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Maturation of sustainability in engineering faculties – From emerging issue to strategy?

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ABSTRACT

Although higher Education Institutions (HEIs) have seen a blossoming of sustainability initiatives of various kinds in recent years, the variety of institutional and socio-economic contexts brings about an equally plural interpretation and implementation of these sustainability change processes. This study focuses on the organizational change processes in six different universities across five countries (Belgium, Chile, Finland, Sweden & the United States of America), by way of a qualitative analysis of in-depth expert interviews. We apply the social issue maturation framework to identify, describe and assess patterns of change across HEIs, with a focus on engineering schools as the inherent inter-disciplinarity of engineering provides a promising entry point for sustainability reflection and action. Our findings indicate that sustainability processes often begin as ad hoc processes which grow and mature over time as a range of different actors join in. The commitment of a small team of 'sustainability champions' is a key factor for success, as is at least a tacit support from the institution's hierarchy. Sustainability in HEIs is increasingly connected with sustainability in the private sector and with other public actors. Moreover there is a growing acknowledgement of the interactions between society, industry and academic engineering programs and projects. Ideally, sustainability change processes are gradually up-scaled from isolated efforts to coordinated actions, involving both academic and non-academic actors within and outside the institution.

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1. Introduction

Sustainability is an idea, a process as well an overarching objective that ideally allows to address the current situation of concatenated ecological, social and economic crises, labelled together as 'global change' (Biggs et al., 2011; Hugé et al., 2016). The variety of sustainability interpretations as well as the diversity of ways in which the concept is used, makes it attractive and explains its enduring relevance (Hugé et al., 2013). Over the past years sustainability initiatives (defined as initiatives in which sustainability is claimed to be a central element) have flourished in many organizations worldwide, including in higher education institutions (Lozano et al., 2013, 2014; Verhulst and Lambrechts, 2015).

But what are these sustainability initiatives or -sustainability change processes-about? The diversity of stakeholders engaging with sustainability gives rise to a multitude of interpretations, ranging from *status quo* to reformist and radical agendas, ranging from mainly eco-centered to mainly social-centered interpretations (Hopwood et al., 2005), and from an economics-centered to an adaptive management or predict & control-approach (Halbe et al., 2015). Hence it is challenging to pinpoint any hypothetical exact definition of sustainability (Glavic and Lukman, 2007; Hugé et al., 2016). This 'constructive ambiguity' (Robinson, 2004) allows sustainability to be translated in a range of context-specific actions adapted to the needs and possibilities of a diverse set of institutions and stakeholders (Sylvestre et al., 2014). We adopt the conceptualization of Griggs et al. (2013) as a basis for discussion: sustainability (or sustainable development) is '*development that meets the needs of the present while safeguarding Earth's life*-support *system, on which the welfare of current and future generations depends*'.

Higher education institutions, students and researchers have a

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critical role to play in fostering and shaping a sustainable future as they educate the professionals of the future (Khalili et al., 2015; Stephens et al., 2008). Considering the role that HEIs play in terms of catalyzing change within societies (Waas et al., 2011), it is essential to understand how organizational change processes towards sustainability unfold in a range of HEIs, *e.g.* to identify critical success factors, triggers, tipping points and high-impact actions. Within the higher education landscape, engineering schools, faculties and departments have a special role to play in contributing to the much-needed 'transition to sustainability' (Loorbach, 2007) by fostering the combination of both deep technical knowledge and a breadth in non-technical skills (Nesbit, 2015). These calls for sustainability in engineering education are not new, but the current acceleration of global change and the ever-increasing calls for inter- and transdisciplinary research and education make this an ever-more pressing issue for engineering schools worldwide. The 1977 Tbilisi Declaration (UNESCO & UNEP, 1977) stressed the importance of 'environmental education' in the wake of the 1972 Stockholm Conference on the Human Environment, and the seminal Brundtland Report definitively launched the concept of sustainable development on a global scale. Regarding sustainability in higher education, many declarations have provided inspiration, guidance and opportunities for benchmarking and mutual learning since the early 1990s (Sylvestre et al., 2013). In the field of engineering, early calls for dialogue among engineers and between engineers and stakeholders resonate in the constructive technology assessment literature since the 1980s (Schot and Rip, 1997), while the 2004 Barcelona Declaration made an important contribution to the conceptualization of engineering education for sustainable development (EESD, 2004).

In this line of thinking, Segalas et al. (2010) call for a 'new kind of engineer' who has the skills and understanding to deal with technology as such, but also with the societal aspects of technologies.

Engineers have to keep strengthening their role of frontrunners regarding the transition from merely technical approaches to teaching and research, to integrated, adaptive and participatory approaches. The unicity of engineering disciplines, which are bound together by societal problems instead of by sets of rules and heuristics, makes engineering schools ideal hubs for change towards sustainability. Engineers are typically used to deal with a range of methods and tools that go beyond disciplinary boundaries, which allows them to acquire and apply strategic competences. The recent surge in 'disciplinarism' however, threatens the future public engagement of engineers (Mulder, 2017), although their work requires an openness and an ability to deal with different kinds of knowledge in a situation of complexity and uncertainty (Halbe et al., 2015).

