Strategies for Education for Sustainable Development
– Danish and Australian perspectives

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Abstract
If we are to provide sustainable innovations for future societies, we need engineers who are able to think and act beyond pure technical competence. This is stressed in political and accreditation frameworks all over the world, and universities are trying to respond to these demands – however, Engineering Education for Sustainable Development (EESD) strategies seem to have a hard time moving from the rhetorical level to the practical level – the overview of sustainability practices and the sense of what “we” should do in terms of EESD seem fragmented and even sometimes blurred.

In this paper, we will systematically compare strategies for Engineering Education for Sustainable Development (EESD) in Denmark and in Australia, considering the similarities and differences in the institutional frameworks and not least EESD practice. Network Theory provides a platform for developing a conceptual framework for EESD, where the actors, activities and resources related to EESD are characterised at both university and national levels.

By document analysis, we provide an overview of institutional frameworks in Denmark and Australia, and we draw on literature and gather results across several studies the authors have been engaged in, including document analysis, case studies as well as action research of curricula change and EESD practice at Aalborg University, Denmark and RMIT University, Australia respectively. Based on this comparative analysis, it is concluded that by comparing these different HEI EESD networks we can get only an overview of current EESD initiatives, but we might also challenge the present understanding of the EESD profile at the university level and, by comparing with other HEIs, point to potential change.

Keywords: Engineering Education, Sustainability, problem based learning, system thinking, capabilities.

1. Introduction
The overall sustainability challenge facing our post-modern society in the 21st century calls for a paradigm shift towards an ecological paradigm for education (Orr and Sterling, 2001). This ecological paradigm is characterised by development and action-orientation; critical and creative inquiry; reflective and iterative learning; an indicative and open curriculum; learning in groups, organisations and communities; and a democratic and participative environment (ibid).

A decade after this statement and at the end of the United Nations declared decade for Education for Sustainable Development (ESD), different approaches and integration strategies for ESD have developed slowly, and in a fragmented manner, throughout the world. The differences in strategies are not surprising due to different political and institutional frameworks, which provide different conditions for the way educational practitioners integrate sustainability into different educational programs. However, if the strategies are to develop and diffuse, more comparative research is needed to clarify potential synergies and degrees of transferability. This paper seeks to point out synergies between such strategies, even across continents, in the context of engineering education, with the intention to improve EESD.

Dowling et al. (2009) link the understanding and learning of sustainability to a new interdisciplinary approach using systems engineering. As systems engineering provides a
‘whole systems’ perspective, integrating different disciplines and requirements (Shamieh, 2011), it serves a purpose of contextualising engineering products beyond the technical problem to be solved – to include the larger complex societal systems and complex challenges such as sustainability of society, of the environment and of the economy.

At the same time, systems engineering allows for subsystems to be designed in a disciplinary fashion – with clear interfaces to other subsystems (Shamieh, 2011). Experiences from Australia shows that systems engineering, as a strategy, provides a framework for bringing sustainability cases into the classroom, and lets the students address these cases with a clear distinction and link between interdisciplinarity and the engineering discipline (electrical, mechanical, civil, etc.).

Another new approach to respond to the sustainability challenge is presented by Jamison et al. (2014) arguing for hybrid learning and an integrated mode of Engineering Education implying increasing emphasis on contextual knowledge, cultural awareness and sustainability agency as well as professional identity and scientific-technical competence. Experiences from Aalborg University, Denmark, have shown that problem based learning (PBL) can be used as a platform for this integrative mode with its focus on real-life problems and self-directed project work, as it calls for contextualisation, collaboration and agency. Students are not only getting prepared for agency, they practise agency, as they interact with surrounding stakeholders and thereby contribute to the development of society in general (Graaff and Kolmos, 2006).

Such strategic frameworks are important either to plan for EESD or to reflect on the type of response to the sustainability challenge. However, it can be difficulty to reflect on the implications of an EESD strategy without the overview of what is actually going on in the specific context. If what we could call the patchwork of EESD institutions and practices and their interrelation seems blurred, then statements in visions and missions are trapped in rhetoric without clear relation to the every day life of the university. Furthermore, the overview of what is, does not necessarily provide a picture of what could be, whereas a comparable framework for EESD institutions and practice would allow potential developments to be revealed. Based on this motivation the following research question has guided the study:

*How can a conceptual framework based on network theory provide first an overview of EESD initiatives, and second be used to question current (local) standards and to seek new EESD practices based on inspiration from elsewhere?*

The purpose is to emphasise the need for exploring, explicating and exploiting the synergies of different strategies across continental borders, as comparative studies will raise awareness of diverse practices.

### 2. Materials and methods

In this paper, we will systematically compare these strategies to Engineering Education for Sustainable Development (EESD) in Denmark and Australia considering their institutional frameworks and the type of responses from educational designers and teachers. The point of departure is a conceptual framework based on network theory.

#### 2.1 Network Theory

Education for sustainability initiatives do not develop from out of the blue. Educational designers are prompted in some way to take the initiative to act, and they do that under the preconditions set by government, universities and faculty management. From that perspective an overview of EESD initiatives should cover the actors, their actions and the present pre-conditions for acting. Furthermore, integrating sustainability in engineering education is, in popular terms, far from a one-man job, done overnight. The complexity of the concept of sustainability in itself, including and balancing economic, environmental as well as social concerns is challenging even at a small scale and in everyday life. Even if we commit ourselves to a path of sustainable development, the decision in designing, constructing, producing, consuming and disposal of
every life product involves a net of multi-sided decision making processes involving diverse actors with diverse competencies and possibilities to act.

