. In essence, this research serves as a modest catalyst for fostering discussions within the faculty, advocating for larger-scale conversations akin to those conducted during the focus group as a potential means to benefit the entire AS community.

References

About nhl stenden [Retrieved October 3, 2023]. (n.d.). https://www.nhlstenden.com/en/about-nhl-stenden

Anderson, C., & Cooper, C. (2022). *The engineering for one planet framework: Essential sustainability-focused learning outcomes for engineering education*. The Lemelson Foundation, Oregon, USA.

Bakker, R., & Sinia, C. (2019). Strategic education policy 2019-2024. *NHL Stenden Hogeschool*.

Benzaghta, M. A., Elwalda, A., Mousa, M. M., Erkan, I., & Rahman, M. (2021). Swot analysis applications: An integrative literature review. *Journal of Global Business Insights*, *6*(1), 55–73. https://www.doi.org/10.5038/2640-6489.6.1.1148

Bianchi, G., Pisiotis, U., & Cabrera Giraldez, M. ((2022). *GreenComp The European sustainability competence framework.* (tech. rep.). https://doi.org/10.2760/13286

Blanco-Portela, N., Benayas, J., Pertierra, L. R., & Lozano, R. (2017). Towards the integration of sustainability in Higher Eeducation Institutions: A review of drivers of and barriers to organisational change and their comparison against those found of companies. *166*, 563–578. https://doi.org/10.1016/j.jclepro.2017.07.252

Brundiers, K., Barth, M., Cebrián, G., Cohen, M., Diaz, L., Doucette-Remington, S., Dripps, W., Habron, G., Harré, N., Jarchow, M., Losch, K., Michel, J., Mochizuki, Y., Rieckmann, M., Parnell, R., Walker, P., & Zint, M. (2021). Key competencies in sustainability in higher education—toward an agreed-upon reference framework. *Sustainability Science*, *16*(1), 13–29. https://doi.org/https://doi.org/10.1007/s11625-020-00838-2

Calvin, K., Dasgupta, D., Krinner, G., Mukherji, A., Thorne, P. W., Trisos, C., Romero, J., Aldunce, P., Barrett, K., Blanco, G., Cheung, W. W., Connors, S., Denton, F., Diongue-Niang, A., Dodman, D., Garschagen, M., Geden, O., Hayward, B., Jones, C., … Ha, M. (2023, July). *IPCC, 2023: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland.* (P. Arias, M. Bustamante, I. Elgizouli, G. Flato, M. Howden, C. Méndez-Vallejo, J. J. Pereira, R. Pichs-Madruga, S. K. Rose, Y. Saheb, R. Sánchez Rodríguez, D. Ürge-Vorsatz, C. Xiao, N. Yassaa, J. Romero, J. Kim, E. F. Haites, Y. Jung, R. Stavins, … C. Péan, Eds.; tech. rep.). Intergovernmental Panel on Climate Change. https://doi.org/10.59327/IPCC/AR6-9789291691647

De Haan, G. (2006). The BLK ‘21’ programme in Germany: a ‘Gestaltungskompetenz’-based model for Education for Sustainable Development. *Environmental Education Research*, *12*(1), 19–32. https://doi.org/http://dx.doi.org/10.1080/13504620500526362

Dit is hvhl [Retrieved October 12, 2023]. (n.d.). https://www.hvhl.nl/over+ons

Executive and management regulations [Retrieved January 9, 2024]. (n.d.). https://www.tudelft.nl/en/about-tu-delft/organisation/regulations/executive-and-management-regulations

Fisher, P. D., Fairweather, J. S., & Amey, M. (2003). Systemic reform in undergraduate engineering education: The role of collective responsibility. *International Journal of Engineering Education*, *19*(6), 768–776. https://doi.org/http://dx.doi.org/10.1109/FIE.2001.963829

Fullan, M. (2007a). *Leading in a culture of change* (Vol. Revised edition). San Francisco: Jossey-Bass.

Fullan, M. (2007b). *The new meaning of educational change* (Vol. 4th ed.). New York: Teachers College Press.

Graham, R. (2012). Achieving excellence in engineering education: The ingredients of successful change. *The Royal Academy of Engineering*.

The green thread [Retrieved October 25, 2023]. (n.d.). https://www.tudelft.nl/greentu/projecten/the-green-thread

Greendatabase [Retrieved October 25, 2023]. (n.d.). https://www.tudelft.nl/en/greentu/greendatabase?category=DB+Courses

Growing as experts in transition, institutional plan 2022-2025. (n.d.) (Retrieved October 15, 2023). Van Hall Larenstein, university of Applied Sciences.