If engineers are to maintain their central position in managing and shaping societal change, self-reflection and a tangible commitment to a newly conceptualized 'public good' are central. This means that the well-known problem solving reflex of engineers is to be combined with a more reflective worldview that engages with social and political dynamics (El-Zein and Henemann, 2016). This evolution of engineering education ideally requires an integration of both engineering innovation and socio-cultural change entailing an enhanced dialogue both among engineers and between engineers and other stakeholders (Sakellariou, 2016). Engineering education needs to put 'contextual awareness' at its centre. This awareness refers to the ability to view problems, actions and solutions in a broader context comprising scientific, technical, economic, social and cultural aspects (Staniskis and Katiliute, 2016).

Despite the fact that engineering schools are typically prone to practice inter-disciplinarity and societal engagement in teaching and research due to the very nature of engineering, which builds on a wide range of disciplines and methodologies (Richter and Paretti, 2009), sustainability is not yet a guiding principle for most engineering schools. Notwithstanding pioneering actions by engineering schools with regard to e.g. sustainability teaching (Watson et al., 2013), and an increased awareness among staff and students of the importance of sustainability (Sylvestre et al., 2014), in most instances a process of – major - organizational change is required in order to gradually evolve towards sustainable engineering schools.

Although higher education institutions should be innovative organizations which foster change, they tend to be conservative and resist change as they are built on paradigms such as disciplinary specialization and on the repetition of what is already known (Ferrer-Balas et al., 2010). Reconfiguring disciplinary boundaries in engineering also requires the development and promotion of new skills and competencies, ranging from complex system thinking to normative, strategic, anticipatory and interpersonal competencies (El-Zein and Henemann, 2016).

Nevertheless, engineering schools have also embraced the call for sustainability actions as a trigger for change and re-invention, acknowledging that they should strengthen their own 'learning organization'-identity and realizing both the intrinsic and strategic importance of sustainability (Ferrer-Balas et al., 2010; Hugé et al., 2016).

While the process of integrating sustainability into higher education usually entails a focus on at least one of these four pillars—teaching, campus management, research, societal outreach- (Hoover and Harder, 2015), the conceptualization and implementation of sustainability change processes in various engineering schools) is particularly diverse. This study aims to analyze the organizational change processes towards sustainability of a range of engineering schools in different contexts.

Scholars have often analyzed the processes of organizational change towards sustainability in HEIs by performing descriptive single case studies (e.g. Sylvestre et al., 2014; Watson et al., 2013), which is a logical choice given the relative novelty of sustainability in higher education and given the importance of a deep understanding of contextual specificities. Building on Corcoran's et al., 2004 criticism of possibly reductionist case studies, we apply a theoretical framework to situate and interpret the cases in our study. We apply the so-called social issue maturation framework as developed by McGrail et al. (2013), to study the evolution of sustainability awareness and ownership within and among the respective engineering schools. The social issue maturation framework articulates the process of evolving issue engagement as a sequence of observable phases, activities and outcomes, and allows to identify patterns, commonalities and differences in how the studied engineering schools engage with sustainability. The social issue maturation framework is not a linear model of change, instead it allows for the conceptualization and visualization of a broad range of evolutionary paths (for 'issues'), including linear, cyclical and emergent paths (McGrail et al., 2013). This approach allows for a realistic conceptualization of change in engineering schools, such as the potential for issues to skip stages (e.g. due to crises), for maturation to be interrupted or stopped if other issues gain prominence, and/or cycling back-and-forth between stages (Bigelow et al., 1993; McGrail et al., 2013). The framework is inclusive and its use does not exclude the use of other explanatory frameworks (such as actor coalitions for example) for organizational and policy change. Future organizational and policy paths depend on institutional dynamics (Hill et al., 2013), highlighting the relevance of a broad view on the change path of engineering schools on their way towards sustainability.

This study aims at contributing to the systematic assessment and the contextualization of organizational change processes towards sustainability in engineering schools. The specific objectives

are: (i) to characterize sustainability change processes applied in HEIs, with a focus on engineering schools/faculties/departments; (ii) to characterize interactions between actors involved in these change processes; and (iii) to systematically describe the organizational change processes by adopting a social maturation lens to look at sustainability. We aim at providing a qualitative comparative analysis that complements the existing body of knowledge on sustainability in higher education. Based on our findings, a series of recommendations and replicable good practices are subsequently suggested.

2. Methodology

2.1. Data collection

The present study utilizes information coming from two sources: i. In-depth face-to-face interviews of relevant actors involved in sustainability change processes in the selected HEIs; ii. Publicly available documentation on the sustainability change processes in the selected HEIs.

The HEIs were selected based on differences in institutional, geographical and socio-economic context. Key resource persons were interviewed in six HEIs, located in five different countries. The studied HEIs are: 1. University of Ghent, Belgium; 2. Engineering School of the University of Chile, Chile; 3. Lappeenranta University of Technology, Finland; 4. Blekinge Institute of Technology, Sweden; 5. Georgia Institute of Technology, United States of America; 6. Stanford University, United States of America.