In other words, the path to sustainable development is in itself an ill-defined problem that calls for comprehensive, inclusive and aligned networks. Along the same lines, Gough and Scott (2008, p. 5) argue that:

“... learning across all levels is essential for organisations and groups of organisations to adapt to major internal and external environmental shifts and challenges such as those presented by sustainable development, and that learning (however conceptualised) within and between networks of individuals, groups and organisations is likely to be an important feature of any successful initiative linking higher education and sustainable development”.

With the emphasis on networks, and following the network theory of Håkansson (1987) we characterise the EESD network in and around higher education (HE) institutions as an interplay of actors, activities and resources. This conceptual framework is chosen as the point of departure, as it provides the opportunity to develop a comprehensive framework that captures the institutional level as well as the local contexts of agency, allocated resources and type of activities that are related to the EESD strategy of the HE institution. At the same time, we recognise that this overview of who, how and by what means, do not go into depth with other yet important aspects of the network, such as the structure of the network, the type of communication flows, the mutual power relations etc.

### 2.2 Empirical sources

To create an overview of EESD initiatives from educational designers and teachers, university cases moving across university and national borders will provide the opportunity to reveal the interplay between initiatives in the universities as well as in the university context. In theory, any cross-national comparison could be of interest. The reason for the choice of Denmark and Australia, of Aalborg University and RMIT, was a shared interest in the research question, familiarity with the two universities as well as an appropriate research foundation to provide the needed overviews.

This paper is gathering a range of previous studies, which the authors have been engaged in, to collect the pieces prompted by the conceptual framework for an EESD-network. This includes:

- Studies related to capability based curricular development and EESD teaching at RMIT (Goricanec and Hadgraft, 2008), (Hadgraft and Goricanec, 2007), (Hadgraft and Muir, 2003), (Hadgraft et al., 2004a), (Hadgraft et al., 2004b) and (Jollands et al., 2005).
- Studies related to the Aalborg model of Problem based learning and EESD (Guerra, 2014), (Guerra and Holgaard, 2013), (Hansen et al., 2014) and (Holgaard et al., 2013).

Furthermore, we have added to this picture through document analysis of institutionalised documents e.g. declarations, accreditation schemes and curricula from the two universities.

### 3. A conceptual framework for understanding EESD

#### 3.1 Political and institutional context for universities integrating EESD

In the context of corporate Environmental Responsibility within the education sector, Alabaster and Blair (1996) pointed to the relation between universities and the growing legal responsibilities and compliance with international policies, regulations and standards and, as well, the growing community empowerment and partnerships with “local authorities, technical and national councils (TECs), enterprise agencies, statutory bodies and NGOs” (Alabaster and Blair, 1996, p. 92). Jones et al. (2010) furthermore stress the role of the international declarations and charters, which offer opportunities for declared commitment to sustainability related policy and practice.

However, besides authorities, standardisation bodies and NGOs, research communities and cross-institutional knowledge networks of practitioners are important drivers for ESD initiatives.
Gough and Scott (2008, p. 122) argue that “learning (however conceptualised) within and between networks of individuals, groups and organisations is likely to be an important feature of any successful initiative linking higher education and sustainable development”. With reference to 7 different case studies, (Gough and Scott, 2008) stress the importance of linking institutions (and individual academics) to create research communities as well as a network of ESD practitioners across institutions.

In a life-long learning perspective, such EESD community should also bring together practitioners from primary, secondary and higher (tertiary) education institutions, as well as work based learning practitioners. Likewise, the network can include local communities and civil society groups. Bawden et al., (2007) stress the critical role of civil society in fostering societal learning for a sustainable world, including civil society initiatives to interact with educational institutions. It is about using the community as a living lab to foster sustainability along with the education for sustainability – what (Orr and Sterling, 2001) would call learning as sustainability.

From an employability perspective, the increasing role of sustainability in the visions and missions of private as well as public companies also have an impact on the motivation, the resources as well as the possible learning environments for EESD. Environmental management, life cycle assessment, eco-design, user-driven innovation, corporate social responsibility, supply chain management and sustainability reporting are increasingly becoming a part of everyday business-discourse.

### 3.2 University EESD-network of actors, activities and resources

Without students, there is no education, and without students that are motivated to be educated for sustainable development, there will most likely be no useful outcomes from EESD. In this perspective, engineering students, as individuals and as student organisations, are central actors in EESD.

A Danish national wide investigation of newly enrolled engineering students and their approaches to sustainability showed that it might be a challenge to put sustainability on the agenda among math/science focused students, as their intrinsic motivation is not closely aligned to other motives to study engineering (Haase, 2013). Thereby, it is not at all given that every engineering student will welcome the emphasis on sustainability, making it more of a challenge for educational designers.

