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Integrating Environmental Sustainability in Construction and Real Estate Management Education

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Abstract It is recommended to integrate specific management competencies in academic education to support the transition towards environmentally sustainable practices, particularly in the construction and real estate sector. This paper explores how architectural management education can integrate environmental sustainability within its current university programmes. In recent years TU Delft explored and experimented with various education initiatives to bring forward environmental sustainability knowledge and to connect with policy, societal and industry practices. This paper describes what we learned from both bottom-up and top-down initiatives implementing environmental sustainability in construction and real estate management education. Bottom-up educational initiatives show that knowledge about transition policies, stakeholder experiences, business models and management practices from a European perspective can help students across the globe to apply knowledge into their local context, reflecting on the overarching management principals across stakeholders, institutions, academic disciplines and cultures. Top-down initiatives show that the university has a vision on integrating sustainability in its curriculum, but that integrating environmental sustainability in construction and real estate management education is still challenging. Adapting the academic curriculum to integrate building and portfolio responses to environmental challenges might be a way forward and the experiences from numerous elective courses and educational initiatives can be a basis to identify the development of a future standard curriculum.

Keyword Education · Environmental sustainability · Real estate management · Architecture · Buildings · Construction · Urban development

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1 Introduction

Multiple scholars and experts (Grosseck et al. 2019) consider that students and teachers need to develop key competencies in sustainability, which can also guide academic program development and course design (Wiek et al. 2015; Wiek and Redman 2022). There is a broad agreement that students need to be enabled and empowered to effectively contribute to sustainability problem-solving (Brundiers et al. 2021). Particularly in engineering disciplines students need to know how to act on deep knowledge in the outside world on the fringes of technological sophistication, societal acceptance and politics (Kamp 2020). Particularly knowledge is needed regarding "environmental sustainability", interpreted by Morelli (2011) as an expansion of our common perception of the nature of *human activity* so as to more clearly connect it with the ecological concept of interdependence and to serve *as a goal for managers.*

Particularly, formulating and managing sustainable development in the form of 17 internationally accepted Sustainable Development Goals and 169 associated targets (UN 2015) present a formidable 'to do' list for the integration of learning objectives in the development of education (Vare et al. 2022).

In 2018, the buildings and construction sector accounted for 36% of final energy use and 39% of energy and process-related carbon dioxide (CO_2) emissions (IEA 2019). It is therefore particularly essential to deal with such goals in construction and real estate management education. At the same time, European policies (EPBD 2010; EPBD 2018; EED 2018; RED 2018; Green Deal 2019; Renovation Wave 2020; eu2020.de 2020) and international environmental sustainability goals (UN 2015; Paris Agreement 2015; UN 2017; UNFCCC 1997) drive countries towards the development of nearly zero-energy buildings including energy efficiency and renewable energy systems, as well as sustainable urban transformation. Furthermore, the sector also recognizes the need for circular, socially just and economically sustainable initiatives, as well as related business innovations. However, most challenges ahead require more of a management perspective instead of a design or policy perspective.

In architecture education, most attention is paid to designing energy-efficient or nearly zero-energy buildings and a low-carbon built environment (Gething and Puckett 2019; Oliveira et al. 2018; Altomonte 2009; Sassi 2006). But reflecting on the original definition from the report *Our Common Future* (Brundtland and Khalid 1987) one could consider in a more holistic manner the need for "managing" the needs of the present generation without compromising the ability of future generations to meet their own demands. From a sustainable housing perspective, this would for example suggest a need to identify housing management strategies in such a manner that this entails equal social and economic opportunity for present and future households, reflecting also on the ability of the already existing building stock to absorb the housing needs and the environmental limits to economic growth in housing portfolios.

To deal with the needed rapid innovation cycles, students need to be trained to provide a fast response to urgent dilemmas (Kamp 2020). They need to be enabled to navigate between conflicting stakeholder viewpoints, and manage change, and be

willing and able to recognise and pursue opportunities for new value creation and problem solving in any organisational setting (Feyen et al. 2019). In the field of construction and real estate management therefore adapted education is needed to be able to manage the transition towards a sustainable built environment.