We used semi-structured systematizing expert interviews. This type of interviews focuses on the exclusivity of expert knowledge and requires interviews with multiple experts to be able to compare and aggregate data to gain process knowledge (Bogner et al., 2009). The interviewees were also encouraged to air their personal perspectives (motives, routines, beliefs) so as to acquire explanatory knowledge on the change processes towards sustainability.

The interviews s were conducted with expert resource persons, who were selected based on their expertise and involvement in the respective HEIs' sustainability change processes. The interviews were based on a semi-structured questionnaire which was the same for every higher education institution in this study; and was then complemented by HEI-specific questions based on preliminary context-specific literature search by the authors.

The interviewed resource persons all had a good overview of the cases at hand and are called 'helicopters' by Hajer (2006), as they 'hover' above the sustainability change processes at their respective institutions. The interviewees were all experts on the topic under study, as they were responsible for the development, implementation and/or control of solutions, strategies and policies regarding sustainability in their institutions. They had a privileged access to information as well as a high level of aggregated and specific knowledge that is otherwise difficult to access (Otto-Banaszak et al., 2011). Although we acknowledge that a full and systematic account of case-specific sustainability change processes ideally requires input from other categories of stakeholders beyond experts, the exploratory and comparative character of the present study does not allow for a full multiple-stakeholder survey for all HEIs under study.

The questionnaire design is inspired by Hoover and Harder (2015) and is structured around nine features chosen to identify and to characterize HEI sustainability change processes. This approach allows us to gather detailed information regarding the organizational change processes fostering sustainability in the various HEIs. The questionnaire includes both open questions and closed-ended questions and serves as a guide for the conversation between researcher and respondent. This approach aims at avoiding bias and allows for sufficient flexibility. The structured questionnaire allows to compare and synthesize the findings emanating from the various HEIs. The questionnaire is structured as follows:

- General questions;
- Questions w.r.t. organizational culture;
- Questions w.r.t. territories, conflict and competition for sustainability;
- Questions w.r.t. collaboration;
- Questions w.r.t. importance of committed individuals;
- Questions w.r.t. individual knowledge and personal characteristics;
- Questions w.r.t. the interplay between people and structures;
- Questions w.r.t. relationships and networks
- Questions w.r.t. power issues;

The interviews were conducted by the author team during November and December 2015. The average duration of each interview was approximately 1 h. Interviews were mostly conducted at the interviewees' institution. For a list of contact details of the interviewees, see Annex.

2.2. Data analysis

2.2.1. Theoretical framework: the sustainability maturation framework

Social issue maturation refers to growing awareness of a particular issue, and to a growing ownership of that issue by an organization, institution and/or community (McGrail et al., 2013). We apply that framework to visualize and analyze the data collected on the maturation of sustainability within the studied higher education institutions/engineering schools. In an ideal-typical social issue maturation trajectory, sustainability as a social issue is still 'immature' in the early phase: it is a niche concern, associated discourses and knowledge is still forming and/or are contested. Once the issue 'matures', new expectations and norms become embedded in the organization, and an enhanced sense of ownership of sustainability ideally leads to more action to address sustainability problems (Hill et al., 2013; McGrail et al., 2013). This does not mean that all behaviors and norms will suddenly change, as the process of social issue maturation is gradual and differs greatly depending on context. There is no guarantee that sustainability will mature in a linear way – there can be cyclical and emergent paths such as the potential for issues to skip stages (e.g. due to crises), for maturation to be interrupted or stopped if other issues gain prominence, and/or cycling back-and-forth between stages. Change towards sustainability can be fragile, and is not always sustained (Mitchell, 2011). Many factors can influence the maturation path, and we use it as a way to identify patterns in the gathered data, without stating that sustainability will always be the logical end-goal of a hypothetical linear path of change.

Still the social issue maturation framework allows to diagnose and also anticipate change. It provides a structuration of observable phases that can be plotted over time and is suited for the analysis of sustainability maturation in particular (McGrail et al., 2013). The key stages inspired by the social issue maturation process used in Table 1 entail the following phases: Phase 1: Emergence; Phase 2: Popularization; Phase 3: Formalization into a governance framework; and Phase 4: Maturity, reflected in normative changes (*i.e.* the uptake of sustainability as a norm).

2.2.2. Coding and data structuring

The interviews yielded qualitative data which were analyzed through open coding (as in Waas et al. (2010) and in Hoover and

Table 1
Matrix structure for data analysis of sustainability processes in HEIs. The rows reflect the key aspects of sustainability change processes in HEI as emerging from the data. The columns refer to the various stages of the social issue maturation framework, applied to sustainability.