Helms, M. M., & Nixon, J. (2010). Exploring swot analysis – where are we now? a review of academic research from the last decade. *Journal of Strategy and Management*, *3*(3), 215–251. https://doi.org/10.1108/17554251011064837

Hogeschool van hall larenstein opnieuw 'duurzaamste hoger onderwijsinstelling van nederland' [Retrieved October 12, 2023]. (n.d.). https://www.hvhl.nl/nieuws/items/2023/hogeschool-van-hall-larenstein-opnieuw-duurzaamste-hoger-onderwijsinstelling-van-nederland.html

Holst, J. (2023). Towards coherence on sustainability in education: a systematic review of Whole Institution Approaches. *18*(2), 1015–1030. https://doi.org/10.1007/s11625-022-01226-8

IPCC, S., Geneva. (2023). Ipcc, 2023: Sections. *In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]*., 35–115. 10.59327/IPCC/AR6-9789291691647

Kamp, L. (2006). Engineering education in sustainable development at Delft University of Technology. *Journal of Cleaner Production*, *14*(9-11), 928–931. https://doi.org/10.1016/j.jclepro.2005.11.036

Knutti, R. (2019). Closing the Knowledge-Action Gap in Climate Change. *1*(1), 21–23. https://doi.org/10.1016/j.oneear.2019.09.001

Kolmos, A., Hadgraft, R. G., & Holgaard, J. E. (2016). Response strategies for curriculum change in engineering. *International Journal of Technology and Design Education*, *26*(3), 391–411. https://doi.org/10.1007/S10798-015-9319-Y

Leerdam, M., & van Gulik, S. (2020). Beoordelingskader duurzame ontwikkeling in het hoger onderwijs she 2021 - (sustainability higher education) versie 1.0. *Hobeon*.

Leydens, J., & Lucena, J. (2017). Engineering justice: Transforming engineering education and practice.

Loorbach, D., Frantzeskaki, N., & Avelino, F. (2017). Sustainability Transitions Research: Transforming Science and Practice for Societal Change. *Annu. Rev. Environ. Resour.*, *42*, 599–626. https://doi.org/https://doi.org/10.1146/annurev-environ-102014-021340

Marshall, C., & Rossman, G. B. (2016). *Designing qualitative research*. SAGE Publications, Inc.

Olga, K., Svetlana, B., & Julia, K. The main trends in the development of engineering education: The role of the university teacher in systemic changes (M. E. Auer & T. Tsiatsos, Eds.). In: *Auer, m., tsiatsos, t. (eds) the challenges of the digital transformation in education. icl 2018. advances in intelligent systems and computing* (M. E. Auer & T. Tsiatsos, Eds.). Ed. by Auer, M. E., & Tsiatsos, T. *916*. Switzerland: Springer, Cham, 2020. https://doi.org/10.1007/978-3-030-11932-4_47

Olmstead, A., Beach, A., & Henderson, C. (2019). Supporting improvements to undergraduate STEM instruction: an emerging model for understanding instructional change teams. *International Journal of STEM Education*, *6*(1). https://doi.org/10.1186/s40594-019-0173-4

Radinger-Peer, V., Pflitsch, G., Kanning, H., & Schiller, D. (2021). Establishing the regional sustainable developmental role of universities—from the multilevel-perspective (Mlp) and beyond. *Sustainability (Switzerland)*, *13*(13). https://doi.org/10.3390/su13136987

Reinholz, D. L., & Apkarian, N. (2018). Four frames for systemic change in STEM departments. *5*(1). https://doi.org/10.1186/s40594-018-0103-x

Sammalisto, K., Sundström, A., & Holm, T. (2015). Implementation of sustainability in universities as perceived by faculty and staff - A model from a Swedish university. *Journal of Cleaner Production*, *106*, 45–54. https://doi.org/10.1016/j.jclepro.2014.10.015

Scharwächter, V. (2023, 10 July). *Swot-analyse in je scriptie | betekenis, voorbeeld & invulschema.* [Retrieved December 8, 2023]. https://www.scribbr.nl/modellen/swot-analyse/

Shell. (n.d.). *Capital markets day 2023 media release. shell media.* [Retrieved September 20, 2023]. https://www.shell.com/media/news-and-media-releases/2023/capital-markets-day-2023-media-release.html?mc_cid=2d7db80a0c%5C&mc_eid=35883950e5

Stoel, O., & Smulders, J. (2021). *Facts & figures tu delft at a glance*. TU Delft, Department Communication.

Sustainabul [Retrieved October 25, 2023]. (n.d.). https://sustainabul.com/

Thyer, B. (2009). The handbook of social work research methods. SAGE Publications, Inc.

Trencher, G., Vincent, S., Bahr, K., Kudo, S., Markham, K., & Yamanaka, Y. (2018). Evaluating core competencies development in sustainability and environmental master's programs: An empirical analysis. *Journal of Cleaner Production*, *181*, 829–841. https://doi.org/10.1016/J.JCLEPRO.2018.01.164

TU Delft. (n.d.-a). *Education for sustainability* [Retrieved May 20, 2023]. https://www.tudelft.nl/en/sustainability/education

TU Delft: Towards a new engagement, a. s. v. f. D. U. o. T. (1994). University board of delft university of technology. naar een nieuw engagement, een strategische visie voor de tu delft.