This paper aims to contribute to a current gap in knowledge and information regarding the degree of implementation of environmental sustainability in higher education, as well as an understanding of what challenges and opportunities universities have faced during attempts at implementation (Wright 2002), particularly for construction and real estate management education. After explaining the research approach, we explore experiences of integrating environmental sustainability in the education at the TU Delft, Faculty of Architecture and the Built Environment, using an integrated framework of competencies for advancing sustainability transformation (Wiek and Redman 2022). In a following section, experiences from some key bottom-up initiatives are identified that either were abandoned or led to a further development of integrating environmental sustainability in design, construction and real estate management education. In the section thereafter this paper scopes what happened simultaneously top-down on the higher level in the development of Bachelor and Masters programmes. After that, the paper discusses further on the specific implementation patterns and challenges that could lead to the further institutionalization of curricula including environmental sustainability (Weiss et al. 2021).

2 Research Approach

The research question put forward is: *How can construction and real estate management education curricula integrate environmental sustainability?*

The question is explored with a case study on the development of education at the Department of Management in the Built Environment at the Faculty of Architecture and the Built Environment of the TU Delft is chosen. The department of Management in the Built Environment (MBE) works towards a built environment where the interests of the end user and other stakeholders are key. "Management in the Built Environment" education at TU Delft focuses on integrating design, managerial, organisational, economic, financial, legal, technological, sustainable and policy aspects into development and operation processes aimed at adding value during the entire life cycle of buildings, areas and housing stock (BOSS 2023).

This research does not aim to give a complete picture on how education for construction and real estate management can implement and manage integrating environmental sustainability in university curricula. Nevertheless, the case is representative to research some key challenges and opportunities for integrating environmental sustainability in education as education at MBE focuses on providing the next generation of managers in the built environment, particularly with knowledge about solutions for the development and management of buildings, portfolios and urban areas (MBE 2023). The organisational sectoral classification includes three

key domains: Design & Construction Management (DCM), Real Estate Management (REM), Urban Development Management (UDM). In this paper we focus on the development of education at REM and DCM and we illustrate also how educational initiatives emerging from UDM and other departments influence integration of environmental sustainability in REM/DCM education. Using DCM and REM as the overarching concepts allows for clearly positioning some of the courses discussed as either oriented towards mutation or towards operation, positioning environmental sustainability as part of engineering and procuring assets or operating and maintaining the assets portfolio.

Education for sustainable development can be implemented from the bottom-up, from the top-down, or both (Weiss et al. 2021). Therefore the following sub questions are addressed in the following sections:

- *What opportunities were detected during attempts of implementing environmental sustainability bottom-up?*
- *What challenges are faced when integrating environmental sustainability in the standard curriculum top-down?*
- *What challenges lie ahead for integrating bottom-up and top-down initiatives?*

3 Bottom-Up Education for Environmentally Sustainable Construction and Real Estate Management

Construction and real estate management education is strongly linked to social, economic, policy and environmental developments. This paper exemplifies experiences from some TU Delft courses that aimed to integrate environmental sustainability and that are standard for, or popular amongst, students construction and real estate management. Besides these developments there are also numerous initiatives to integrate social and economic sustainability, which are not covered in detail in this paper; in a later section this paper discusses the embedding. Earlier initiatives to integrate environmental sustainability in construction and real estate management education at TU Delft started from the notion that the development of sustainability in the built environment is inherently linked with changing technology management practices as used by demand, supply and policy actors. Therefore, education for sustainable housing developed a close relationship with–and knowledge from–these stakeholders and their practices to bring forward needed transitions. We exemplify some experiences on three levels: 1. Changes in the courses in the standard curriculum; 2. Development of elective courses, and 3. Development of other educational initiatives.

3.1 Examples of Implementing Environmental Sustainability in the Standard Curriculum

In most courses from DCM/REM there is attention for the sustainability agenda. Here we illustrate some courses that put environmental sustainability more central as part of the course goal.