Key aspects/Stages	Stage 1: Emergence	Stage 2: Popularization	Stage 3: Formalization	Stage 4: Maturity
Actors				
Resources				
Values				
Drivers & barriers				
Policy & strategy of the institution				

Harder (2015)). Open coding aims to open up the data to as much potential as possible in order to identify and integrate categories of meaning coming from the grouped data (based on grounded theory (Locke, 2003)). No pre-elaborated coding list was imposed on the data, instead the data was coded in an emergent way, *i.e.* starting from the data. Through constant comparisons similar data were grouped, which allowed for an inter-institutional comparison of the key characteristics of the sustainability change processes. Based on the data collected from the interviews and the institution's official documents, a matrix was constructed to organize the findings of the qualitative coding so as to allow for comparisons. The matrix rows' titles are the result of the qualitative coding categories that emerged from the data and they describe key dimensions of sustainability processes in HEIs (actors; resources; values; drivers & barriers; institutional policy & strategy). The matrix columns reflect the stages of the social issue maturation framework (cf. Section 3.2.1). The matrix allows to identify patterns and to establish relations between the respondents' perspectives, and facilitates the interpretation and comparison of context-dependent change processes towards sustainability at various HEIs.

2.3. Contextual information on the selected HEIs

This section presents background information on 'sustainability in higher education'-initiatives in the six selected HEIs based on publicly available documents and websites outlining the HEIs' sustainability policies. Table 2 is not meant to provide exhaustive information. Only illustrative initiatives are mentioned, based on what the HEIs emphasize in their online sustainability communication, as accessed in August 2016.

3. Results & discussion

3.1. Results

The in-depth interviews were trans-scripted and subsequently coded. The key structuring aspects that emerged from the data include: actors, resources, values & ideas and drivers & barriers – these form the rows of Table 3. While some of the information was inevitably difficult to assign to a particular 'aspect', and while there is some overlap (e.g. some key actors are facilitators; particular actors hold particular values; others decide about resource allocation *etc.*), overall the coding exercise allowed to identify emerging patterns in the data. The columns of Table 3 refer to the sustainability maturation framework presented in Section 2.2.1.

Table 3 provides an overall synthesis of all sustainability change processes in the six HEIs. Numbers refer to the HEIs (ordered alphabetically based on the country in which they are located): #1 Ghent University, Belgium; #2 Engineering School of the University of Chile, Chile; #3 LUT, Finland; #4 Blekinge Institute of Technology, Sweden; #5 Georgia Tech, USA; #6, Stanford University, USA.

4. Discussion

4.1. Sustainability change processes at engineering schools explored

After an *in-extenso* review of each HEI experience, it appears that institutional change processes towards sustainability vary depending on local, institutional and cultural realities. As these change processes are inherently dynamic, the 'informed snapshot' for each HEI also reflects the different degrees of maturity among HEIs. However, our primary aim is not to compare the hypothetical scores of different HEIs. Rather, we aim at identifying and describing patterns that can inform change processes and lead to a further 'maturation' of sustainability in engineering schools. This section follows the structure of Table 3, describing the key aspects of the HEI sustainability change processes, and is complemented by a concluding section outlining the change process in a nutshell.

4.1.1. Actors

The reasons that trigger a sustainability change process vary, ranging from students' pressure to formal top-down institutional efforts, often reflecting the degree of sustainability awareness of different groups and decision-making levels (see also Sylvestre et al., 2014). There is not one dominant actor category whose support is absolutely required, yet strong –personal and/or formal- linkages between students, faculty staff and administrators make it possible to move on much faster, as classical hierarchically motivated slowing maneuvers are less prevalent then. The relatively high staff turnover at higher education institutions may make sustainability issues and interpretations especially dynamic, with coalitions of sustainability advocates forming and dissipating fast, as is also mentioned by Mitchell (2011). Some respondents also stressed the unexpected side effects, such as enhanced collaboration: "*Sustainability is very important in bringing people together, it has that potential and we have already seen the fruits of that potential*". Sustainability also helps to attract more students in an increasingly competitive higher education landscape. Moreover as a result of sustainability change processes, unexpected coalitions can emerge among professors, students, school staff and other HEI members.

4.1.2. Resources

Realistic and clear budgeting is a key point in the popularization phase so as to avoid obstacles related to cost, especially when facing a critical audience in times of dwindling academic funding. Different funding arrangements support sustainability change processes; these include direct Department funding, funding from the central HEI administration, project funding, governmental support, private support, or voluntary work and community support. For example, a "Green Fund" originating from the central administration can be set up, as it "provides *a budget which allows to make investments, specifically aiming at reducing utility bills*". In the case of some public universities, money may come directly from the state and a significant amount of funding can possibly be found from external sources - typically linked to research projects or through federal grants structured as a triple public private partnership (university-state-private sector).

4.1.3. Values & ideas

The existing variety of definitions of sustainability and the concept's relatively open interpretation provides various starting points and visions about what to do and about how to do it. This was clearly visible in the range of interpretations, values and ideas regarding sustainability as held by the respondents. The indicative classification of sustainability interpretations provided by Reed (2007) allows to identify which kind of sustainability framing

Table 2
Overview of sustainability in higher education-status in the six selected HEIs.

