The Contribution of University Curricula to Engineering Education for Sustainable Development

Sustainable Development and the Engineering Profession

Abstract
Global failures to reach a sustainable development within present-day societies as well as recent breakthroughs within technoscience pose new challenges to engineering education. The list of competencies which engineers should have to rise to these challenges is long and diver, and often encompasses radically new attributes. The task of engineering education for sustainable development is to address these competencies and to prepare engineers for their active role in society. Besides, while competencies correspond to optional behavior, actual behavior must be accounted for as well to fulfil the requirements for a transition towards sustainable development. Such an approach calls for new modes of teaching and learning as well as for their meaningful integration in existing educational contexts. This paper presents the diversity of competencies needed, introduces a focus on actual performance, and identifies five appropriate modes of learning. The combination of these different modes (their prevalence, sequence, and balance) within university curricula is discussed referring to empirical examples.

Keywords
engineering education, inter- and transdisciplinary skills, learning modes, sustainable development, technoscience, transboundary competencies

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Die CO₂-Abscheidung und -Lagerung, kurz CCS, ist eine nicht unumstrittene Option, Emissionen zu senken und damit Klimaschutzverpflichtungen nachzukommen. Überwiegen die Chancen der neuen CCS-Technologien für den Klimaschutz oder führt die Unsicherheit über geeignete Lagerstätten sogar dazu, dass Entwicklungsländer für ein...
Lists of engineers’ preferable attributes for sustainable development

The Declaration of Barcelona presents a long list (EESD 2004), including the ability
- to “understand how their (engineers’) work interacts with society and the environment, locally and globally, in order to identify potential challenges, risks, and impacts”;
- to “understand the contribution of their work in different cultural, social, and political contexts and take those differences into account”;
- to “work in multidisciplinary teams, in order to adapt current technological demands imposed by sustainable lifestyles, resource efficiency, pollution prevention and waste management”;
- to “apply a holistic and systemic approach to solving problems and the ability to move beyond the tradition of breaking reality down into disconnected parts”;
- to “participate actively in the discussion and definition of economic, social, and technological policies to help redirect society towards more sustainable development”;
- to “apply professional knowledge according to deontological principles and universal values and ethics”;
- to “listen closely to the demands of citizens and other stakeholders and let them have a say in the development of new technologies and infrastructures”.

The European “Dublin” Descriptors (Joint Quality Initiative 2004) are the European framework of qualifications awarded to higher education students, distinguishing learning outcomes along the categories “knowledge and understanding”, “applying knowledge and understanding”, “making judgements”, “communication skills”, and “learning skills”.

Within the Criteria for Accrediting Engineering Programs of the US-based Accreditation Board for Engineering and Technology (ABET 2009, p. 3) a focus on sustainable development was achieved only gradually (cf. Splitt 2002). The current list of criteria for engineering program outcomes includes
- “an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability”;
- “an ability to function on multidisciplinary teams”;
- “an understanding of professional and ethical responsibility”;
- “the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context”;
- “a recognition of the need for, and an ability to engage in life-long learning”, and
- “a knowledge of contemporary issues”.

The Dutch Criteria for Academic Bachelor’s and Master’s Curricula (Meijers et al. 2005, p. 23) specify that (among other aspects) at the master’s degree level a student “is able to analyse the consequences of scientific thinking and acting on the environment and sustainable development” as well as “the ethical and the normative aspects of the consequences and assumptions of scientific thinking and acting” and integrates these considerations in her/his scientific work, and that she or he “has an eye for the different roles of professionals in society” and “chooses a place as a professional in society”.

An alphabetical list that may also serve as food for thought is the Alphabet of Inter- and Trans-Disciplinary Engineering Work and Education in Sustainable Development provided by Sotoudeh and Kastenhofer (2008).

FOCUS: ENGINEERING EDUCATION IN SUSTAINABLE DEVELOPMENT

Several authors and organizations have put forward lists of skills, knowledge, and approaches geared toward a sustainable future (see box).

That engineering education for sustainable development (EESD) should answer to the specific demands of SD is also reflected in a call for inter- and transdisciplinarity, resulting in a demand for an education that prepares students for interdisciplinary and transdisciplinary research activities. A number of scholars have stated that SD calls for engineers with a broad-based and systematic education (Nichol and Sillitoe 2006), and that finding a way to include the societal context in engineering and science curricula poses as yet unresolved problems (e.g., for ethics education: Smith-Doerr 2006). However, comparative analyses, scholarly debate, and the development of new experience- and theory-based strategies remain the exception rather than the rule. This situation can partly be explained by the highly-fragmented and praxis-bound views on academic engineering education that still prevail – at least in Europe.