3.1.1 Re-Design: From Area to Building Block

Re-design is a MSc course that aims to bring students' knowledge to analyse and re-design cases in a demanding, realistic context. Students are introduced to the structure and processes of management at multiple, interconnected levels involving individual buildings, larger complexes, the areas they belong to, the portfolios they belong to, relevant policies and governance. The course focuses on the development of essential cognitive and practical skills for applying management methods and techniques at these levels. The focus in this course is on understanding the effectiveness, efficiency, consistency, comprehensiveness and reliability of processes including reflection on various types of political, economic, social, technological, legal and environmental conditions.

In Re-design students are requested to examine a particular case also from various viewpoints, including environmental sustainability. Environmental sustainability is one of the public values that local and national governments focus on (in process and product) and that play a role in the design and development of real estate. Although environmental sustainability is not at the core of the course, it's importance is increasing and is seen as a value—next to societal and financial values.

3.1.2 Housing: Policy, Management and Sustainability

The MSc course "Housing" was the first in the Real Estate Management department that reserved specific attention for environmental sustainability as well as social sustainability and affordability. In this course, students learned about the way in which housing is provided for, and sometimes by, a variety of users and stakeholders, including (local) governments, professional organizations such as housing associations, individual households and self-organised groups. The core study topics were the housing market, user preferences, housing policies and institutions, the strategic portfolio management of housing providers; policies, measures and processes to increase the environmental sustainability of the housing stock; and policies and practices to improve the social sustainability of housing and neighbourhoods. Students defined sustainable housing challenges on various scales and in relation to social, economic, policy and environmental developments. As a learning goal, they were enabled to analyse and develop management strategies, particularly also from the perspective of various stakeholders and professions.

To support such learning objectives teaching activities explained and illustrated for example:

- Policy developments, particularly showcasing the effect of recent housing and energy policy measures on housing management practices;
- Existing housing management strategies from an environmental sustainability perspective, particularly analysing factors influencing the adoption of measures and strategies;
- Housing developments from a management perspective, particularly analysing the role of various stakeholders in implementing sustainability goals.

The course received excellent student ratings. A few years ago, when the course merged with the Real Estate Management course that had been running parallel with it for years, environmental sustainability was positioned therein as a goal and context of overall real estate management, next to safety, reliability, adequateness, sufficiency and efficiency. Several specific techniques to achieve environmental sustainability were added to the supporting management tools. Some parts of the Housing course were moved to a new elective course on social sustainability.

3.1.3 Urban and Infrastructure Redevelopment Game

The MSc course Urban and Infrastructure Redevelopment Game focuses on understanding the changing context of the global and local environment and economic, social and cultural elements that contribute to various urban problems. Students study the context, content, players and means of implementation during the cyclic phases of urban area development. To be able to do that, they play roles in project simulation and learn how to assess, analyse, research and improve operation practice in the field or urban development. The course aims to train students to grasp an integral approach when managing urban (re)development both at the urban area scale and at the portfolio and object scale. Through a role-playing simulation project, students are given design assignments that drive them to (re)develop a complex urban location with both residential and non-residential elements.

Environmental sustainability is an important part of the course as it runs as a red thread through the four dimensions of urban development, namely place, process, product and person. The term Product refers to the physical outcome of an area-based urban development project, i.e. the real estate, infrastructure, and/or public space that the project seeks to realize. Place refers to the geographic situation of a project, often sharply defined in spatial plans, briefs or contracts and signified by a specific history and distinct locational qualities. Person relates to the individuals involved in an intervention, acting either for themselves or in behalf of a larger group or organization (i.e. ‘actors’), such as government bodies, real estate developers, investment agencies, businesses, pressure groups, or public private partners. The decisions and actions of these actors shape the content of an area-based project, and the negotiations between them are conceptualized as an on-going, dynamic, and interactive Process (van Bueren et al. 2016). Moreover, there are specific roles students play as part of

their simulation game that focuses on environmental sustainability at the core. They are named as environmental law adviser and climate change and resilience officer.

