No Time To Waste

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NO TIME TO WASTE
A PLEA FOR IMMEDIATE IMPLEMENTATION OF SUSTAINABILITY IN ENGINEERING EDUCATION

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ABSTRACT

There are many ways of integrating sustainability into engineering education. While renewing the Bachelor's Programme in Architecture, Urbanism and Building Sciences at TU Delft, The Netherlands, we discovered that these ways can easily lead to a stalemate: while there is the forward thrust of a curriculum renewal with its strict deadlines, uncertainty about useable concepts to integrate sustainability can cause delays and the avoidance of fundamental decisions. In this practice paper we give a brief overview of the ways to integrate sustainability we have considered, and explain how we subsequently chose what to do first and why. After an inventory of UNESCO's Sustainable Development Goals (SDGs) in the current courses, we reasoned that our faculty themes on sustainability were not directive enough, and that sustainability frameworks were not fully developed yet. Therefore we adopted a twofold method, top-down and bottom-up: redesigning the curriculum based on a preliminary framework, and connecting it with the SDGs in all 24 courses. This new combination did not provide a 'finished' sustainable curriculum, but does allow for follow-up steps that will update it based on fully developed frameworks and sustainable competences in the learning objectives. Our conclusion is that any method of integration may work, but that change can only start by choosing a method and going with it. Our advice is therefore nothing less than a plea for a cultural shift: to break the stalemate by choosing any way of implementing sustainability as soon as possible, in order to gradually transform education *as* sustainability.

1 INTRODUCTION

1.1 TU Delft Context

The campus vision of Delft University of Technology (TU Delft), The Netherlands, approved by the Executive Board in January 2022, includes ambitious goals on sustainability: by 2030, TU Delft will be carbon neutral, climate adaptive, circular, contributing to liveability, and demonstrating its sustainability and excellence on the campus (Van den Dobbelsteen and Van Gameren 2022). Besides sustainable campus operation and becoming climate neutral and adaptive, sustainability in education is part of this transition. Also based on literature, it is imperative that we fully integrate sustainability into our education (Weiss et al. 2021a).

Back in the 1990s, efforts were already made to introduce sustainability in education at TU Delft, with a basic course and a certificate programme. The implementation was both add-on and integrated. Research on how to implement sustainability in education was done; a combination of top-down and bottom-up was suggested (Kamp 2006).

In the years that followed, sustainability and climate education was mainly implemented bottom-up in various courses. Graham indicates in her research that this is one of TU Delft's strengths (Graham 2018). A disadvantage of the bottom-up approach is the lack of an overall view on how the competences are implemented. As in TU's own research (Kamp 2006), in literature a combination of bottom-up and top-down is preferred (Weiss et al. 2021a; Weiss et al. 2021b; Reynante 2022).

1.2 Faculty Context

At the Faculty of Architecture and the Built Environment, pursuing a high level of sustainability in education fits within the faculty's broad approach towards sustainability. This approach has been formalized in the *Sustainability Action Plan*, which was set up in 2023 (Faculty of Architecture and the Built Environment 2023a). The plan describes the faculty's ambitions and goals for primary processes (research and education) and operational processes (building exploitation, energy use, etc.).

The need for a *Sustainability Action Plan* relates to the aforementioned campus vision. The sheer size of the university as an organization, and the many differences among its faculties and services, necessitated the development of local action plans tailored to each faculty and its curricula.

In terms of education, the faculty has interpreted the campus vision's ambitious goals as a responsibility to educate students who are able to contribute to a sustainable society in a responsible way, and who are able to critically address sustainability related issues. To us, the goals set out for the university stress that our education should be fully transitioned to a sustainable default by 2030 as well.

In parallel to the *Sustainability Action Plan*, the faculty has updated its *Vision on Education* in 2023, prescribing a strong emphasis on sustainability in the curricula (Faculty of Architecture and the Built Environment 2023b). It too describes the need to critically evaluate how to shape engineering education in a changing society.