HEI	Country	Strategy & vision	Teaching & research	Campus management	Reporting
University of Ghent	Belgium	• Sustainability in university policy; • Memorandums for Sustainability (2012, 2014);	• University-wide sustainability course; • Inter-disciplinary research centre & project funding;	• Sustainable campus initiatives ranging from mobility to energy, based on university-wide Transition Initiative;	• First sustainability report in 2013; • Using G4 guidelines of the Global Reporting Initiative;
Engineering School, University of Chile	Chile	• Engineering School has its own Sustainability Policy	• Sustainable Engineering minor for graduate students; • Sustainability diploma for practitioners;	• Office of Engineering for Sustainable Development (°2014) • Sustainable Campus Commission;	• Brief annual informal reporting (disseminated internally);
Lappeenranta University of Technology (LUT, 2015)	Finland	• Strategy 2020, built on 4 key themes (fossil fuels, water pollution, waste, Europe in the world);	• LUT Green Campus Initiative (education & research);	• 'Best campus award' granted by the International Sustainable Campus Network (ISCN);	• LUT Sustainability Report (2015) structured around International Sustainable Campus Network (ISCN) requirements;
Blekinge Institute of Technology	Sweden	• Sustainability is institutional focus;	• Master in Strategic Leadership towards sustainability; • Department of Strategic Sustainable Development (Fac. Engineering);		
Georgia Institute of Technology	USA	• 'Serve, Learn, Sustain'-Plan focuses on creating sustainable communities;	• Centre for Business Strategies for Sustainability;	• Office of Campus Sustainability (°2007) • Sustainability Task Force to foster institution-wide sustainability 'culture';	• Green Revolving Investment Tracking System (energy efficiency & resource use assessment)
Stanford University	USA	• Sustainability as core value, knowledge focus, and minimization of environmental impact (vision)	• Centre for Sustainable Development; • Department of Sustainability & Energy Management;	• Sustainable Stanford (portal) presents all info on sustainability actions on campus;	• Sustainability at Stanford: Year Review, available, plus: operational sustainability metrics summary;

prevails in each HEI. These can vary from conventional (reductionist), green, sustainable, restorative, regenerative, natural system-based to holistic (integral) interpretations. The reviewed experiences show that most change processes start with some fairly conventional idea, *e.g.* a recycling initiative. In other and fewer cases, when the process begins as part of a university-wide plan, it tends to be more holistic: *e.g.* the sustainability initiative relates with campus resources utilization, with academic programs and with infrastructure design. These debates reflect the particularity of the humanistic and technocratic approaches to sustainability in engineering, which are subject to cyclical change, depending on institution-specific actor constellations, and on societal pressures and influences. A wide range of approaches to sustainability is present to different degrees at various points in time in the various studied engineering schools. While all interviewees of this study reflected a kind of pervasive cautious optimism regarding sustainability maturation in engineering schools over time, survey results indicate that in reality, engineering students' concern in sustainability-related public welfare concerns actually fall over time (Cech, 2014). This finding emphasizes the need for complementary research tracks and caution regarding overoptimistic renderings of sustainability change processes. In the same vein, the alternative university ranking system developed by Lukman et al. (2010) is worth mentioning, as it could provide an incentive for HEIs to position themselves actively with regard to research, education and environmental quality criteria.

4.1.4. Drivers & barriers

The drivers and barriers underpinning sustainability change processes at HEIs have been studied by *e.g.* Lozano (2006), Hoover and Harder (2015) and Arroyo (2017). Recurrent barriers include: a lack of leadership, budgetary constraints, deficient organizational structure, inertia and resistance; whereas communication, open-mindedness and inter-disciplinary collaboration are identified as key drivers. Some of these studies explicitly acknowledge the role of 'human' factors in change processes. The present study is based on a combination of document analysis and interviews with resource persons, which proved to be a feasible approach that yielded dense qualitative data. The focus being on institutional transformation processes, the social issue (*in casu* sustainability) maturation framework contributed to a better understanding of these HEI-wide change processes, and in particular on engineering schools.

Commonly cited drivers underpinning a sustainability change process include: a commitment towards 'doing good for society'; a commitment towards students' quality of life; cost/financial savings; resources conservation (mostly energy and water). The respondents cited illustrative examples where "*sustainability grew from the start, so it was part of the university's development process*" or: "*as the university was participating in national ranking systems and parameters around sustainability", this* triggered decisions to formally assign someone to a sustainability initiative. In the emergence phase, one can find either collective action where "*the first initiative arises from a group of students, who originally became organized with the idea of promoting recycling. They also noticed other problems related to the environment that needed a broader framework, so they adopted the Sustainable Campus concept*"; or individual initiatives such as "*there was one professor who had the motivation and this was followed in the next period, by another professor who was willing to increase the scope*". When new HEIs or schools/departments are created, this offers a unique opportunity to integrate sustainability from the start. One respondent stated: *"Things can be done differently in a new university. The low level of hierarchy of the institution made it easier to talk to the decision makers, there was a pioneering spirit and an open-mindedness to new ideas*".

Table 3
Synthesis of results of all six HEI sustainability change processes.