3.1.4 Graduation Laboratory Management in the Building Environment

The Graduation Laboratory Management in the Built Environment was recently reconfigured to introduce specific thematic graduation labs, some of which also explicitly deal with environmental sustainability. The labs focus for example on management for a circular built environment or for achieving a faster energy transition of the existing building stock. So far, these specific labs attracted a few dozens of students. However, it is observed that for current student generations, sustainability is no longer a special theme. They include the topic in most of their reflections and course work. Even if environmental sustainability is not the main theme of a paper, thesis or discussion, it is often present as part of the goal or process.

3.2 Development of Elective Courses with a Focus on Environmental Sustainability

3.2.1 Solar Decathlon Europe

The Faculty of Architecture and the Built Environment of the TU Delft also regularly participates in the Solar Decathlon, which is offered as an elective management course. The course enables students to work together in an interdisciplinary manner with teachers and students from multiple departments and faculties. Initiated in 2002 by the United States Department of Energy (US DOE, n.d.), the Solar Decathlon is a university-level student competition for resource-responsible and energy-efficient architecture and engineering in the building sector. The competition challenges universities from all over the world to design, build and operate a solar-powered and energetically self-sufficient home equipped with advanced technologies, and designed to the highest standards of sustainability (SDE 2021). Award criteria such as reflections on affordability, viability, and sustainable innovation are typically developed and covered by students from Construction and Real Estate Management. Influenced by construction and real estate management strategies, student teams chose for radically different thinking compared to newly-built home construction, for example, the demonstration of a nearly zero-energy home renovation, the transformation of an office building unit and the development of topping-up units for responding to the increasing housing needs.

3.2.2 Climate Proof Sustainable Housing Renovation

In this course the renovation process of a housing complex is unravelled as a challenging social-technical system. Students gain knowledge of sustainable renovation from different perspectives and apply gained insights and knowledge in conducting a feasibility study. The interests of all involved stakeholders in housing renovation have to be merged to result in a successful renovation, the process as well as the end result. This course is organised as in-depth lectures covering all perspectives of integral climate proof adaptations of housing and a tender game for the renovation of a housing complex. The award criteria of the tender cover stakeholder involvement and process management, energy performance, environmental performance, health & comfort, financial case for housing association and tenants, and the integration of all the perspectives.

3.2.3 Social Sustainability in Human Habitats

In this newly established elective course, students learn about the role of housing to achieve socially sustainability human habitats in different geographical contexts. This elective course focuses on maintaining and improving social inclusion and wellbeing in housing and living environments and teaches four core dimensions: (1) the social preconditions for sustainable development (i.e., values, habits and rules); (2) the equitable distribution and consumption of housing; (3) the quality of social relations in housing and living environments; and (4) the physical conditions or liveability of housing and living environments. In parallel to the introduction of this course there was also a development track to establish an elective on Environmental Sustainability in Human Habitats.

3.2.4 Energy-Friendly Renovation Processes

This case-based elective blended course was based on developing process management competencies for high quality and energy ambitious renovation projects within the existing housing stock. The goal of the course was amongst other to guide students through interpreting and managing the complexity of the processes and taking a position from different stakeholder perspectives. The course pays attention to technical and financial factors, however the main focus lies on other success factors like the skills to work with various parties with different interests on ambitious goals. Students develop a real case solution, reflect in an on-line environment with involved professionals, and hold face-to-face meetings with stakeholders.

The course thus delivered student competencies to identify and eliminate barriers for sustainable housing renovations, particularly looking at:

- The impact of changing policies on decision-making, with a focus on the implementation of innovative measures and processes to increase the environmental sustainability of the housing stock;
- The business models of stakeholders with a focus on solving split-incentive (tenant-landlord) problems and identifying financially viable business cases that are applicable for market up-scaling;
- The influence of stakeholder interests on management practices and the opportunities for stakeholder dialogue;
- Real-life examples of social practices to improve the development, affordability and sustainability of housing renovation at various scales.

Although the course was highly relevant and rewarded by the sector as outstanding blended educational initiative, in the end it did not attract enough students any more to pursue the needed yearly educational effort.