The commitment of program leaders is a considerable driver for EESD – not only in a rhetorical sense, but also by taking the lead in making the curriculum changes needed to respond to what has been termed a needed paradigm shift in HE towards an ecological paradigm. Johnston and Johnston (2012, p. 2) point to the lack of such incentive from faculty management as a considerable barrier for EESD:

“Often times, in spite of institutional demand, faculty members seem reluctant to cede control over the curriculum to make possible more innovative curricular developments. It is their notoriously conservative and slow response to social and market needs that results in this dearth of graduates who have a vision of what a sustainable career, much less a society, looks like.”

University management (Heads of School, Deans of Faculty, Rectors/Vice Chancellors/Presidents) also play a leading role in “walking the talk” making comprehensive strategies for a sustainable university including environmental management, corporate social responsibility and a healthy economy as well as supporting EESD activities, including sustainable campus activities and support for EESD development projects and research.

At a more local level, the commitment from schools and program managers is necessary if EESD are to be integrated formally into curricula with or without incentives for the faculty, and make sure that the staff are sufficiently trained to cope with the integration of EESD.

Last but not least, the teachers that formally or informally educate for sustainable development and who have the direct relationships with the students, are essential gatekeepers for the realisation of EESD. However, due to the complex and integrative nature of EESD, teachers
may have to move or collaborate in an interdisciplinary mode covering the field of sustainability as well as the specific engineering domain.

3.3 Overview of a conceptual framework of EESD actors, activities and resources

The conceptual framework developed concretises the conceptual framework from Håkansson to name the specific EESD actors, activities and resources (Figure 1).

![Figure 1: Political and institutional context for HE institutions integrating EESD.](image)

### 4. The integrated approach to EESD – the Danish case

#### 4.1 The institutional framework for EESD in Denmark

In Denmark, the regulatory framework and demands from accreditation bodies to integrate sustainability in HE is weak. The Ministry of Higher Education and Science have presented no specific strategies, policies or legislations for ESD in Higher Education, beyond a reference to the Copenhagen Declaration from 2002 stating the aim of “transition towards a knowledge based economy capable of sustainable economic growth with more and better jobs and greater social cohesion brings new challenges to the development of human resources” (Ministry of Higher Education and Science, 2013).

The Ministry of Education, having authority over primary, secondary and high school education, however, have formulated a strategy for ESD. Experiences with ESD at primary school and high school levels offers inspiration for HE institutions, and prepares students to develop knowledge, skills and competencies related to sustainability before entering HE institutions.

Some HE engineering institutions in Denmark have mentioned sustainability in their institutional profile (typically universities), but there are few guidelines to promote ESD. One example is from the student associations, e.g. Green Roskilde University Centre (GRUC), who have
formulated input to the University’s ESD strategy. Another example is Aalborg University, where the UNESCO Chair in PBL in Engineering and Science made a study of the ESD practices at the Faculty of Engineering and Science, and will use this as a platform to develop institutional guidelines on how to proceed with the integration of ESD.

International actors have framed the institutionalisation of ESD in Denmark. The acknowledgement from the United Nations of the Danish Regional Centre of Expertise (RCE) in Education for Sustainable Development provides a platform for collaboration for HE institutions in Denmark, where 4 out of the 16 university educators have membership (in the first three years, 10 out of 16 were members). In the first three-year period, the state funded project activities. After the three-year period, the funding from the state came to an end, and on 25 February 2013, the RCE Denmark network was formally constituted as an association with the new name: Learning and Education for Sustainable Development – RCE Denmark.

Another example is UNESCO establishing Chairs and Centres related to EESD under the auspices of UNESCO. The national government has offered political and, to some extent, financial support, whereas HE institutions have also taken the initiative to allocate resources for EESD activities. Whereas the Danish Regional Centre of Expertise for Sustainable Development have focused on creating a national network including all disciplines and levels of education, the newly established (on 26 May, 2014) Aalborg Centre for Problem Based Learning in Engineering Science and Sustainability under the auspices of UNESCO reaches out to global communities and focuses their activities on Engineering Education for Sustainable Development.

Embedded in such collaborations are the research communities, which combine sustainability and educational research. There is a strong discourse, both in the media, in business relations and also in the research communities, related to sustainable development as well as to education, but the linking of the two is still at an early stage. There is a SD perspective on education, which has been focused on disciplines within the domain of sustainability science, and an educational perspective on sustainability, where the focus has been on integrating sustainability across disciplines by a more comprehensive view of curriculum change.

In university-business relations, which are strong in Denmark in relation to engineering education, the sustainability perspective has been strong, focusing on business processes and, to some extent, work based learning, whereas not much emphasis is put on sustainable development from an educational perspective that moves beyond disciplinary programs. Even though the sustainable development discourse represented by the users of technology can find its way to business processes in conceptual frameworks such as user centred design, the push from citizens and users of technology for EESD is limited as well as fragmented.

Furthermore, there is no tradition to provide specific staff training on ESD in Danish HE institutions moving beyond pedagogical training and courses in Human Resource Management (HRM). However, few examples have been identified, e.g. seminar activities at the Danish Technical University in 2010 and 2011, Aalborg University in 2012, 2013 and 2014, a few development projects have been carried out, providing international courses on sustainability (e.g. University College Northern Jutland, University College LilleBaelt).