TUDelft. (n.d.-b). *Career prospects. tu delft.* [Retrieved September 20, 2023]. https://www.tudelft.nl/onderwijs/opleidingen/masters/cheme/msc-chemical-engineering/career-prospects

TUDelft. (n.d.-c). *Career prospects. tu delft.* [Retrieved September 20, 2023]. https://www.tudelft.nl/onderwijs/opleidingen/masters/applied-physics/msc-applied-physics/career-prospects

TUDelft. (n.d.-d). *Career prospects. tu delft.* [Retrieved September 20, 2023]. https://www.tudelft.nl/onderwijs/opleidingen/masters/life-science-technology/msc-life-science-and-technology/career-prospects

Van Den Dobbelsteen, A., & Van Gameren, D. (2022). Sustainable TUDelft: Vision, Ambition and Action Plan for a Climate University. https://d2k0ddhflgrk1i.cloudfront.net/TUDelft/Research%20sites/Sustainability/Sustainable%20TU%20Delft%20-%20Vision%20ambition%20and%20action%20plan%20v5.3_220927.pdf

Van hall larenstein officieel de duurzaamste hogeschool van nederland [Retrieved October 25, 2023]. (2018). https://www.hvhl.nl/nieuws/items/2018/de-duurzaamste-hogeschool.html

Vare, P., Rieckmann, M., & Lausselet, N. (2022). Introduction, 3–10. https://doi.org/10.1007/978-3-030-91055-6

Verhulst, E., & Lambrechts, W. (2014). Fostering the incorporation of sustainable development in higher education. Lessons learned from a change management perspective. *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2014.09.049

Weiss, M., Barth, M., & von Wehrden, H. (2021). The patterns of curriculum change processes that embed sustainability in higher education institutions. *Sustainability Science*, *16*(5), 1579–1593. https://doi.org/https://doi.org/10.1007/s11625-021-00984-1

Wiek, A., & Lang, D. (2016). Transformational sustainability research methodology. https://doi.org/https://doi.org/10.1007/978-94-017-7242-6_3

Wiek, A., Withycombe, L., & Redman, C. L. (2011). Key competencies in sustainability: A reference framework for academic program development. *Sustainability Science*, *6*(2), 203–218. https://doi.org/10.1007/S11625-011-0132-6

Yuan, H. (2013). A swot analysis of successful construction waste management. *Journal of Cleaner Production*, *39*, 1–8.

A

Interview guide R1 and R2

Method: Qualitative, semi-structured interview

A.1. Interviewees

The individuals being interviewed work for the TU Delft, the NHL Stenden university of applied sciences or the Van Hall Larenstein university of applied sciences, all based in the Netherlands. They each engage with the concept of ESD implementation (and systems change) at applied sciences institutions from a different perspective. An overview of interviewees can be found in Figures A.1, A.2 and A.3.

A.2. Introduction

Welcome,

My name is Puck and I am currently writing my graduate thesis of the MSc Industrial Ecology, joint degree between TU Delft and Leiden University. The aim of my research is to establish a conceptual guideline that can help Applied Sciences Faculties to implement Education for Sustainable Development in a Systemic way. During this research I am conducting multiple rounds of interviews with experts to get a better view of what has already been done, what is currently in process and what could be established.

Please respond naturally and candidly; I value all forms of responses. This interview follows a semi-structured format, allowing ample space for you to articulate your thoughts openly without judgment. Your responses will be handled with sensitivity and maintained anonymously and confidentially. If you ever feel uneasy or wish to halt the interview for any reason, please feel free to express it openly. You're welcome to interrupt the interview at any point.

Would it be acceptable for me to record this interview? If you agree, I will begin recording now.

A.3. Interview scripts

Hereafter, the interview protocols for all three interview phases are delineated. As the interviews followed a semi-structured methodology, the questions served as a framework rather than an exhaustive set of directives. The Dutch participants were interviewed in Dutch. The interviews with non-Dutch-speaking participants were held in English.

A.3.1. TU Delft interviewees - Round 1

Introduction:

- Personal introduction.
- Introduction to the research.
- Introduce the goals of the interviews.

Introduction interviewee:

- Which initiatives have been implemented through the years to include more sustainability and climate change frameworks at AS?
- Which initiatives have been started, but not been implemented?
- During your work at the AS faculty, have you been involved in any process of including sustainability and climate topics into the educational programs?
- What kind of impact do you think AS graduates have on the world, and do you think the faculty has any influence on their graduates' impact?

Barriers, drivers and uncertainty questions:

- What are current barriers for the implementation of ESD?
- What are current drivers for the implementation of ESD?
- What are current uncertainty factors for the implementation of ESD?
- Are there any AS specific cultural characteristics that can be seen as a barrier, driver or uncertainty factor?
- What is the role of [SPECIFIC ROLE OF INTERVIEWEE] during the implementation of ESD?

Closing:

- Is there anyone else you'd recommend that I speak to about designing and implementing sustainability education in the AS program?
- Thank interviewee for their time and insights.
- Remind them of their consent rights.
- Remind them they can contact researcher with remaining questions or remarks.