To sum up, neither education for inter- and transdisciplinarity nor education for sustainability-oriented science and engineering have yet established a “gold standard”. Quite on the contrary, the results achieved so far seem still to lag behind current requirements for contributing to a societal transition towards sustainability.
Linking Professional Practice, Technological Education, and Sustainable Agency

The goal of EESD is to stimulate and enable students for sustainability-oriented engineering practice and agency. This goal obviously entails multiple challenges: sustainable societal development and the closely related approaches of interdisciplinary and transdisciplinary research and engineering practice are terms open for a variety of different theoretical definitions and practical approaches (conceptual fuzziness). They touch on conflicting interests and incommensurable paradigms, they are not very well suited to specialization or reductionist approaches, and they are difficult to assess. Since the 1960s and 1970s, education experts have been struggling to translate society’s search for (more) SD into feasible teaching strategies and programs. Both the practical difficulty of accomplishing this and the importance attributed to it (as well as ongoing conceptual debates and local differentiations) have increasingly led to the formulation and elaboration of new educational approaches. These can encompass lists of

- societal problems and goals, opportunities and challenges (cf. NAE CEE 2004),
- roles engineers might assume and actions they might take in order to contribute to resolving these problems,
- specific attributes engineers need to exhibit in order to be capable of assuming these roles and taking these actions and to be likely to do so and which can be defined and assessed as learning outcomes (see box), and
- didactic approaches and teaching techniques for conveying these attributes within engineering education.

Each of the four types of lists comes with its own challenges: The list and the wording of societal problems changes over time and is closely linked to specific events and media reporting. Lists of engineers’ roles and actions are rarely provided in explicit terms. Lists of engineers’ preferable attributes and didactic approaches are shaped by different taxonomies relating to different local traditions and presumptions of didactic theorists and practitioners about education in general and education for SD in particular. In the following, the latter two categories are presented in more detail to enable a better informed discussion of what lies at the core of education: allowing for learning individuals.

Engineers’ Attributes for Sustainable Development

Preferable attributes, or learning outcomes, are typically called “key qualifications” or “competencies”1. In the context of EESD, these are often centred on multi-, inter-, and transdisciplinary skills as add-ons to disciplinary education and specialisation. Some authors offer a more differentiated perspective and distinguish between knowledge, skills, and attitudes, or – more precisely – knowledge and understanding, skills and abilities, and attitude (Segalàs et al. 2009, p. 18). Others emphasize the affective outcomes of the conveyed values, attitudes and behaviors (Shepherd 2007). Sipos et al. (2008) draw on the principles of education formulated by Swiss pedagogue and educational reformer Pes-talozzi about 200 years ago: they call for an approach “engaging head, hands and heart” in transformative sustainability learning, thereby addressing the translation of passion and values into behavior. With a similar emphasis on actual behavior, the list can be extended to include compassion, care, and commitment (e.g., Carew 2004); empathy and solidarity, competency in self-motivation and motivation of others, and competence in distanced reflection on individual and cultural modes (Barth et al. 2007); or contextual support, social norms, action difficulty, and habitual behavior (Arbuthnott 2009).

This shift from a focus on capabilities (or competence) to a focus on actual behavior (or performance) runs parallel to the general diagnosis that our present-day highly-educated knowledge societies still fall short of attaining an SD standard. Acquired competencies are not – so a feasible conclusion – enough to achieve a major transition. Approaches focusing on actual behavior, such as the norm-activation model formulated by Schwartz and Howard (1981) and the Planned Behavior Theory (cf. Ajzen 2002), recognize that human agency is not guided by norms and competencies alone. They emphasize the influential role of beliefs about the likely consequences of a behavior and about the normative expectations of other people, and of the awareness of factors that may further or hinder performance of the behavior. Other authors stress the impact of rituals, habits, and cultures on the likelihood of decisions actually being made and actions being taken.