What characterises these and other good examples is that it is seminars, workshops or collaborations, with the main purpose of establishing interest or mutual inspiration about ESD that works, and not formalised staff training. This does not mean that ESD is not practised, as there are examples of integration of sustainability in courses and projects. The Danish way is to create interdisciplinary staff teams. Where there is strong collaboration among those teachers, this can be very effective – however, when this is not the case, there is a risk that sustainability is seen as an add-on, which is not really related to the wider institutional strategy.

4.2 EESD at AAU – an integrative PBL approach

4.2.1 Educational model and alignment with ESD

All educational programs at Aalborg University are based on the Aalborg model of problem-oriented, project based learning, with emphasis on interdisciplinary, team-based and participant
directed learning. The Aalborg model takes its point of departure as real/life authentic, practical or purely theoretical problems depending on the overall objective of the learning process (Kolmos and de Graaff, 2014). In the Faculty of Engineering and Science, problem based learning is structured as a combined 50/50 lecture courses and projects. In the projects, the students work in self-selected and self-directed groups of up to 8 persons. The courses are taught courses but, whenever possible, are in an inductive and active mode, where the students are actively engaged.

In every case the problem has to be analysed in the context in which it has evolved and is to be addressed. A problem can arise from the fact that some people consider a certain situation as unsatisfactory (aligned with a common-sense understanding of a problem), but a problem can also be to identify by the lack of attention/action to a yet unexplored potential or opportunity, a vision or a lack of knowledge (Holgaard et al., 2013).

Whatever the point of departure, the students have to analyse the problem and align the problem with possible contributions in their field of study. In this way they narrow down the problem and formulate a concrete problem related to their engineering and science field without neglecting the context in which their techno-scientific solutions are to be appropriated.

This problem based and project based learning model offers an appropriate platform for integrating ESD considering the interrelated primary requirements for education for sustainability summarised by (Sterling, 2014, pp. 22–24). This call for contextual, learning-centred, socially orientated learning and the specific reference to experiential learning cycles and democratic owner ship are directly aligned to the problem based learning principles above.

4.2.2 University and faculty ESD strategy

Aalborg University is committed to the COPERNICUS Charta whereas sustainable development has to be given fundamental status in the university strategies and promote comprehensive and integrated sustainability actions in relation to its functions (Copernicus Alliance, 2011). This is supported by Green campus initiatives and specific faculty strategies for ESD.

Although the main activities in the Green campus initiative have been related to environmental management of campus operations, initiatives have started to grow by supplementing the concept of a green campus activity with a concept of “Green Knowledge” focusing on integrating sustainability into research and educational programs and “Green minds” with special attention to the attitudes and behavioural patterns of employees and students in relation to environment and sustainability (Aalborg University, 2014).

At the Faculty of Engineering and Science, the Dean has allocated strategic funds to support the development and continuation of the problem based and project based learning (PBL) model in the engineering and science domain alongside an increasing focus on integrating sustainability in the educational programs. This cross-faculty organisation and global network under the UNESCO Chair of Problem based learning in Engineering was in 2014 further institutionalised into the Aalborg Centre for Problem Based Learning in Engineering Science and Sustainability under the auspices of UNESCO (UCPBL). The Aalborg Centre embraces and aligns Engineering Education Research (EER), PBL as well as EESD, reaching internally into the faculty as well as externally out to the global Engineering Education research community by, PhD-training, staff development activities, consultancy and network activities (UCPBL, 2014).

4.2.3 Strategy at formal school and program level

The Faculty of Engineering and Science at AAU includes three Schools, and the Heads of Schools are active players in a taskforce initiating implementation and development of sustainability in existing programs under UCPBL. The strategy has been to investigate already existing ESD initiatives in the institutions, and build on those experiences to plan for the implementation of further activities. Based on the recommendations from this analysis, the next step is to initiate concrete experiments in three programs at Aalborg University, where sustainability is not yet integrated in the formal curricula or have reported best practices.

In the study of existing ESD initiatives at AAU funded by the Faculty of Engineering and Science, a document analysis of 111 study programs showed that in more than half of the
programs there was no mention of sustainability indicators extracted from the Global Report Initiative (Hansen et al., 2014, p. 24). However, a follow-up study, including in-depth interviews with chairpersons of study-boards and a questionnaire identifying good examples of teaching that integrate aspects of sustainability, revealed that even though sustainability was not integrated in the formal curricula, ESD was practised occasionally and personal interest and commitment to sustainability was one of the strongest drivers (Hansen et al., 2014).

4.2.4 Examples of EESD practice

One of the examples of the integration of sustainability in the PBL learning environment is from the Bachelor program of Media technology. Some of the characteristics from this case were that (Holgaard et al., 2013):

• The integration of sustainability was initiated by presenting a semester theme that related to sustainability, for example, sustainable lifestyles. As a part of the semester theme introduction, a workshop on sustainability was held.

• Within this theme, students themselves identified and analysed a problem and argued for different solutions that in one way or the other would foster a more sustainable lifestyle. They combined knowledge in the domain of media-technology with sustainability science facilitated by two supervisors from each of these domains.

• The students were strongly encouraged to use contextual inquiry to explore attitudes and behavioural patterns related to sustainability, and their media-technology product was targeted to make a change of these patterns.