The questions on Symbols, Power and Structures were posed depending on the depth of the answers to the questions on barriers, drivers and uncertainty questions.

Symbols

- How does sustainable development and climate crisis data currently inform decision-making?
- What is the current mindset towards ESD implementation; What are shared assumptions and values?
- Do you see a difference in how the AS faculty approaches ESD topics in comparison to other engineering education?

Power

- Is there support for change?
- Who are the change agents during the implementation of a new educational policy plan?
- How is progress communicated and are coalitions built?

Structures

- What are currently the key structures that influence the implementation of ESD into the educational programs?
- Do these align with the TU Delft wide goal to include ESD into all educational programs?
- What incentives and supports are in place to facilitate this alignment?

A.3.2. NHL Stenden interview - round 1

Introduction:

- Personal introduction.
- Introduction to the research.
- Introduce the goals of the interviews.

Introduction interviewee and NHL Stenden:

- During your work at NHL Stenden, how have you been involved in ESD implementation processes?

- What does Education for Sustainable Development mean for NHL Stenden?
- What kind of impact do you think AS graduates have on the world?
- Do you think the type of education AS students get, can influence their impact?

Framework created by NHL Stenden, barriers, drivers and uncertainty factors: Additional question to the interviewee: would it be possible to answer the next eight questions with a focus on education?

- Can you tell me more about the creation of NHL Stenden's Design Based Education Framework?
- Can you tell me more on who the change agents are and were during the creation and implementation of DBE?
- What/who are and were barriers for the implementation of DBE?
- What/who are and were drivers for the implementation of DBE?
- What/who are and were uncertainty factors for the implementation of DBE?
- Can you tell me more on the current progress of DBE implementation?
- What are the next steps for future (strategic) education policies?
- Can you tell me more about the Key Performance indicators of the educational policy plan?

Applied Sciences:

- Are there any AS specific cultural characteristics that can be seen as a barrier, driver or uncertainty factor?
- Do you see a difference between a university college such as NHL Stenden and a university such as TU Delft when it comes down to ESD implementation?
- What would be your advice for an applied sciences faculty such as at the TU Delft in their goal to implement ESD throughout?

Closing:

- Thank interviewee for their time and insights .
- Remind them of their consent rights.
- Remind them they can contact researcher with remaining questions or remarks.

A.3.3. HVHL interview - round 1

Introduction:

- Personal introduction.
- Introduction to the research.
- Introduce the goals of the interviews.

Introduction interviewee and HVHL:

- During your work at HVHL, how have you been involved in ESD implementation processes?
- What does Education for Sustainable Development mean for HVHL?
- What kind of impact do you think AS graduates have on the world?
- Do you think the type of education AS students get, can influence their impact?

Framework created by HVHL, barriers, drivers and uncertainty factors:

- Additional question to the interviewee: would it be possible to answer the next eight questions with a focus on education?
- Can you tell me more about the creation of HVHL's educational policy plan?
- Can you tell me more on who the change agents are and were during the creation and implementation HVHL's educational policy plan?
- What/who are and were barriers for the implementation of HVHL's educational policy plan?
- What/who are and were drivers for the implementation of the plan?

- What/who are and were uncertainty factors for the implementation of the plan?
- Can you tell me more on the current progress of HVHL's educational policy plan implementation?
- Can you tell me more about the Key Performance indicators of the educational policy plan?
- What are the next steps for future (strategic) education policies?

Applied Sciences:

- Are there any AS specific cultural characteristics that can be seen as a barrier, driver or uncertainty factor?
- Do you see a difference between a university college such as HVHL and a university such as TU Delft when it comes down to ESD implementation?
- What would be your advice for an applied sciences faculty such as at the TU Delft in their goal to implement ESD throughout?

Closing:

- Thank interviewee for their time and insights .
- Remind them of their consent rights.
- Remind them they can contact researcher with remaining questions or remarks.

A.3.4. Interview structure round 2

From the data from round 1, information was retrieved of the status quo of ESD implementation and influential variables for ESD implementation. During R2, the researcher first mentioned twelve of the most influential variables, explained the context that was given in round one and then asked if the interviewees of R2 saw the specific variable as a barrier, driver or uncertainty factor. Regarding the two interviewees that were interviewed in both round one and two, elements from the first interview were used to ask for validation and go into more depth. The twelve discussed variables are:

- Implementation level
- Integration approach
- Resources
- Communication
- Internal Collaborative Culture
- Faculty Support
- Student support
- Involvement internal stakeholders
- Perception of sustainable development-faculty
- Synergies between different areas
- Internal culture AS
- Perception of Own influence.

During the interview with the internal stakeholder that had experience with both Dutch University Colleges and Universities (Program Director 2), a special focus was on the difference between the two types of institutions. During the interview with Student 2 a special focus was on the variables and bottom-up initiatives.