Key aspects/ Stages	Stage 1: Emergence	Stage 2: Popularization	Stage 3: Formalization	Stage 4: Maturity
Actors	• Sustainability/Environment Coordination Unit (2, 1) • Think Thank on sustainability (1) • Student group on sustainability (2, 1) • Emergence in curricula & teaching (3) • Set-up of a neutral Sustainability department (4)	• Networking between staff, students & society (2, 6, 5, 1) • Coverage in national newspaper (1) • Simultaneous formal and informal actions (1) • Advisory Commission to the Dean set up (2) • You need sustainability champions as much as coordinator (6)	• Support from scientific staff & research (1) • Decentralized HEI creates opportunities for piloting sustainability ideas (1) • Involvement of everyone is key, not just like-minded people (1) • Office of Sustainability created/ one person in charge (2) • New dean led to linkage between overall HEI strategy & sustainability (3) • Young academics are pro-sustainability (3) • International network of universities allows for benchmarking and new ideas (5, 3) • Symbiotic relationship with the private sector (4, 5)	• Support from leadership (5, 1) • University-wide coalition (1) • Sustainability not associated with one particular faculty (1) • Increasing involvement of academics (2) • Multi-actor dialogue is now institutionalized (2)
Resources	• No financial support whatsoever (1) • Seed money for sustainability research provided (4)	• Fear voiced that sustainability would mean extra cost (1) • Government funding for sustainability research is key (6)		• Support for the sustainability initiative's coordination after formalization (3, 2, 1) • Own budget for the sustainability office (5)
Values & ideas	• Sustainability transition idea as rallying concept (1,3) • Sustainability moves from a technical to a change concept (6) • Culture of creation and experimentation is a plus (6)	• Loss of power is seen as bigger threat than sustainability ideas as such (1) • Sustainability brings people together (2) • Sustainability culture is technology- and business-oriented (3) • Sustainability is about flows rather than objects (6) • Cultural shift brought about by students on sustainability (5) • Use of a back-casting approach to sustainability (4)	• Sustainability itself remains multi-interpretable (2) • People are increasingly willing to use the 'sustainability' label (3) • Take sustainability beyond its usual association with the environment (5)	• Sustainability promoted as key value of the HEI (1) • Sustainability allows to talk to all actors at the HEI (2)
Drivers & barriers	• Credibility of Coordination Unit facilitates sustainability initiatives (6) • Low number of sustainability specialist staff (3) • Institutional inertia (3) • Collaboration between departments is key for sustainability initiatives (3) • Benchmarking w.r.t. other HEIs (5) • Support & buy-in from all sides of the HEI community (5) • Lack of funding is obstacle (4)	• Accusations of stealth decision-making (6) • Accusation of fundamentalist 'green' thinking (6) • Constant and long-term negotiation with all actors solved issues (6) • Support of authorities can in fact be mere tolerance, without embedding sustainability (2) • Publications track record is key, not sustainability (3) • International networks facilitate sustainability initiatives (5)	• The more collaboration there is, the less risk there is for internal conflicts (2) • Need for both sustainability champions and institutional support (3) • Communication and marketing are important (5)	• No official recognition of sustainability efforts, no impact on measured track record, no rewards (2) • Rewards are indirect, e.g. a strong sustainability track record attracts new students (4)
Policy & strategy of the institution	• There needs to be an enabling environment for bottom-up initiatives (3)	• Linking overall HEI strategy/master plan & sustainability-enhancing processes is key (2, 1,6)	• Endorsement by HEI Board of Directors (6) • Matching timing of new HEI Strategy & sustainability initiative (6) • Communicating sustainability successes is key (3) • Curriculum development linked to overall sustainability policy of the HEI (4) • Mainly project-based sustainability collaboration (4)	• HEI development itself in part based on sustainability (4) • Visibility of sustainability actions (incl research) enhanced as link with strategy of the HEI is present (3) • Working on sustainability is now a 'politically relevant' issue (3) • Membership of Board of Directors of a sustainability champion helps (4)

4.1.5. Policy & strategy of the institution

In the popularization phase, it is critical to start planning the long-term management of the change process. How will the sustainability change process be run? One must take into account the perception of power loss or power sharing among traditional hierarchies within the HEI, which can be countered by creating formal or informal advisory commissions and networks in a spirit of open communication. Moreover, the plurality of sustainability interpretations will not suddenly disappear once a sustainability change process is on. An open-minded, non-fundamentalist approach to sustainability is necessary, which can be realized through forums, meetings and easily accessible events.

Generally, it appears that the popularization phase is a critical step. It is the phase in which sustainability awareness and actions need to break out of the inner circle of HEI-actors who have been thinking, talking and acting about this for a long time. Too much coordination and formality at this stage can halt or slow down the change process, while an overly loose organization may make it impossible to broaden the support base for sustainability. The central HEI administration and the Board of Directors typically harbor at least a few conservative people from a sustainability perspective. The common bottom up approach to sustainability change processes may clash with university traditions. A fear to lose grip over decisions with university-wide implications can hence surface. Real or perceived loss of power can become a barrier to change. At this stage, there are also concerns about the fact that the discovery of negative findings could cast a shadow on sustainability efforts already underway (Mitchell, 2011). This may explain why some sustainability advocates do not want to be absolutely transparent regarding how particular decisions were made. Projecting an image of fragility needs to be avoided in their view, and strong (over-)confidence about the solidity of sustainability maturation may ensue.