The interdisciplinary staff-team, the open-ended thematic frame, the design methods calling for contextual inquiry and students agency to foster change is aligned with the hybrid and integrated model of engineering education and the emphasis on contextual knowledge, cultural awareness and sustainability agency (Jamison et al., 2014). However, the study of the case in Media-technology also showed that the students found it very hard to address sustainability without a defined platform of subject knowledge as the students experienced a scope which was too large for them to cope with in the learning situation. This is reinforces the call for a common understanding of sustainability that both students and teaching staff use noted in the study at the faculty level (Hansen et al., 2014).

A case-study of the integration of sustainability in the specialization Urban Planning and Management in the Master of Environmental, Energy and Urban Planning at Aalborg University (Guerra, 2014) also brought attention to the challenge students face when addressing the complex and ambiguous concept of sustainability. But even though students struggle to select an appropriate sustainability content to their profession, the self-directed way of constructing an understanding of sustainability in relation to different projects motivate students to reflect, take a stand and discover potential relations to their field of sustainability (Guerra and Holgaard, 2013). As one of the students stated:

“I’ve been working with sustainability at least two semesters, and I know I have a very clear and comprehensive understanding of what sustainability is, but it would be very interesting if this institution kind of have its own official understanding of sustainability. That also would have limited us in some of my project, because there was this one semester where I, myself, used a lot of time describing what sustainability could be in an urban planning context. And I would not have done that if they had an explicit explanation of what it was. Then… OK, we may have used our time in something else but however this was the way we learned what sustainability is, or at least how we see it”

As noted by Guerra and Holgaard (2013) it is a balance in the curriculum process to make the curriculum so open that the students can in fact construct their own view and select the most relevant aspects of sustainability in relation to the problem they are studying, and at the same time make sure that all students are guided through all relevant aspects of the multidimensional concept of sustainability.
5. The system engineering approach to EESD – the Australian case

5.1 The institutional framework for EESD in Australia

5.1.1 Government context

Since the election of the Liberal-National government in 2013, there has been a reduction in support for sustainability in Australia. The new government has been steadily removing support for renewable energy and other responses to climate change, such as abolishing the ‘carbon tax’. The government also appears to be reducing its support for renewable energy targets, which are modest by Danish standards: 20% of Australian energy from renewables by 2020. In Denmark that figure is 50% by 2020 and 100% by 2050. So, the long-term support for ESD from this government looks bleak.

Nevertheless, good work has been done in the last decade by previous governments, particularly in encouraging the efficient use of energy (Department of Industry, 2014) and website eex.gov.au. One aspect of this work in higher education was to convene a higher education Energy Efficiency Advisory Group that would develop means to increase education around energy efficiency, particularly in engineering programs. This work eventually led to two contracts to develop resources to support teachers in universities in energy efficiency. Queensland University of Technology and the Australian National University are leading these two projects. The resources are expected to be available in late 2014 or early 2015.

The government has also been active in supporting education for sustainability across K-10 school education by providing a curriculum framework (Department of Environment, 2010). The downloadable framework for curriculum developers and policy makers establishes a national curriculum in sustainability.

State governments have also been active, for example, the New South Wales, (NSW Dept of Education and Communities, 2014). The Department has established 25 Zoo and Education Centres to help school children learn about sustainability and the environment: “learn about the environment, investigate and solve issues in the environment, acquire attitudes of care and concern for the environment, adopt behaviours and practices which protect the environment, and understand the principles of ecologically sustainable development”.

In higher education, the New South Wales Government has also funded a range of training courses to help business to become more energy efficient (NSW Environment & Heritage, 2014). Another is the Energy Efficiency Training Module from The Australian Research Institute for Environment and Sustainability (ARIES, 2011).

5.1.2 Engineers Australia’s accreditation framework

Engineers Australia accredits engineering programs in Australia by specifying the Stage 1 Competency Standard (Engineers Australia, 2011), which defines those outcomes that a graduate should be able to demonstrate at the end of their university education. Engineering programs must demonstrate how these outcomes are achieved in order to achieve accreditation. Australia is a signatory to the Washington Accord, which ensures international recognition for graduates of Australian programs (International Engineering Alliance, 2007).

The elements of competency relevant to EESD are elements 1.5a, 1.6c, 1.6d, 2.1g, 2.3b, 2.4e, 2.4f and 3.1c (below).

1.5 Knowledge of contextual factors impacting the engineering discipline:

a) Identifies and understands the interactions between engineering systems and people in the social, cultural, environmental, commercial, legal and political contexts in which they operate, including both the positive role of engineering in sustainable development and the potentially adverse impacts of engineering activity in the engineering discipline.

1.6 Understanding of the scope, principles, norms, accountabilities and bounds of contemporary engineering practice in the engineering discipline:
c) Appreciates the principles of safety engineering, risk management and the health and safety responsibilities of the professional engineer, including legislative requirements applicable to the engineering discipline.

d) Appreciates the social, environmental and economic principles of sustainable engineering practice.

2.1 Application of established engineering methods to complex engineering problem solving:

g) Identifies, quantifies, mitigates and manages technical, health, environmental, safety and other contextual risks associated with engineering application in the designated engineering discipline.

2.3 Application of systematic engineering synthesis and design processes:

b) Addresses broad contextual constraints such as social, cultural, environmental, commercial, legal political and human factors, as well as health, safety and sustainability imperatives as an integral part of the design process.