Interviewee	Job title	Reason of selection	Date of interview
1	Top Management	Top-down, Middle-Management and Bottom-up view on history, status quo, and potential ESD implementation. The interviewee has a lot of experience within the TU Delft and AS system. The main reason is the overview the interviewee has on the AS system.	31-10-2023
2	Faculty Student Council (FSC) Member	Bottom-up view on history, status quo, and potential ESD implementation. The FSC has an overview of all student initiatives while being part of management discussions.	30-10-2023
3	Program Director 1	Top- and Middle-Management view on history, status quo, and potential ESD implementation. Program Director 1 has experience with changing the structure and culture in a program.	06-11-2023
4	Assistant Professor 1	Middle-Management view on history, status quo, and potential ESD implementation. Special focus on GreenTeam functioning and the process of structural program changes.	01-11-2023
5	Assistant Professor 2	Bottom-up and Middle-Management view on history, status quo, and potential ESD implementation. Interviewee started as a student at the faculty, which means they have seen the faculty evolving through the years from different perspectives. Furthermore, has experience with GreenTeam and Innovative Teaching collaborations.	01-11-2023
6	NHL Stenden Education Consultant	Learn from the mistakes and working strategies from another Applied sciences institution in the Netherlands.	08-11-2023
7	HVHL Sustainability Policy worker	Learn from the mistakes and working strategies from another Applied sciences institution in the Netherlands.	02-11-2023

Table A.1: Interviewee Selection Round 1. Interviewees 1-5 are currently working and/or studying at the AS Faculty of TU Delft.

Interviewee	Job function	Reason of selection	Date of interview
1	GreenTU Boardmember (Student 2)	Bottom-up view on the history, status quo, and potential ESD implementation. Focus on the role of students.	24-10-2023
2	Program Director 2	Middle-Management view on history, status quo, and potential ESD implementation. This interviewee has experience at both Universities of Applied Sciences and Universities in the Netherlands. This interview connects the two other case studies to the TU Delft one.	27-11-2023
3	Assistant Professor 1 (Same as R1)	Middle-Management view on history, status quo, and potential ESD implementation. Special focus on GreenTeam functioning and bridging role R2-R3.	14-12-2023
4	Assistant Professor 2 (Same as R1)	Middle-Management view on history, status quo, and potential ESD implementation. The interviewee started as a student at the faculty, which means they have seen the faculty evolving through the years from different perspectives.	21-11-2023

Table A.2: Interviewees Round 2.

Interviewee	Job function	Reason of selection	Date of interview
1	Student 3; Head of Education TG	Bottom-up view on the history, status quo, and potential ESD implementation. Study association and MST student perspective.	15-12-2023
2	Student 4; GreenTeamAS member	Bottom-up view on the history, status quo, and potential ESD implementation. GreenTeamAS and Nanobiology students perspective.	15-12-2023
3	Assistant Professor 3	Middle-Management view on history, status quo, and potential ESD implementation. Special focus on GreenTeam functioning and innovative teaching collaboration at the faculty.	15-12-2023
4	Core team of sustainability	This interviewee focuses on the education portfolio of the Climate Action Road map of TUD. Can be seen as an education for sustainable development expert and has experience with the educational policies and management hierarchies of faculties.	15-12-2023

Table A.3: Interviewees Round 3.

B

R1, R2 and R3 Transcripts

If one would like to know more insights into the coded interview transcripts, one can email sustainability@tudelft.nl for more information.

C

Coding and analysis of R1 and R2

C.1. Coding framework, results and methodology

See attached excel document named Codebook. Additionally an excel document named 'R1 and R2 Results' is added that shows the outcomes of R1 and R2, and methodology behind the selection in R2.

C.2. Co-occurrences R1

Variable Co-Occurrence	Barrier Gr=97	Driver Gr=65	Uncertainty Factor Gr=146	Status quo Gr=74
Level of Implementation				
Implementation level Gr=76	**33**	23	**47**	19
Integration approach Gr=73	**38**	21	**54**	19
Preparation/Institutional environment				
Strategic Plan Gr=28	10	12	16	16
Vision Gr=46	13	24	22	17
Resources Gr=41	18	14	**33**	8
Professional Development Opportunities Gr=23	6	5	16	8
Incentives Gr=20	8	10	11	4
Communication Gr=64	28	18	**40**	26
Coordination Gr=32	19	9	24	17
Organizational Structure Gr=35	18	8	25	19
Educational Environment				
Internal Collaborative Culture Gr=61	27	16	**43**	**30**
Internal stakeholders				
Attitude towards innovative teaching and learning methods -faculty Gr=26	10	9	13	11
Faculty support Gr=112	**46**	**43**	**76**	**39**
Students support Gr=88	**40**	**30**	**60**	**32**
Involvement Internal Stakeholders Gr=77	27	28	**51**	**31**
Perception of curriculum link-faculty Gr=35	16	11	23	6
Perception of sustainable development-faculty Gr=92	25	**33**	**57**	23
External influences				
Window of Opportunity Gr=95	15	**49**	**45**	**30**
External influence_other Gr=30	13	12	24	4
Involvement external stakeholder Gr=36	8	13	25	12
Sustainability Areas				
Sustainability research Gr=43	8	20	26	9
Synergies between different areas Gr=46	16	18	**33**	19
Research specific variables				
Internal culture AS Gr=95	**42**	28	**68**	**38**
Perception of own influence (impact) Gr=66	14	21	**35**	16
Bottom-up Gr=64	29	19	**39**	24
Top Down Gr=66	28	22	**41**	27

Table C.1: Co-occurrence of variables interviews round 1. Gr = Total number of quotations of specific code. All co-occurrences of 30 occasions and more have been expressed in bold.