Although such approaches have primarily been applied to lay people’s behavior, empirical analyses of expert performance likewise point to the importance of (either explicit or habitualized) beliefs. Wynne (1988, p. 163) in his analysis of failures related to experts’ handling of risk technologies identifies as a major source of risk the false assumption that “organisations can operate with perfect communication, or that expert people are not prone to distraction, illogic or complacency”. According to his analysis, this “deeper form of human error” hinders dialogue between experts and the public that “might (…) produce more socially viable technologies in the long term, because technological development would be more socially open to people with relevant knowledge about (parts of) the technology”. Wynne’s case study also reminds us of the fact that the tasks, roles, and definition of engineers have become ever more complex, diverse, and blurred over the course of the past decades.2 Engineering is no longer restricted to build-

1 “(A)n individual is considered ‘competent’ when possessing the ability to do something specific. (...) The concept encompasses not only cognitive aspects, but also explicitly motivational, moral, volitional, and social components.” (Maag Merki 2008, p. 518)

2 Funtowicz and Ravetz (1992, p. 256) note that science, engineering, and professional consultancy are no longer distinct fields. This amalgamation results in a corresponding lack of expertise. “(T)he characteristic problems of the development and regulation of (the) new technologies, which could have been familiar to any engineer, were for a long time completely unnoticed. And the lack of scientific conclusiveness to the calculations of risks, which every engineer knew and managed through engineering judgment and good practice, came as an unwelcome surprise to the scientists who tried to apply the laboratory style to these new and difficult problems.”
ing stable bridges or planning durable houses. Engineers negotiate the construction of nuclear power plants, they develop nanomaterials and make far-reaching decisions about our future energy production and consumption systems.

Drawing on these insights, we conclude that while focusing on understanding, skills, and attitudes is important, education for SD also needs to address professional practice (or behavior) and performance. It needs to make provision for the role of the engineer as an active player within society, or, in other words, as a social, political, and ethical persona. To achieve this, education has to provide opportunities to learn and reflect upon one’s actions, the beliefs underpinning them, and their outcomes, in the context of professional agency. EE needs to address the way in which acquired competencies are applied in socially, culturally, and politically determined situations, including critical thinking and trying out different perspectives (Carew 2005, De Werk et al. 2006). Otherwise, learned competencies remain merely theoretical abilities, while their actual application in real-world contexts is not considered. Lifelong learning allows for such a combination of acquired experience with new knowledge in an SD context.

Educating Engineers for Sustainable Development

Didactic approaches adopted to achieve certain learning outcomes are often divided into general instructional methods, problem-based learning, and cooperative learning (Felder and Brent 2003). The traditional approach of teacher-directed instruction has repeatedly been criticized for neglecting active participation.

“The conventional teaching approach used in engineering education emphasizes lectures over active engagement (favoring reflective and verbal learners over active and visual learners), focuses more on theoretical abstractions and mathematical models than on experimentation and engineering practice (favoring intuitive learners over sensing learners), and presents courses in a relatively self-contained manner without stressing connections to material from other courses or to the students’ personal experience (favoring sequential learners over global learners).” (Felder and Spurlin 2005, p. 110)

Hence, a plurality of further labels has been introduced in the past for educational approaches aimed “at the integrated mediation of theoretical knowledge and practical abilities through a reality- and problem-related learning, which simultaneously integrates social action and is controlled by the learners themselves” (Howe 2008, p. 539). Such labels include project-oriented as well as work-related learning; on-the-job-learning, learning-oriented working, and lifelong learning; and action-based, action-oriented, or task-oriented learning. With respect to the specific requirements of education for SD, De Werk and colleagues (2006, p. 56) also point at educational practices that reach beyond the traditional didactic concepts; they refer to “three ingredients [that are needed] as a complement to current teaching methods: involvement of students in developing education, genuine interaction of students of different backgrounds (interdisciplinary and/or transdisciplinary teams for example), and student organizations to communicate the importance of SD in an informal way (worldwide)”.

Other authors (e.g., Van den Bergh et al. 2000, Heijs 2006) emphasize the importance of learning in informal settings, such as self-directed, self-organized, and self-regulated learning, incidental/experiential learning, and socialization to foster Gestaltungs- kompetenz for SD (Barth et al. 2007). Moreover, the embedding of the didactic approaches in specific curricula, time frames, and institutional settings is discussed. El-Sayed (2001) favors the integration of industrial work at the end of a collaborative educational curriculum, Kelly (2006) stresses the importance of developing reflexive thinking in the first years of engineering courses.