The development of these plans has led us to question how the current curricula could be updated, adjusted and reformed, to accommodate a sustainable default for education. Both the faculty's ambitions and the campus vision evoke a sense of urgency in their commitment to sustainable reform, with many calls for immediate action. Often however, there is a multitude of possible approaches for achieving the set goals. This should not lead to indecision, because taking no action is the worst option of all. With no time to waste, we seized the planned Bachelor renewal as a benchmark opportunity to start a transition towards sustainability in education.

2 THE CASE OF THE BACHELOR RENEWAL

2.1 Reasons for the Bachelor Renewal

In 2022, the Faculty of Architecture and the Built Environment decided to update and renew its Bachelor's Programme in Architecture, Urbanism and Building Sciences, after ten years of intensive use. Our dean launched a project to design an improved curriculum, to be launched in the academic year 2024-2025. Since 2022, a large group of course coordinators, teachers and students is busy preparing this.

The ambition of the broad Bachelor's Programme was – and is – to educate students to become "skilled, academic and context-aware designers of the built environment". However, major changes have occurred since the start of the present curriculum in 2013. In the social context, the climate crisis and the housing crisis have become much more urgent. Also, the speed of digitalisation is ever increasing. In academic research and teaching methods, innovations such as blended learning and open education have led to new forms of didactics, and more importance is being given to teaching interpersonal and intrapersonal skills. The architecture discipline itself has seen a shift towards interdisciplinarity and transdisciplinarity (respectively,

collaborating with other disciplines, and with society). All of this necessitated a rethinking of our programme.

2.2 Aims of the Bachelor Renewal

Our aims for the renewed Bachelor's Programme were fourfold (Faculty of Architecture and the Built Environment 2022):

1. More 'breathing space'

Making courses and the curriculum less full, improving the 'study- and teachability'

2. More academic attitude

Strengthening scientific and critical reflection, increasing freedom of choice

3. Updated content

Integrating the current 'faculty themes', increasing digital and personal skills

4. Updated didactics

Renewing teaching methods

In the remainder of this paper, we focus on ways in which relevant aspects of sustainability could be structurally embedded in the new curriculum, in relation to these four goals.

2.3 Faculty Themes

In its *Multi-Annual Plan 2021-2025*, the faculty presented a number of strategic aims or "faculty themes", all of which directly or indirectly link to sustainability (Faculty of Architecture and the Built Environment 2021). In the document, the faculty identifies three societal challenges as a basis for further action: urban inequality, climate crisis and scarcity of resources. These are followed by three perspectives: on sustainable urbanization, healthy cities, and heritage futures. Finally, the document states three strategies to be developed further: digitalization and artificial intelligence, climate adaptation and energy transition, and circularity in the built environment.

2.4 Problem Statement

Whereas it is abundantly clear that sustainability is a central concept for the faculty, it was not so clear at the outset of the Bachelor renewal how to integrate these broad themes in the renewed programme. This can easily lead to a stalemate: on the one hand there is the forward thrust of the curriculum renewal process with its strict deadlines, on the other hand, uncertainty about useable concepts to integrate sustainability can lead to the desire to take it slow and avoid fundamental decisions affecting all of our teaching. The challenge in 2022 was how to bridge this gap.