D

SWOT Analysis

As half of the R3 participants were only available when the focus group was performed online, an online focus group was organised. Miro has easy to use collaborative tools in which participants can brainstorm freely. Before the focus group started, a lay out was made that could guide the participants in performing the SWOT analysis. The script is based on Scharwächter (2023, 10 July) and the purpose and wanted outcomes of the assignment.

Overall, participants found the board user-friendly, actively engaging in discussions. The researcher fulfilled the role of facilitator, moderating discussions and providing clarifications.

Focus group goal: Find the variables most important for the creation of the Education road map of the Climate Action Plan of the AS Faculty, TU Delft.

D.1. Step 1: introduction and ground rules

D.1.1. Explanation Miro board

Participants accessed the platform via the provided Miro link.

Navigation: To move around the Miro Board, simply click and drag with the mouse cursor. Open the Frames panel located at the bottom of the screen to quickly move between each section.

Adding Content: Use the toolbar on the left hand side to add the following content: Text, Sticky Notes, Drawing and Notes.

D.1.2. Time schedule

- 11:00-11:05 Opening introduction
- 11:05-11:10 Introduction Participants
- 11:10-11:15 Explanation list of variables
- 11:15-11:25 Each participant gets four dots to place on the options they prefer.
- 11:25-11:50 SWOT Discussion and Next Steps
- 11:50-12:00 Summarize Results and Conclusions
- 12:00 Check-out - An opportunity for team members to share their thoughts on how the meeting went, what worked well and what could be done to improve future meetings.

D.1.3. Ground rules

- Respect each other and refrain from making personal attacks.
- Acknowledge that it is OK to disagree.
- Listen to others, don't interrupt.
- Everyone participates; no one dominates, value the diversity of team members.

- Honor time limits: be on time, start on time, end on time.
- Recognize that all ideas are potentially good ideas, don't rush to evaluate suggestions; keep an open mind.
- Stick to the agenda – stay on task. The meeting leader serves as a facilitator and is responsible for facilitating the meeting and keeping it on task and on time.
- Be prepared for the meeting by reviewing materials distributed beforehand and bringing any requested materials with you
- Respect confidentiality, what is said in the meeting should stay in the meeting.
- Make arrangements to not be interrupted during the meeting; turn off cell phones.

D.2. Step 2: variable selection

In the subsequent phase, each participant was assigned a specific color and allocated 12 colored dots. Individually, they chose four of the most important drivers, barriers or uncertainty factors. Each participant places a dot (four dots per category) on the barrier, driver or uncertainty factor they see as most influential for ESD implementation. See Figure D.1. The outcomes of this step can be found in Tables D.1, D.2 and D.3.