2.4 Application of systematic approaches to the conduct and management of engineering projects:

e) Is aware of the need to plan and quantify performance over the full lifecycle of a project, managing engineering performance within the overall implementation context.

f) Demonstrates commitment to sustainable engineering practices and the achievement of sustainable outcomes in all facets of engineering project work.

3.1 Ethical conduct and professional accountability

c) Understands the accountabilities of the professional engineer and the broader engineering team for the safety of other people and for protection of the environment.

Despite this substantial collection of required outcomes, it would be fair to say that the demonstration of the outcomes by engineering schools at accreditation time is weak, though improving. There continues to be an over-focus on technical outcomes through the four year programs with a few exceptions, e.g. (Hadgraft et al., 2004b).

One project that has attracted Engineers Australia’s support over several years is the Natural Edge Project (TNEP, 2014). This group of young engineers, founded in 2002, have been resolute leaders in the field, producing 5 books and 10 sets of learning resources, including Whole System Design, which sets out a 10 step process for the design of engineering systems incorporating a whole systems approach (Stasinopoulos et al., 2011). TNEP has attracted funding from a range of national and international funding agencies.

5.1.3 ALTC/OLT funded projects

Over the last 25 years, the Australian Government has funded innovation in learning and teaching in Australian universities through a succession of agencies, the most recent of which have been the Australian Learning and Teaching Council (ALTC) and the current Office for Learning and Teaching (OLT) in the Federal Department of Education. Both of these groups have funded several projects on sustainability (Office for Learning & Teaching, 2014).

Many of these projects are also reported on the Sustainability.edu.au website, which has been developed through at least two projects, with the purpose of building a community of practice around the teaching of sustainability. Each academic can establish their own profile and use it to make teaching materials available to others. Each institution can also highlight the programs that they teach with a significant sustainability focus. The site can be searched to find materials and also people who can assist in the further development of teaching practices.

5.1.4 Universities themselves

The Talloires Declaration (University Leaders for a Sustainable Future, 2001) was composed in 1990. Universities around the world have become signatories, including 60% of Australian universities (University Leaders for a Sustainable Future, 2014). One tangible outcome from these efforts has been the establishment of the International Journal of Sustainability in Higher Education (Emerald Publishing, 2014).
In 2000, the Global Sustainability Institute was established at RMIT University in Melbourne, to encourage the development of sustainable practices within the University and in partner organisations. This institute has now closed though replaced by several other centres at RMIT focussed on sustainability. The National Centre for Sustainability at Swinburne University of Technology was established in 2002 and continues to work across organisations to provide education for sustainability services, including its Education for Sustainability Hub (National Centre for Sustainability, 2014).

Another initiative is the Australasian Campuses Towards Sustainability (ACTS, 2014) originating in 1990. “ACTS aims to inspire, promote and support change towards best practice sustainability within the operations, curriculum and research of the Australasian tertiary education sector. We do this by providing resources, knowledge, developmental and networking opportunities for members and by critically challenging and supporting collaboration with stakeholders to lead sustainability innovation in the sector.” ACTS runs the Green Gowns Awards, Australasia to acknowledge good practice in the field.

In June 2013, a National Forum for Sustainability in Engineering was organised in Sydney, with the sponsorship of the Federal Department of Resources, Energy and Tourism. The intent was to bring together thought leaders from government, industry and academia to discuss the role of sustainability in educating graduates for the workforce. Industry representatives outlined current and recent projects that were transformed by a focus on sustainability.

In 2012, a new program in sustainable systems engineering was established at RMIT University to embody a new combination of systems engineering (INCOSE, 2006) and sustainability. This program draws from the mechanical engineering program, with core studies in energy, systems engineering and mathematical modelling and with options in sustainable energy systems and in sustainable transport and logistics. The program includes a project sequence that focuses on a systems approach to solving engineering problems. It begins with Engineering, Society and Sustainability in semester 1 and is followed by Engineering Design for Sustainability (semester 2), Sustainable Systems Design (semester 3), ... Students undertake an additional mathematics course in Systems Dynamics and a specific Systems Engineering course.

During 2009-2011, the ALTC funded a national Academic Standards Project to develop Threshold Learning Outcomes across the nine discipline clusters represented in higher education (Discipline Scholars Network, 2013). This project is similar to the European Tuning Project (Tuning Project, 2012). Current work is addressing threshold learning outcomes for Environment and Sustainability (McBain et al., 2014). The key outcomes developed so far are: Trans-disciplinary Inquiry; Understanding Complexity; Skills for Environment and Sustainability; and Professional, Civic and Personal Responsibility. Each of these meta-skills is divided into finer grained outcomes in the draft standard at the above website.

5.2 **EESD at RMIT – a capability and systems approach**

5.2.1 **Educational model and alignment with EESD**

In 2001, RMIT University started a transformation of all engineering degree programs from traditional content-based curricula to capability-based curricula (Jollands et al., 2005). The focus shifted from a conceptual concern to teach the theory and methods within specialised technical domains, to a professional concern to provide students with the capabilities needed in their future professional practice.