3 Overview: Sustainability in Curricula

3.1 Frameworks

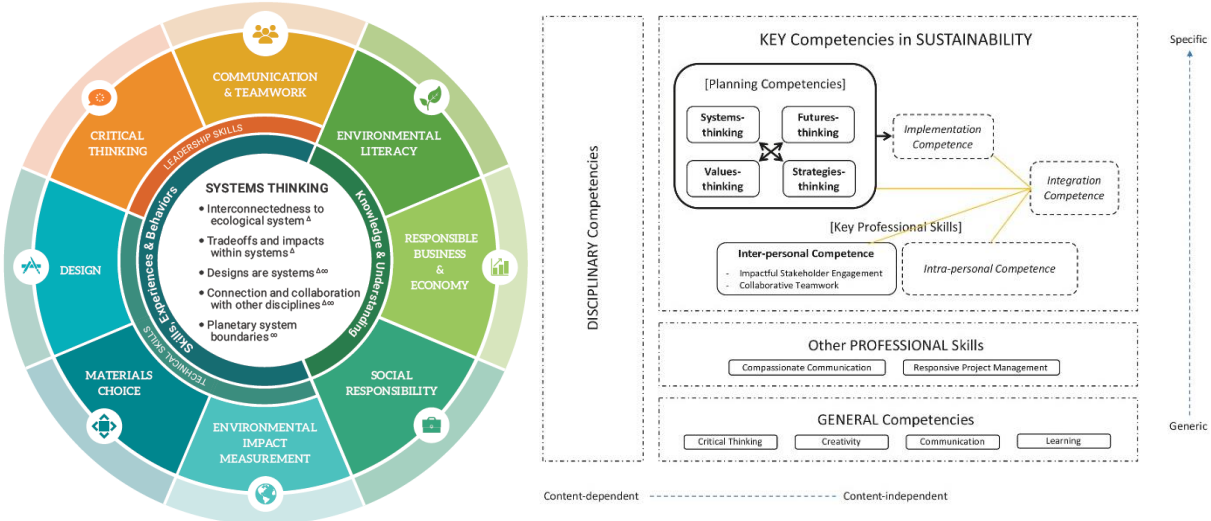
Twenty years ago, Sterling stated that "sustainability is not just another issue to be added to an overcrowded curriculum, but a gateway to a different view of curriculum, of pedagogy, of organisational change, of policy and particularly of ethos" (2004, 50). Sustainability can thus be implemented at different levels in education. When

connecting to TU Delft's other transition goals, it is necessary to go for the highest level of implementation, redesign, education *as* sustainability, instead of education *about* sustainability, see Figure 1 (Weiss et al. 2021a).

Level		Type of ESD	Description	Pedagogical Approach
high/ very strong	redesign	education *as* sustainability	-holistic change and paradigm shift that places sustainability principles, ethics, and values at the core of the curriculum requiring the engagement of the whole person and institution -ESD is integrated into common core requirements and/or the vision of the HEI	emancipatory & transformative (third-order learning)
middle/ strong	'build-in'	education *for* sustainability	-significant changes to the curriculum by including a coherent coverage of content, values, and skills associated with sustainable development and a critical questioning of assumptions -sustainability is addressed in (interdisciplinary) programs/courses focusing on integrating sustainability issues -first linkages from ESD modules to other HEI areas such as operations/campus	
low/ weak	'bolt-on'	education *about* sustainability	-leaves current paradigm change unchallenged -sustainability concepts are added to specific disciplinary existing courses or programs (content based sustainability literacy) -minimal effort from the institution	instrumental & simplistic (first-order learning)
very weak	denial	no change	/	

Figure 1. Levels of implementing sustainability in curricula (Weiss et al. 2021a)

The usage of a framework for implementing Education for Sustainable Development (ESD) seems to be helpful (Wijnia, 2024). For our situation, we mainly looked at the Engineering for One Planet (EOP) framework and Wiek's framework, see Figure 2, left and right. Wiek's framework is the most frequently cited (Wiek and Redman 2022). This is a more general framework, with the disciplinary competencies placed next to the sustainability competencies. The Engineering for One Planet framework was developed specifically for engineering education (Anderson and Cooper 2022). It fulfils the Accreditation Board for Engineering and Technology (ABET) criteria, uses the United Nations Sustainable Development Goals (SDGs) and was prepared in collaboration with universities and industry. Knowledge on the specific implementation processes that lead to sustainable curricula still has to be developed (Weiss et al. 2021a). Wiek et al. (2011) indicate that it is more important to get started implementing ESD rather than developing the most ideal framework.