The elective courses are situated in a highly competitive framework where students can also choose courses from other departments and faculties, some of which also focus on environmental sustainability. For example, other TU Delft elective courses are available regarding climate change, ocean energy, fuel cell systems, wind energy, waterpower, solar energy, renewable energy systems, geothermics, geo-design for a circular economy, aesthetics of sustainable architecture, green building, zero energy design, recycling engineering materials, environmental physics, urban sustainability, innovation and sustainability, sustainable urban engineering of territory, architectural sustainability, ecological engineering, water management, sustainable business models, strategic and sustainable design, sustainable innovation and social change, sustainable innovation and transitions, climate ethics, sustainable energy innovation and transitions, and so on. The sheer number of electives illustrates the complexity of course alignment. In reality—besides their standard curriculum–students only have a limited amount of time to grasp the complexity of environmental sustainability issues.

3.3 New Educational Approaches with a Focus on Environmental Sustainability

3.3.1 Summer School Sustainable Housing from a European Perspective

The department manages a summer course where, during two weeks, students gain insight into the European perspective on the development of sustainable housing stock, and speeding up energy transition goals, using European and national goals, policies, regulations, assessment tools, process innovations, behavioural, institutional and management approaches. The course also embeds reflection on emerging economies and on the role of institutions and urban contexts in less developed countries. The course mixes Bachelors, MScs, PhDs and professionals from all around

the world using groups based on a mix of nationality, educational background and gender. Interaction with practice was also provided with a visit to a project example involving residents, professionals and staff and a building innovation centre.

Within the Summer School, the GO2Zero Game introduces a simulation environment to support understanding transition processes in a safe playful environment for students and experts to jointly experiment with process challenges (Bekebrede et al. 2018). The Game particularly represents the transition towards a renewable energy system in urban districts as strongly embedded within society, therefore requiring a thorough analysis of the stakeholder complexities (Bekebrede et al. 2018). Playing the game helps students to formulate stakeholder viewpoints and collaborative strategies for collaboratively achieving energy transition goals. The simulation game was introduced for further experimentation as part of the curriculum of a summer school.

Winning a Tender was developed to be a core objective of the whole Summer School. It was developed as an active teaching method for gradually improving environmental sustainability in management processes. In a competitive environment, groups of students are asked to develop and defend a plan for a sustainable housing renovation responding to a "tender" with political, economic, social, technological perspectives. Proposals prepared by the students are regularly reflected by peers, tutors (who also sometimes act as social media influencers) and a professional 'jury', that takes up stakeholder roles for evaluating predefined award criteria. Students finally also reflect lessons on their own national context, preparing take-home messages for local development.

As an experiment a one-week summer school was also tailor-made for Chongqing University, China at TU Delft and later on site at Xi'An University. In this course students were also challenged to connect with local residents to understand their renovation needs, and to interact with speakers during a high-end policy development workshop. Bringing awareness to local graduates and professionals and using a local project case in particular, made a significant impact not only on the way students perceived sustainability challenges in their own context, but also at a societal level on how they could change the construction culture locally.

3.3.2 Massive Open Online Courses (MOOC)

The Faculty of Architecture and the Built Environment of the TU Delft also provides successful massive online courses, some of which pay specific attention to environmental sustainability and might attract students from REM/DCM. The courses *Zero Energy Design* and *Advanced Zero-Energy Design* teach international students who possess basic technical knowledge how to make a building more sustainable and net zero energy in different climates using both passive and active measures. Students use their own home or building as a case. In the advanced course they also validate their design using energy performance calculations. The course *Circular Building Products for a Sustainable Built Environment* aims more towards professionals and shows opportunities that circular building products can offer, investigating various perspectives (design, technology, business case, implementation methods).

The course *Sustainable Urban Development*—embedded in the Amsterdam Institute for Advanced Metropolitan Solutions (AMS), a cooperation of TU Delft and Wageningen University—introduces first steps regarding urban challenges using a holistic, systemic and transdisciplinary approach, and integrating knowledge from urban planning, urban design, urban engineering, systems analysis, policy making, social sciences and entrepreneurship. Other courses that are offered are for example *Co-creating Sustainable Cities*, which focuses on citizen interaction, and *Rethink the City*, which focuses on new approaches to local urban challenges and sustainable urban transitions in the Global South.