Formalization requires -at least some-formal recognition of the sustainability change process by the administrators at faculty or HEI-wide level. Most cases in our study indicate that the sustainability change processes are typically initiated at the faculty level, as a standalone process, and not at the university-wide level. Nevertheless collaboration between faculties does happen when the central HEI administration delivers guidelines or strategic plans. One responded stated that "*initiatives that can flourish at different faculties do not necessarily influence the rest of the University*". The following experience illustrates a frequently encountered pattern in a sustainability change process:

> 'The sustainability approach in education started within the mechanical engineering department, and at that time I was a member of the board of directors of the university, so coming into such an important decision-making unit at the top level enabled the university to realize the importance of sustainability and even more, to make it explicit in its vision. At the same time, sustainability operational policies and strategies were developed. So I would define it as a two way process, where sustainability spread from the mechanical engineering department, to the engineering school, to the top level, and then down dissipating into other units of the university.'

The creation of a centrally endorsed office in charge of sustainability change processes typically leads to a stronger process of incorporation of sustainability-related skills and competences in the profile of HEI staff. These units allow to create an interdisciplinary knowledge base and to foster a pluralist sustainability discourse. Moreover it formalizes the acknowledgement of sustainability at the HEI-wide level and sends out a strong signal to staff, students and outsiders. Sustainability offices also provide room for experimental approaches and are perceived as being much more accessible than sustainability-focused research departments *sensu stricto*.

4.1.6. The change process in a nutshell

Maturity in sustainability awareness is reached when there is an in-depth, mainstream understanding and ownership of sustainability. This is reflected in the diffusion of new behavioral patterns, in more widespread innovation and raised expectations (McGrail et al., 2013). Typically maturity is reached faster when the sustainability change process is triggered at an institutional level, and slower when students or individuals initiate it. However when the right 'sustainability entrepreneurs' simultaneously emerge at different levels in the HEI hierarchy and collaborate, the change process can be surprisingly swift and strong. These 'sustainability entrepreneurs' (the term is derived from Kingdon's (2011) policy entrepreneurs) are sustainability advocates that are willing to invest resources (time, energy, reputation, money) to promote their cause. They recognize possibilities for change, they see the opportunities to combine agendas and they are in a position to convince others to join them in triggering change processes. In the studied HEIs, often initially isolated sustainability entrepreneurs triggered sustainability initiatives utilizing existing structures and resources.

Regardless of the phase of the sustainability change process, one can distinguish collaborative and competitive initiatives, reflecting a different degree of information sharing, joint actions and coordination. Mixed strategies appear to be successful, as one respondent states: "*a department is locally-driven, it has this ability and freedom to do what it wants to do*" but the same respondents also remarks that: "*the real change comes from linking with the other schools and departments, so it's the web of webs that crosses over and that we have been creating which are very relevant to bring about sustainability*".

Further general recommendations emerge from the lessons learned in the studies HEIs: respondents stress the participation of students, academic and administrative staff. Ultimately –when reaching maturity-all core dimensions of a HEI should be covered: teaching, research, campus operations and outreach (in line with Hoover and Harder (2015)).

Although HEIs have different contexts and structures, the core element of all of the studied cases is the importance of some key aspects: a dedicated team of 'sustainability entrepreneurs', continuous interaction among all HEI actors, the creation of a sustainability office of some kind, a predictable budget, alignment with the topics of the imparted careers, formal networks and open and recurrent communication on sustainability on campus and beyond. Still there are many roads to sustainability (Barth, 2013), and there is not one single trajectory that fits all institutional contexts or that is able to address all specific barriers to and drivers of sustainability change. However, the initial inter-disciplinarity of any engineering challenge offers a key entry point for sustainability change processes.

4.1.7. Strengths & limitations of this study

From a methodological perspective, qualitative expert interviews have a strong theoretical backing (Bogner et al., 2009). Interviews allow to elucidate expert information, opinions and judgements, and are widely used in research with regard to sustainability in higher education (e.g. Barth, 2013; Hoover and Harder, 2015; Waas et al., 2011). Interviews using semi-structured questionnaires allow researchers to gather comparable and reliable information (provided the recruitment of interviewees is transparent and their qualifications can be verified) at relatively low cost (Qu & Dumay, 2011). However, data gathered from interviews cannot be lifted out of the contexts in which these data were gathered without caution. Exploring an issue and accessing specific information can be done with interviews, but ideally these interviews need to be complemented with other data-gathering methods (quantitative surveys, Q methodology, time series analysis) in further research stages. We minimized researcher bias by using the same format of semi-structured questionnaire in each interview; and minimized the inherent risks of the interviewees's possible lack of sincerity by cross-checking their assertions with publicly available information whenever possible. As our study is the first to apply the social issue maturation framework to sustainability change processes in engineering schools, we opted for qualitative systematizing expert interviews (following the typology of Bogner

et al., 2009). Future research is needed in order to increase our understanding of sustainability change processes in engineering schools and in order to identify generalizable patterns of change.