EOP framework	Wiek's framework
Model made for engineering education	General model
Disciplinary competences in the model	Competencies are largely independent of specific topics
2 levels: core and advanced	3 levels: novice, intermediate (BSc) and advanced (MSc)
Cross-referenced with engineering education and UN SDGs	Most cited research

Figure 2. Comparison of frameworks (Anderson and Cooper 2022; Wiek and Redman 2022)

3.2 Preliminary Adaptation

To fit in with TU Delft's education model, it was decided to use the EOP framework as a starting point. In 2023, a preliminary adaptation to our own educational situation has been made, see Figure 3. In the coming period, this will be further developed by a to be formed focus group. The ultimate goal is then to put this framework alongside new curricula and to see to what extent it is satisfying, can help curriculum development and needs to be updated. Educational redesign takes time to be implemented properly, and with our target there is time for improvement until 2030.

Figure 3. TU Delft Engineering for Sustainability (TUD ES) framework (own illustration based on EOP)

4 SUSTAINABILITY IN THE BACHELOR RENEWAL

4.1 Inventory

In order to check whether and where the faculty themes and sustainability could be implemented in the Bachelor renewal, an inventory of the current curriculum has been made. This started in 2022 with the report of GreenTU (GreenOffice TU Delft), in which all TU Delft education was examined and mainly looked at in outline terms, providing a general overview (GreenTU 2022). To get a better picture, research was

conducted on the state of education in 2022-2023 by studying the publicly accessible information in the online Study guide. Keywords were examined and an inventory of the universally used SDGs was made using AI (see Figure 6 for all SDGs). The results were presented in the GreenDatabase. In the current Bachelor of Architecture, Urbanism and Building Sciences, a significant proportion of the courses was found to be dealing with sustainability: 10 out of 24 courses (42%), see Table 1. The courses were part of the so-called 'learning trajectories' 'Design' (ON), 'Technology' (TE) and 'Society' (MA), see Figure 4 for the curriculum.

Figure 4. Current Bachelor's Programme with 4 quarters per year (horizontal) in a 3-year curriculum (vertical) with 6 learning trajectories (see Table 1) (own illustration)

Table 1. Sustainability keywords and SDGs (for the numbers, see Figure 6) in the current programme, based on Study guide (GreenDatabase and own illustration)

Design ON (60 EC)	**Technology TE (25 EC)**	**Fundamen-tals GR (20 EC)**	**Representa-tion and Form OV (15 EC)**	**Academic Skills AC (15 EC)**	**Society MA (15 EC)**
BK1ON1 11, 12, 13	BK1TE1 7, 9, 11, 13	BK1GR1	BK1OV1	BK2AC1	BK3MA1 11, 12
BK2ON2	BK1TE2	BK2GR2	BK2OV2	BK4AC2	BK4MA2 11
BK3ON3 11, 15	BK2TE3 7, 9, 11, 12	BK3GR3	BK3OV3	BK6AC3	BK6MA3 11, 12
BK4ON4 11	BK3TE4 11, 13	BK4GR4			
BK6ON5	BK4TE5 11, 12, 13				
BK6ON6 11, 12, 13, 15					
Contains 'sustainability'		Not sure		No 'sustainability'	

Next, in early 2023, the learning objectives of all courses were studied in detail by the programme coordinators. This confirmed the results of the GreenDatabase, with only one difference in the 10 courses dealing with sustainability: BK3ON3 instead of BK1ON1 in the ‘Design’ trajectory. However, most courses appeared to deal with sustainability only in a rather superficial way, e.g. in a subclause or as an ‘add-on’.

4.2 Problems with the Faculty Themes and the TU Delft ES Framework

A major aim of the Bachelor renewal was to better embed and deepen sustainability in the programme, initially using the faculty themes. However, because these are quite abstract, thematically ordered and not linked to international examples, while the courses’ learning objectives are specific and focused on assignments, the faculty themes proved difficult to use to give direction to the Bachelor renewal, in a way that is understandable also outside the faculty. Because the TUD ES framework was not fully developed during the renewal process but we did not want to delay, we adopted a twofold method, top-down and bottom-up: redesigning the curriculum based on the preliminary framework (Figure 3), and relating all courses to the SDGs.