4 Changes in the Educational Context at the University and Faculty Level

As exemplified above, environmental sustainability challenges were gradually bottom-up integrated in academic courses and educational initiatives at the TU Delft, to fit a growing demand to integrate environmental sustainability in construction and real estate management education. The goal of the educational initiatives was to prepare future professionals not only with immediate knowledge, but also with a flexible mind-set to adapt know-how to real applications. With such a methodological capacity students can be prepared to make their impact for achieving sustainable goals in their future professions. Based on these experiences as well as the sharing of experiences from the departmental and educational programming, TU Delft nowadays responds to sustainability challenges with formally stated goals.

The Bachelor Education of the Faculty of Architecture and the Built Environment (TU Delft 2022:1) now states that a student with a Bachelor Degree should be able *to connect human needs and the environment from a perspective of sustainability*, including design, technique and society and have knowledge and understanding about the life cycle of the built environment including initiative and programme, (re)design, (re)development and (re)use. The Bachelor programme also foresees basic knowledge about, amongst other, urban and building physics, climate design, climate systems in buildings and global dimensioning of urban mobility, green and water infrastructures. A Bachelor student is further trained to identify societal urgencies, digital opportunities and to critically and ethically reflect, research and communicate. Scientific and systemic approaches are further elaborated in the Master's programme where students can specialize in Architecture, Urbanism, Architectural Engineering and Technology, Landscape Architecture, and Management in the Built Environment. The education in Management in the Built Environment (MBE 2023) focuses explicitly on working with end users and stakeholders towards a sustainable built environment. Amongst other, Master students explore and assess solutions for the development of management of buildings, portfolios and urban areas.

According to the setting of Masters education (TU Delft 2022:2), an MBE graduate has thorough knowledge of design and construction management (DCM), real

estate management (REM), housing management (HM) and urban development management (UDM). An MBE graduate achieves advanced knowledge, intellectual and inquisitive skills and competencies for understanding, researching and analysing societal, legal, financial, economic, commercial, entrepreneurial, policy and informational processes and procedures (TU Delft 2022:2). Combined with design skills and collaborative settings, this supports MBE graduates to design, plan, and decide about appropriate context-sensitive management processes, business models and governance strategies in a particular context (TU Delft, 2022:2).

5 Discussion: Detected Educational Challenges and Opportunities

The research confirms some critical factors that can enable universities to embed environmental sustainability into university areas, such as: a strong policy environment, resourcing of strategies, and encouragement of leaders and environmental sustainability advocates (Ralph and Stubbs 2014). For universities to comprehensively address sustainability, a 'learning for sustainability' approach needs to be embedded across every aspect of institutional operations in a synergistic way (Ralph and Stubbs 2014). In the field of construction and real estate management education it is perceived that environmental and social sustainability are still poorly embedded compared to the economical perspective.

The various initiatives respond to needed changes regarding engineering disciplines as pointed out by (Kamp 2020) as well as the moral and ethical responsibility of universities to develop and facilitate the use of the new technologies to empower society, particularly with regards to social change and social justice (Kamp 2020). Educational initiatives develop social consciousness by getting familiar with the human aspects and ethical issues, and interdisciplinary, systems thinking and interpersonal communication skills. Instructors are regarded as facilitators and collaborators rather than sources of authority (El-adaway et al. 2015).

Our experiences confirm that to achieve more comprehensive education for sustainable development, open communication among all stakeholders should be facilitated (Weiss et al. 2021). Feedback as well as reflection should be encouraged, and strong informal collaboration and communication can compensate for a lack of formalized leadership support from the top (Weiss et al. 2021).

Given the fast progress of sustainable technologies, design solutions and management practices, a constant renewal and flexibility of curriculum design is perceived, which is mainly focused in the development of elective courses and new educational initiatives. The theme of environmental sustainability inherently brings interests from colleagues across departments and faculties and their expertise on sustainable management topics could be more integrated, looking systematically at technological, financial, economical, management, policy, social, design, institutional,

behavioural, and other perspectives. The adoption of innovative solutions and sustainable measures by various stakeholders as presented in electives would demands a systemic review of changes in the standard curriculum that ought to be made institutionally and behaviourally.