RMIT has had a long tradition of Program Advisory Committees (PAC) and these committees were used as the focus for setting up industry forums in 2002 to develop the capability based curricula (Hadgraft and Muir, 2003). Through several industry meetings, the diversity and variability of views on engineering capabilities were explored. A Teaching and Learning Director from RMIT facilitated the group discussions and RMIT staff were invited to probe responses. This change from content-based to capability-based curricula had a great impact on the integration of sustainability in the engineering curricula at RMIT, as noted by (Hadgraft et al., 2004a, p. 33):
"Working with industry partners to gain a contextualised perspective of engineering for the twenty-first century, we found the traditional view of the engineer as technical problem solver with economic, social and environmental awareness was challenged in favour of a clear focus on sustainability, highlighting the need for trans-disciplinary approaches."

The call for a trans-disciplinary approach that moves beyond awareness about sustainability, led to a socio-ecological approach based on the work of Trist et al. (1997). The socio-ecological approach is “an open system approach based on an appreciation of the levels of interdependence, measured by connectivity and dynamism) between systems and the environments in which they are embedded” (Hadgraft and Muir, 2003, p. 3).

This open system approach has been influential both in the transformation process of the curricula as different partner perspectives on engineering capabilities have merged, but it has also been influential in terms of changes in the pedagogical approach. Together with an explicit call for capabilities related to teamwork, communication and problem-solving (Hadgraft and Muir, 2003), the pedagogical approach was adapted to capture systems thinking by a blended curriculum including process/project courses as well as technical/technology courses (Hadgraft and Goricanec, 2007).

5.2.2 University and Faculty ESD strategy

In more recent times, RMIT has established a Sustainability Committee to provide “leadership, coordination and guidance to the University for integration of sustainability principles and practices throughout the University’s core teaching and learning, research and operational activities.” (RMIT, 2014a). In part of the sustainability policy, tertiary education is required to (RMIT, 2014b):

- Engage students at all levels in learning about relevant sustainability concepts (knowledge, skills and values/attitudes), identifying issues of importance and taking actions in order to empower them as future leaders in industry and society in their chosen field.
- Embed sustainability capabilities/competencies within disciplinary and professional contexts, including where relevant challenges from beyond narrow or chosen discipline(s).
- Support academic and teaching staff to develop high levels of discipline relevant sustainability literacy so that they are able, competent and confident to facilitate sustainability learning.

However, in reality, little of this staff development occurs except within the initiative of individual academics who seek their own professional development through specialised workshops and conferences, usually related to their research interests.

In total, there are 24 courses listed as Sustainability courses on the “Think green at RMIT” website (RMIT, 2014c). The sustainability campus activities are supported by in-house research, primarily related to sustainability science although a spin-off of curricula changes also have resulted in ESD research. The Global Cities Institute, for example, embodies a range of research programs related to the sustainability of cities. ESD research is not gathered in a single cross-disciplinary Centre; rather it is a patchwork of research activities related to different disciplines across the university.

5.2.3 Strategy at formal school and program level

Out of the 23 schools at RMIT, there are 5 engineering and ICT schools: 1) Aerospace, Mechanical and Manufacturing Engineering, 2) Civil, Environmental and Chemical Engineering 3) Computer Science and Information Technology 4) Electrical and Computer Engineering and 5) the School of Engineering TAFE (Technical and Further Education – vocational engineering).

Even though the learning outcomes are aligned with the national accreditation of Engineers Australia, as explained above, the overall learning objectives from the courses that can be seen in the program handbooks of the different engineering degree programs (RMIT, 2014d) are rather broadly related to sustainability. A standard formulation in the knowledge and skill base is
for example a) referring to knowledge of contextual factors impacting the engineering discipline and b) understanding the scope, principles, norms, accountabilities and bounds of contemporary engineering practice in the specific discipline.

However, when specific programs choose to elaborate on the overall Program Learning Outcomes, there are examples of explicit emphasis on sustainability. One example is the Bachelor of Industrial Design where it is stated that on completion of the program the student will be able to “Demonstrate through practice-based design research an advanced knowledge of the socio-technical, environmental and economy eco-systems of industrial design both locally and globally” (RMIT, 2014d).

The EESD strategy is strongly attached to the change from content-based to capability-based curricula. The focus on professional capabilities has on the other hand not initiated more cross-disciplinary courses. Goricanec and Hadgraft (2008, p. 123) argue that there is a lot of sustainability expertise spread across RMIT, but much is “trapped” in the disciplines and furthermore, (Hadgraft et al., 2004a, p. 47) note that engineering programs at RMIT are still trapped in the ‘teach the fundamentals’ model. There is, however, one compulsory cross-disciplinary course, a first year engineering practice course, in each of the three higher education engineering schools. Each of these courses uses a humanitarian engineering project designed by Engineers Without Borders – the EWB Challenge (Engineers Without Borders, 2014).

5.2.4 Examples of EESD practice

One example of a blended curriculum is the renewed Bachelor of Chemical Engineering from 2004. In the first year, new project based learning courses were introduced to develop a “capability set made up of personal and professional development, sustainability, problem solving and decision-making, technical competences (engineering analysis), teamwork & leadership and communication” (Jollands et al., 2005, p. 1).