4.3 Curriculum Redesign

First, during the first half of 2023, we redesigned the structure of the curriculum partly based on and incorporating the known knowledge, skills and attitudes from the preliminary TUD ES framework. This was one of the reasons for the fusion of the 'Academic Skills' (AC) and 'Representation and Form' (OV) trajectories into the new 'Science and Skills' (WV) trajectory, with more focus on critical thinking and personal skills, and for the introduction of the education-free and reflection-based Personal Development Week (P) twice a year (Bohm et al. 2023), see Figure 5. With these two innovations, the competences reflection & critical thinking, communication & teamwork, and social responsibility from Figure 3 are better incorporated.

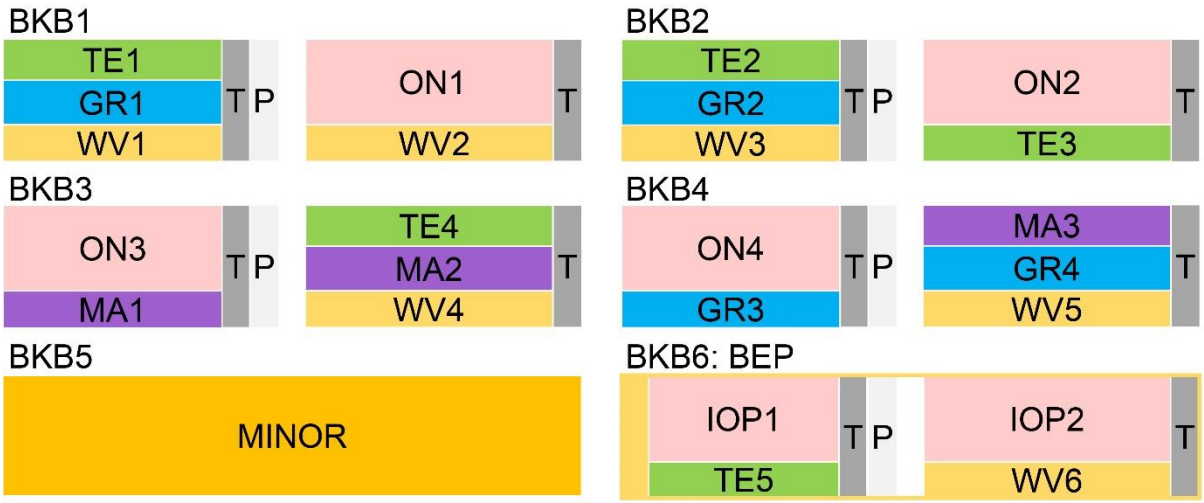


Figure 5. Renewed Bachelor’s Programme starting in September 2024 (own illustration)

4.4 Sustainable Development Goals in all Renewed Trajectories and Courses

Second, we chose the SDGs as an extra framework (Beagon et al. 2022), and from summer 2023 asked all trajectory teams to what extent their renewed courses could be linked to them and steered by them. The initial question was to look at the primary (and possibly secondary) interfaces with the SDGs from the course description in development, and to interpret them broadly. For this we used the ‘Wedding Cake

Model', in order to facilitate relating the SDGs to the natural and built environment, and its influencing contexts, see Figure 6 (Rockström and Sukhdev 2016).