Combining the strengths of the various bottom-up educational initiatives and aligning their content would certainly benefit developing a more integrated view on implementing education for sustainable construction and real estate management. Next to energy and material sustainability, social sustainability and affordability are being more emphasized in management education. One way to approach these challenges could be to identify the educational needs on various scales (building, portfolio, district), with particular attention for various related core stakeholders interests. Now environmental sustainability is mainly positioned as one of the many goals or context aspects of management in the built environment that are related to other goals, such as safety, reliability, adequateness, affordability, sufficiency and efficiency of the designed, constructed and used buildings, assets and portfolios.

Looking at the perceived instability and wide range of elective courses, a more holistic view on addressing environmental sustainability challenges seems to be needed in the standard curriculum, including for example the development of socially sustainable practices, changing policy developments, bottom-up stakeholder initiatives, process innovations, supply side perspectives and collaborative entrepreneurship, just transition and spatial justice challenges, economical behaviour, design and management of public goods, and so on.

Given the need to use integrated approaches to achieve environmental sustainability, thematic overlap now can occur in various courses, leading to a perceived lesser need for new elective courses on environmental sustainability. On the other hand, new active teaching methods such as those developed in the Summer School, student competitions such as the Solar Decathlon, and MOOC's are popular for students. Moreover, there is a trend to test sustainability principles within a specific local context and to analyse and reconstruct decision-making processes. Enthusiasm for cross-border, inter-disciplinary and intra-disciplinary working was also detected with students, professionals and teachers alike. More emphasis could still be placed on how to effectively incorporate blended and on-line education in management education, although this might increase the needed staff effort.

Moreover, internal reflection groups showed that there is an ongoing debate whether sustainability should be a separate specialisation or integrated in the standard curriculum. Pathway for new specialisations can be challenging as they might be perceived as competing with regular programmes; initiatives have to prove that a sufficient number of students can be reached. In practice, temporarily optional courses can provide a response to the curriculum needs, as new subjects need time to gain their place in the curriculum. Further elaboration of principles and implementation of teaching methods from isolated initiatives within the Master and Bachelor education could lead to optimization of the standard curriculum. This should be strategically planned in co-creation and well-balanced with shared responsibilities. Course revisions can be related to the management of construction phases from initiative to development with a focus on the building scale, or related to the phases from

maintenance to programming of operations with a focus on the asset and portfolio level.

6 Conclusion

There is a high need for competencies to manage visions, tactics and operations including energy and sustainability requirements at the level of individual buildings, facilities, building portfolios, districts and energy systems. This requires the development of an adapted academic curriculum for construction and real estate management. This paper explored how construction and real estate management education is integrating environmental sustainability, using as a case the development of education on Management in the Built Environment at the TU Delft Faculty of Architecture and the Built Environment.

Bottom-up initiatives showed that the developed education responds to design, technological, business and urban sustainability challenges, managing stakeholder relations and developing strategies to cope with the energy transition and other policy and governance challenges. Experiences show that facilitating behaviour change, adapting management practices to include stakeholder dialogue, innovation management for sustainable business development, and projected institutional revisions based on policy development can be core issues for the curriculum development. This can be facilitated by students working in multidisciplinary teams and competitive simulation environments, and teachers empowering participative teaching methods, vision formation and strategic thinking, and interdepartmental, cross-faculty and cross-cultural knowledge exchange.

On the other hand, environmental sustainability education is perceived as being still incomplete and scattered in various courses with a certain lack of alignment top-down. The university has a vision on integrating sustainability in its curriculum, but currently bottom-up environmental sustainability initiatives are more likely to be positioned in elective courses and MOOC's, which has the disadvantage that only a limited amount of regular students are reached. Standard curriculum changes are often difficult to achieve as the sizes of the Bachelor and Master programme are fixed. Adding a new theme to the curriculum would imply that other themes get less attention.

In conclusion, this paper showcased that further efforts are still needed for systematically introducing environmental sustainability in education. The research finds that middle-out it could be explored further how the regular curriculum can be improved based on the experiences from the various bottom-up initiatives and top-down developments, exploring the connections between research, education and application of environmental sustainability on various scales and levels.

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