One of the project based learning courses is Sustainable Engineering for first year Chemical Engineering students, which is designed to allow a stronger focus on problem based learning, including an increased focus on problem-identification, alternative applications and self-directed teamwork in smaller groups of four students (Jollands et al., 2005).

But besides developments to provide more blended curricula on the horizontal level (integrating a new type of EESD activity during a semester), the integration of sustainability was also considered in the vertical dimension to address the progression throughout the study in students’ capabilities to address sustainability. For example, in the Civil and Infrastructure Engineering program, introduced in 2003, the progression of sustainability capabilities (Hadgraft et al., 2004b, p. 43) is as follows:

**Year 1.** Students study environmental principles for sustainability design and perform a conceptual design project to put these principles into action.

**Year 2.** Students focus on economic principles and project evaluation.

**Year 3.** Students design an eco-home, applying the full range of sustainability principles.

**Year 4.** Students tackle an infrastructure project (rather than a design project) extending the system view. They also study sustainability and lifecycle principles in an accompanying course called Infrastructure Management.

This way of gradually increasing students’ sustainability scope provides possibilities for students to handle the complex nature of sustainability “in parts” and at the same time relate sustainability to professional practice.

Furthermore, recognising that less-recent engineering graduates will not necessarily have the same system view including not only technical and economic, but also environmental and social aspects in a life cycle perspective, RMIT has introduced a Master of Sustainable Practice, using project based learning methods (Goricanec and Hadgraft, 2006) and adult learning principles (andragogy). Besides, echoing the story of a blended curriculum with focus on continual development of capabilities, this Master’s degree also exemplifies the way that academic and professional practice interact to move the focus from content to capabilities.
6. Discussion

When the two types of EESD network are compared (see figures 2 and 3) some interesting questions and potentials for further development arise.

In the Danish case, a lack of focus on ESD in HE from government as well as from accreditation bodies has led to a limited push on Universities to integrate sustainability across engineering programs. The Danish government supports ESD initiatives such as the Danish Regional Centre of expertise for ESD and the Aalborg UNESCO centre for Problem Based Learning in Engineering Science and Sustainability, but economic funding is primary driven by private funds or allocated in university budgets. Thereby, the examples of integration of sustainability into the engineering curricula are mostly due to first movers among educational staff having personal commitments to SD and/or to EESD research.

In the Australian case, although there is currently little support from the Australian Government for sustainability efforts, there has been much activity over the last 15 years across government and universities. Universities themselves have often taken a leading role to champion conversations around sustainability, with a growing focus on climate change. The impact on curricula despite the focus on sustainability from accreditation bodies has, however, been slow. Although some universities list sustainability as a required graduate outcome, it is often difficult to find clear evidence of explicit sustainability outcomes in program descriptions. Like in the Danish case, the EESD-integration is fragmented and based on personal commitment rather than a comprehensive strategy.
Figure 2: Danish context for HE institutions integrating EESD.

For the Danish case, one potential compared to the Australian case is to experiment with vertical integration of EESD in specific programs, and a corresponding question for reflection is, how a call for vertical integration in the curricula corresponds with the open problems and self-directed learning embedded in the Aalborg model. Another potential is to investigate whether employes in the Danish context emphasise sustainability to the same extent as has been the case in Australia, and how this can be used to motivate students to engage in sustainability in relation to their problem based learning projects. And, last but not least, the system engineering approach could be explored as a way to translate the Science, Technology and Society discourses into the engineering community.

For the Australian case the possibilities of responding to the closing down of centres for ESD in Australia could be to team up with international networks as, for example, the global network related to the Aalborg centre for PBL in Engineering Science and Sustainability. Another potential is to explore how interdisciplinary staff teams together can facilitate student learning for sustainability and ensure an integration of disciplinary and contextual knowledge.

This might even implicitly provide technical staff with training about sustainability, and staff with expertise in sustainability science with enough technical knowledge to bridge the two subjects, or rather mind-sets. And as the systems engineering approach has shown its worth as a conceptual framework for introducing sustainability as an integrated part of engineering systems, the problem based learning philosophy might be able to inspire by the focus on problem analysis as well as collaborative and self-directed learning.

7. Concluding remarks

In this paper we have introduced a conceptual framework for creating an overview of EESD initiatives, and by comparing different HEI EESD frameworks we have pointed to potential
change. Because of its simplicity, the framework might also be used internally to challenge the present understanding of the EESD profile of the university. Looking for the exceptions (the black swan among the whites) can provide inspiration for further development of an EESD strategy that exemplifies the path from rhetorical statements to practical implementations.

The findings provided in this paper show that there is considerable potential for cross-fertilisation when comparing different EESD-networks and potentials for rethinking the current approach to EESD. It is a balance of creating room for different ways of relating to sustainability depending on the discipline and the professional contexts, and at the same time provides concrete guidelines so it is obvious that anything will not go.

However, if the challenge of creating a basic awareness and understanding of the pillars of sustainability and their relation to the different professions is not taken, even the most concrete statements are open for multiple interpretations – and the EESD initiatives will stay fragmented and student learning outcomes might be unpredictable.

Engineering education for sustainability is too important and engineering students future professional actions too influential for EESD to become a random activity in terms of content, integration and commitment. Coordinated action and common change strategies are needed and, to prompt this, the EESD-networks we have shown in this paper may find a purpose.

8. References


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