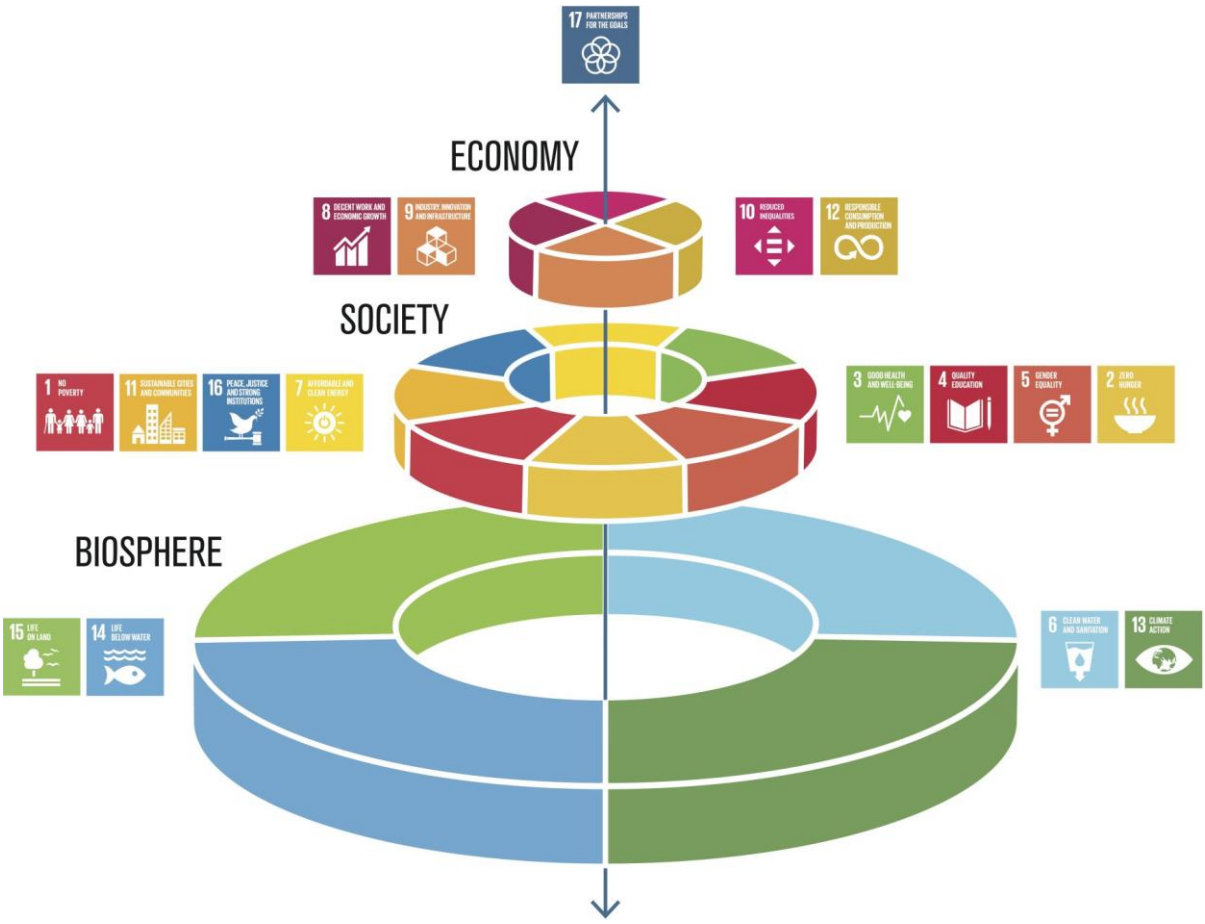


Figure 6. SDGs Wedding Cake Model (Rockström and Sukhdev 2016)

It was explicitly not the ambition to cover all 17 SDGs with the 24 courses, as some SDGs are less related to the building domain in terms of content. Instead, the intention was to see where our programme is strongly or less connected, so an overall picture emerges.