In order to reflect on the potential generalization of our findings, we compared our findings with available literature on sustainability change processes. Notwithstanding the diversity of experiences in different contexts, examples from the literature do support some of our own study's key findings: there appears to be no blueprint approach for sustainability change processes (Brinkhurst et al., 2011; Mitchell, 2011); key individuals or 'critical leaders' are required to achieve lasting progress towards sustainability (Brinkhurst et al., 2011); a forum for discussion and communication needs to be created (Holmberg et al., 2012) and a clear commitment from a wide range of HEI actors is required (Holmberg et al., 2012; Sharp, 2002). Our findings did not allow us to identify the importance of societal outreach (beyond higher education institutions) as an element of commitment to sustainability (Broussard and Bliss, 2007); nor did our study give clear answers to the desirable degree of institutionalization of sustainability change processes and how this may interfere with bottom-up approaches (Brinkhurst et al., 2011; Sharp, 2002). A case-by-case time series analysis of the actual change processes at the various institutions would be interesting, but lies beyond the scope of the present study. Furthermore, the design and application of institutional assessment tools would allow to measure the maturation of −aspects of-sustainability in a semi-quantitative way (Shriberg, 2002; Arroyo, 2017).

In summary, the methodological choices and the application of a descriptive framework of the present study allowed us to gather relevant information and to identify patterns in sustainability change processes in various engineering schools.

5. Conclusion

As anthropogenic global change continues unabated, the responsibility of higher education institutions (HEIs) in contributing to address this change is now increasingly recognized. In order to act effectively and purposefully, sustainability is still a most relevant concept and idea, from an environmental, social and economic perspective. All over the world, HEIs have initiated sustainability change processes that have succeeded to some degree in integrating and fostering sustainability in teaching, research, campus management and/or societal outreach. Within HEIs, engineering schools have both a special responsibility and a particular propensity to act towards sustainability, because of the inherently interdisciplinary and challenge-based conceptualization of engineering. The application of the social issue maturation framework to sustainability change processes allows us to make sense of the context-dependent experiences of six institutions.

Sustainability change processes typically emerge as ad hoc processes which grow and mature over time. In case of newly established institutions or schools, sustainability is incorporated from the beginning, leading to a quick uptake of sustainability norms and behavior. In the majority of studied cases though, the integration of sustainability comes along with the modification of existing structures, habits and working methods, which creates many challenges related to the involved actors, the available resources, values & ideas and strategic choices to be made.

While the diversity of experiences and lessons learned is a necessary quality of the inherently experimental learning-by-doing approach underpinning sustainability change processes, some patterns emerge. In the emergence phase, communication and networking among different categories of actors is key in order to maintain an open and pluralist interpretation of the contested sustainability concept. The popularization phase is built on a broadening of the support base and on the planning of future management steps. The next step entails formalization, in which a commitment from the central administration and the set-up of some type of sustainability office structure is key. Finally, in order to achieve maturity in the organizational uptake of sustainability, a network of interlinked, innovative sustainability entrepreneurs is necessary. Sustainability maturation is not a linear process, and there can be setbacks, pauses and accelerations at any time, especially due to changing actor constellations and emerging "coalitions of the (un-)willing".

The future of sustainability change processes in higher education institutions, and in engineering schools in particular will be shaped in part by the connections that these build with external actors, both private and public. The interactions between society, industry and academic −engineering- will be key. Given that reward mechanisms are usually not in place, in order for sustainability to become fully integrated into the academic and operational functions of all schools, a strong and shared commitment is necessary. Ideally, sustainability initiatives would evolve from isolated efforts to coordinated actions between academic and non-academic actors within, and outside the institution. This study provides new information on the design and implementation of sustainability change processes but is limited by the fact that the respondents did express their own perception and developed their own narrative of the sustainability initiatives they were involved with. In a future research stage, an independent evaluation based on even more diverse sources of information, and the application of institutional assessment tools is advisable to enhance and finetune our understanding.

Future research is needed on the context-specific interpretations of sustainability in a variety of contexts; on the identification of possibly competing interests between involved actors and on processes to find common ground; and on the practicalities of organizational change processes towards sustainability. Building on a gradually developed knowledge base on the experiences of engineering schools and higher education institutions in general, from all over the world, sustainability initiatives will hopefully become ever more numerous and effective.

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Annex. : List of interviewees

- Prof. Göran Broman. Head of Department − Strategic Sustainable Development Director - Sustainability-Driven Innovation Research Group. Director - Centre for Sustainable Product-Service System Innovation. Blekinge Institute of Technology. Sweden.
- Anne Rogers. Sustainability Program & Portfolio Manager. Office of Campus Sustainability. Georgia Institute of Technology.
- John Barton FAIA. Director, Stanford Architectural Design Program. University of Stanford.
- Prof. Lassi Linnanen. Lappeenranta University of Technology. Finland.
- Dra. Maisa Rojas Corradi, Professor. Geophysics Deparment. University of Chile.
- Riet Van de Velde, Environmental & Sustainability Coordinator, Sustainability Transition initiative (Transitie UGent), Ghent University, Belgium.

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