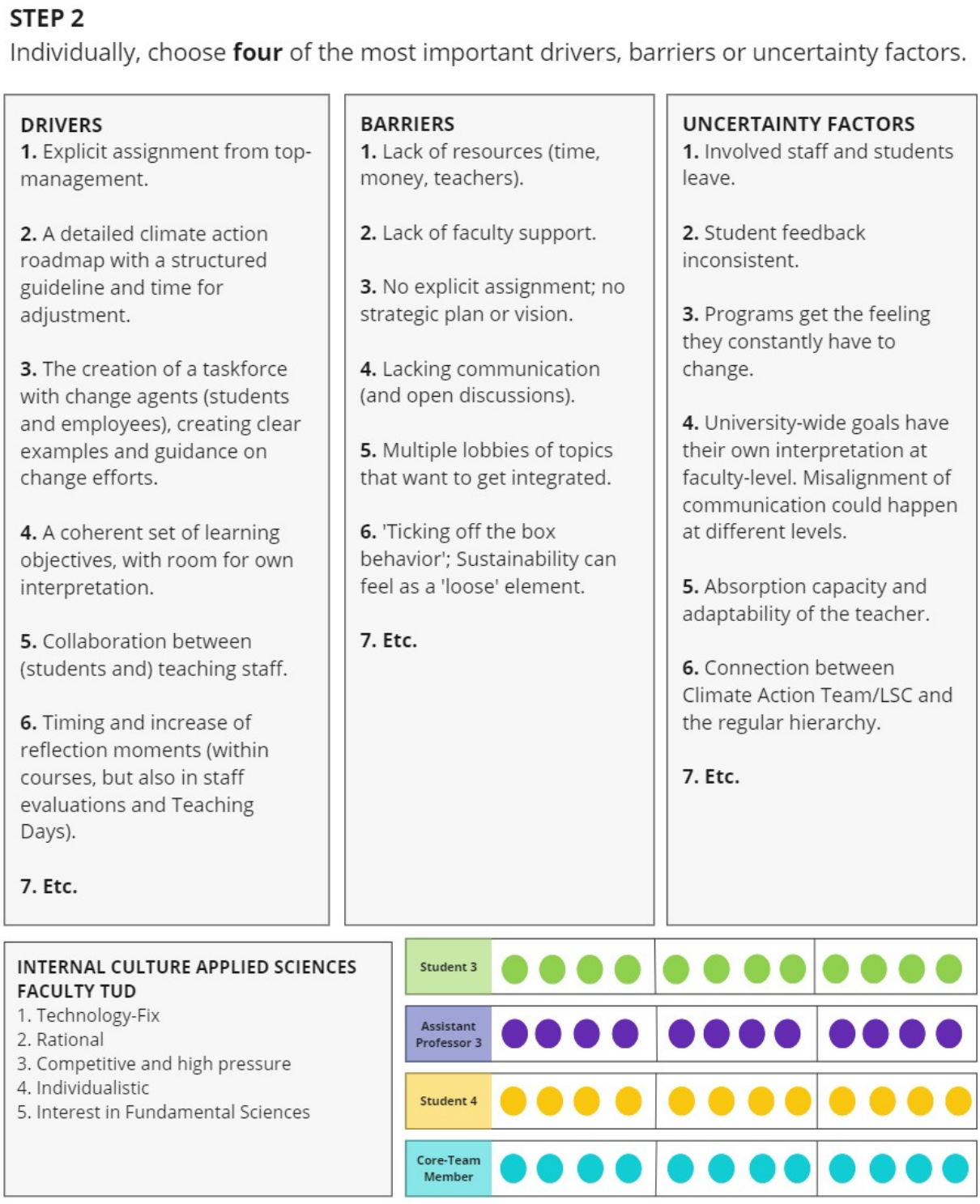

Figure D.1: Set-up of Step 2 of the performed SWOT Analysis.

Table D.1: The list of drivers derived in Step 2 of the Focus Group.

Driver	Votes	Participants
Intrinsic motivation of employees and student.	5	Student 3, Student 4, Assistant Professor 3, Core-team member Assistant Professor 1.
A detailed climate action road map with a structured guideline and time for adjustment.	4	Student 3, Student 4, Assistant Professor 3, Core-team member.
A coherent set of learning objectives, with room for own interpretation.	2	Core-team member, Assistant Professor 1.
The creation of a task force with change agents (students and employees), creating clear examples and guidance on change efforts.	2	Student 3, Assistant Professor 1.
New hires of intrinsically motivated (young) teachers.	2	Student 4, Assistant Professor 1.
Collaboration between (students and) teaching staff.	1	Assistant Professor 3.
Different definitions of sustainability are allowed and constantly discussed and communicated.	1	Student 4.
Increase in Research that focuses on sustainable development and/or the fundamentals of climate change.	1	Core-team member.
Simultaneous changes in education, research and operations.	1	Student 3.
Explicit assignment from top-management	1	Assistant Professor 1.

Table D.2: The list of barriers derived in Step 2 of the Focus Group.

Barrier	Votes	Participants
Lack of resources (time, money, teachers).	5	Student 3, Student 4, Assistant Professor 3, core-team member, Assistant Professor 1.
No explicit assignment; no strategic plan or vision	4	Core-team member, Student 3, Student 4, Assistant Professor 1.
Full (overcrowded) curricula. Assistant Professor 1.	4	Core-team member, Student 3, Student 4,
Lacking communication (and open discussions).	2	Assistant Professor 3, Core-team member.
Different views on what sustainability and climate change entails.	2	Assistant Professor 3, student 4.
Research results as priority, without reflection moments that focus on impact on the bigger system.	1	Student 3.
Only bottom-up initiatives.	1	Assistant Professor 3.
Only top-down initiatives.	1	Assistant Professor 1
Current teaching content is ready to use and of high quality	1	Assistant Professor 1

Table D.3: The list of uncertainty factors derived in Step 2 of the Focus Group.

Uncertainty Factors	Votes	Participants
A detailed climate action road map with a structured guideline and time for adjustment.	4	Student 3, Student 4, Assistant Professor 3, Core-team member.
Teaching staff needs to be intrinsically motivated to effectively cover a topic in their courses.	4	Student 3, Student 4, Assistant Professor 3, Assistant Professor 1.
One mandatory course is not sufficient.	3	Core-team member, Assistant Professor 3, Student 4.
University-wide goals have their own interpretation at faculty-level. Misalignment of communication could happen at different levels.	3	Core-team member, Student 3, Assistant Professor 1.
Involved students and staff leave.	2	Student 4, Assistant Professor 1.
Connection between Climate Action Team/LSC and the regular hierarchy.	2	Student 3 and Assistant Professor 1.
What is the relationship between community, operations, education and research.	1	Assistant Professor 3.
Technology Fix mindset	1	Assistant Professor 3.
Strategic plan changes every few years.	1	Student 3.
More resources needed than expected.	1	Core-team member.
Multiple lobbies of topics that want to get integrated.	1	Core-team member.
Not all applied sciences students and researchers focus on sustainability and climate change; certain employees and students will leave if only focused on ESD.	1	Student 4.
Transparent communication and open discussions take a lot of resources.	1	Assistant Professor 1.
Differing faculty support 'ticking of the box' behavior.	1	Assistant Professor 1.