In resolving duplications or omissions, UNESCO's publication *Education for Sustainable Development Goals* has been used (UNESCO 2017). This educational elaboration provides guidance on how to implement the SDGs in education, including suggestions for learning objectives. Besides learning objectives per SDG – subdivided into cognitive, socio-emotional and behavioural learning objectives – the publication also lists 8 generic key competences for sustainability: systems thinking, visualising multiple futures, using norms and values, strategic action, collaboration, critical thinking, self-awareness and integral problem solving. Using this, the trajectory teams started thinking about where in their courses (which) knowledge and skills about climate and sustainability could be conveyed, and how these could be captured in (assessable) learning objectives. For now, this has led to an updated version of Table 1, see Table 2, in which all courses now relate to one or more SDGs (with SDG 11 being present in 20 courses, and SDGs 1, 2 and 16 being absent).

In a future stage, the trajectory teams can fine-tune their course content as they continue to develop it during the 2024-2025 academic year, parallel to the further development of the TUD ES framework, and by using the European Commission's

competence framework Greencomp (European Commission Joint Research Centre 2022). This contains 12 competences in four areas: sustainability values, complexity of sustainability, visualising a sustainable future, and pursuing sustainability.

Table 2. Sustainability keywords and SDGs (for the numbers, see Figure 6) in the renewed programme, according to the course coordinators (own illustration)

Design ON (60 EC)	**Science and Skills WV (30 EC)**	**Technology TE (25 EC)**	**Fundamentals GR (20 EC)**	**Society MA (15 EC)**
BKB1ON1 3, 6, 15	BKBWV1 4	BKB1TE1 4, 7, 13	BKB1GR1 11, 15	BKB3MA1 3, 10, 11, 13
BKB2ON2 7, 11, 12	BK1WV2 4	BKB2TE2 4, 11, 12, 13	BKB2GR2 11, 15	BKB3MA2 8, 11, 12, 17
BKB3ON3 11, 13, 15	BK2WV3 4, 11	BKB2TE3 3, 4, 6, 7, 11, 12, 13	BKB4GR3 11, 15	BKB4MA3 11, 12, 13, 17
BKB4ON4 3, 4, 5, 11	BKB3WV4 4, 11	BKB3TE4 3, 4, 7, 11, 13, 15	BKB4GR4 11,15	
BKB6IOP1 11, 17	BKB4WV5 7, 11, 14, 15	BKB6TE5 3, 4, 6, 9, 11, 12, 13, 15		
BKB6IOP2 6, 7, 11, 12	BKB6WV6 4, 11			

Contains ‘sustainability’	Not sure	No ‘sustainability’

5 DISCUSSION

5.1 Conclusion

Looking back at the renewal process, and forward to the start of the renewed Bachelor’s Programme in September 2024, we can conclude that our method did not provide a 'finished' sustainable curriculum at once. However, it has provided guidelines, also for other institutions, on how top-down and bottom-up approaches can be integrated: it did change the curriculum in a fundamental way, by a change of perspective on the design of a more sustainable curriculum, and on the courses’ content with the SDGs; in line with the aforementioned quote of Sterling (2004).

Moreover, our method ensured that studyability (not adding more, but sometimes doing less) and teachability (a new curriculum demands a lot from staff) could receive a lot of attention. It also allows for follow-up steps from 2024-2025, that will update the curriculum in line with frameworks in development (including the TU Delft ES framework), and that will include sustainable competences in the learning objectives, while evaluating the courses and the needs of teachers and students. At the same time, our Bachelor renewal will serve as a pilot for other TU programmes.

With Wiek et al. (2011) and Weiss et al. (2021a), who indicate to get started with implementing sustainability rather than to wait for fully developed frameworks, our conclusion is that any method of integrating sustainability in engineering education

may work, but that change can only start by daring to make a deliberate choice for a method and going with it. Given the implementation time, this is the first step in a process, and it will take several iterations to realise the highest level of integration.

5.2 Advice

Based on our case of the Bachelor renewal as well as on literature, our advice on integrating sustainability in engineering education is therefore nothing less than a plea for a cultural shift: to break the stalemate that may occur because of the many useable concepts, by choosing any way of implementing sustainability as soon as possible, in order to gradually transform engineering education *as* sustainability.

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