D.3. Step 3: identify strengths, weaknesses, opportunities and threats.

Collectively, pick five variables per category. See Figure D.2. The outcomes of this step can be found in Chapter 6.

D.4. Step 4: how can this information be made useful?

Brainstorm on the next steps:

1. How can we maximize the use of our strengths?
2. How can we overcome the threats identified?
3. What do we need to do to overcome the identified weaknesses?
4. How can we take advantage of our opportunities?

Due to time constraints, the focus group's depth of analysis was limited during step 4. The outcomes of this step can be found in Chapter 6.

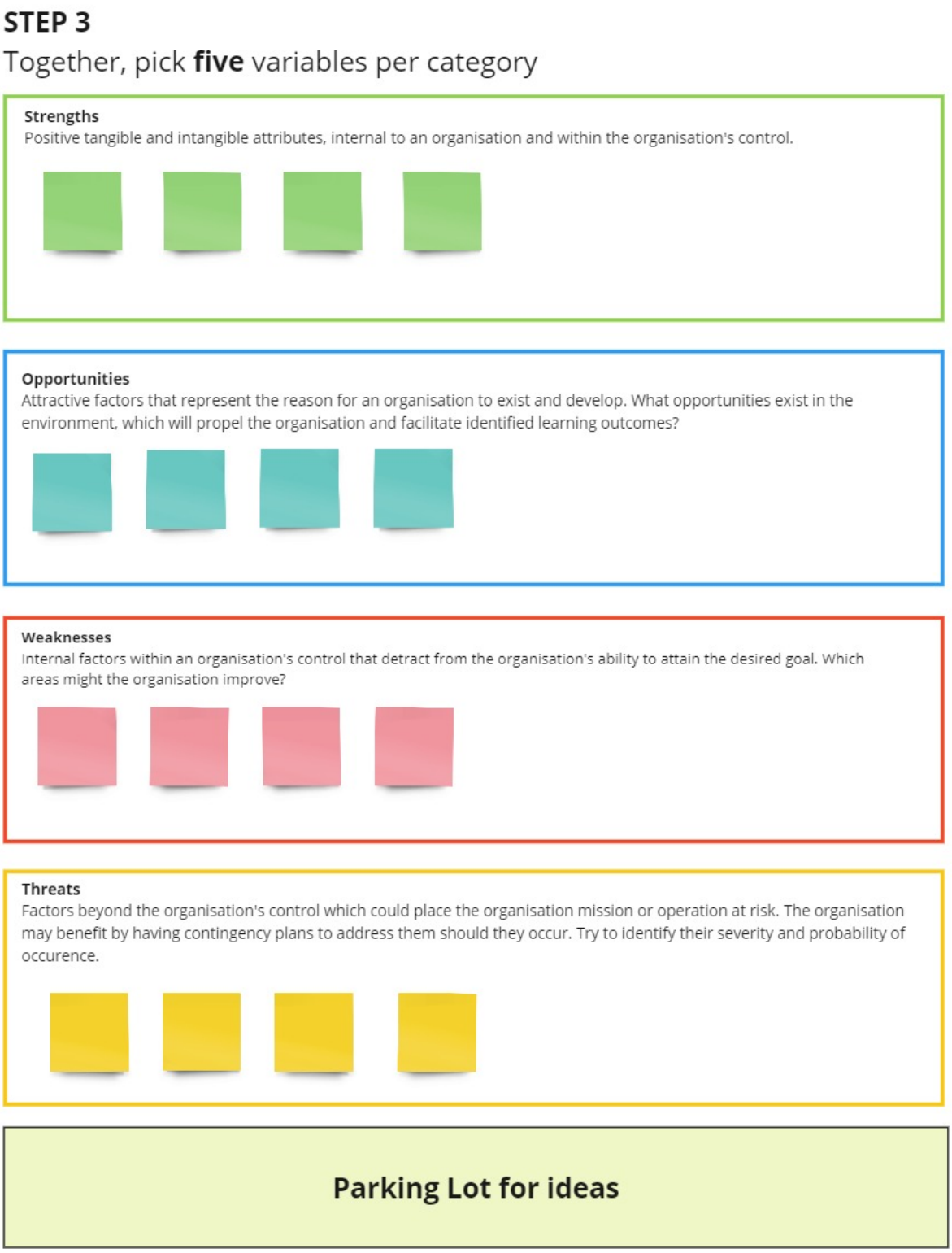

Figure D.2: Set-up of Step 3 of the performed SWOT Analysis.