One example of science and engineering education for SD in an institutional context is provided by the Environmental Sciences program of the School of Science of the Open Universiteit Nederland (OUNL). The OUNL is a distance-teaching university for lifelong learners, including professional engineers. Working professionals enrol at an average age of 36. About one in three of the one hundred students enrolling for a BS in Environmental Sciences is a technical, agricultural, or lab professional already holding a Bachelor of Engineering. In recent years, the Environmental Sciences program has been transformed so that it meets societal needs better while at the same time satisfying professional demands and maintaining academic standards. This transformation was embedded in a general reorientation of OUNL curricula towards competence-based learning outcomes (Lansu 2006). A competence road map was developed, based on professional demands on the one hand and on the “Dublin” Descriptors (see box) on the other. According to the new road map, the students experience the complexity of performing transboundary tasks for themselves. They develop inter- and transdisciplinary competencies for SD right from the first year onwards.

How can this road map’s contribution to EESD be assessed against the background of the conceptual approaches mentioned above? In the following section, we suggest a taxonomy of different, but interrelated modes of learning, all of which have to be accommodated within EESD. It allows for the comparative analysis of different curricula.

Five Modes of Learning

As is the case with preferable attributes and didactic approaches, different lists and taxonomies exist for modes of learning. These lists are shaped by evaluations of what the necessary learning outcomes are, by theoretical conceptions of what learning is, and by practical ideas on how learning can be advanced throughout education. Carew (2004, p. 217), in her noteworthy work on “reflective and post-normal engineering” and its implications for teaching and learning, delineates learning as “knowing, thinking and feeling”. She discerns three realms of learning: facts, ways of thinking, and ethics. Based upon a focus on competencies as

3 According to Carew (2004, p. 90) “ethics” implies ethical principles such as fairness, responsibility, and awareness.
well as actual behavior, we suggest a similar scheme, adding the realm of practice. Hence, we discern four realms of learning output: knowledge (facts), skills (practice), commitment and attitude (ways of thinking), and social role and agency (ethics). With reference to these types of learning outputs as well as the different didactic approaches presented above, we identify five different modes of learning:

**Mode 1: Factual learning or learning-by-memorizing** is aimed at the acquisition of basic engineering knowledge as well as knowledge about the concept of SD and about associated (social, ecological, technical) systems. Additional content (e.g., the history of the engineering profession) and contextualizations (e.g., by posing meaning-oriented, relational, and value-oriented questions, cf. Dahlgren and Öberg 2001, p. 270) can be added as sources of critical reflection.

**Mode 2: Practical learning or learning-by-doing** is aimed at the acquisition of basic engineering skills and abilities. Later on, skills like designing engineering projects, scientific writing, or presenting engineering work to an academic audience are added.

**Mode 3: Collaborative learning or learning-by-interacting** is aimed at the acquisition of experience with intersubjective collaboration. Later on, interdisciplinary collaboration is added. This mode fosters communication skills and project-oriented working skills.

**Mode 4: Authentic learning or learning-in-context** is aimed at the acquisition of the transdisciplinary skills, attitudes, and experience needed to understand and enact the social role of engineers within real-world contexts. It ranges from problem-based, interdisciplinary learning scenarios already applied in mode 3 to the fulfillment of professional tasks in a real-world setting. It fosters the competence to interact with actors from the private and public sectors and facilitates the recognition, adoption, and re-evaluation of ethical principles, new paradigms, strategic skills, and priority settings. This mode also enables the establishment of networks that can be referred to later on.

**Mode 5: Re-positioning or learning-by-reflection** entails re-evaluating gained knowledge and skills acquired, attitudes developed, and actions and roles taken. The resultant re-positioning equates to a change rather than the accumulation of more of the same. It depends on new experiences or the acknowledgment of new contexts and on the ability to use these to gain a new perception or position. It relies on formal as well as informal learning settings.

These five modes are not to be understood as independent modular elements of EE that can be established separately, but are related to one another as well as to the different categories of learning outputs (providing for specific aspects of professional expertise) (see figure). Especially mode 5 cannot take place on its own; it can only be achieved in combination with other types of learning.

**Importance of the Learning Sequence**
As stated above, the learning of knowledge and skills is not the only requirement for engineering for SD. There also needs to be provision for changing attitudes and for reflecting actively upon contents learned, practical skills acquired, values assimilated, and actions taken, so that they can be re-considered, re-arranged, and adapted. Against the background of SD, the reflective activity depends upon the acknowledgment and consideration of relevant interdisciplinary and transdisciplinary contexts. This situation raises the question which mode of learning should come first: the learning sequence (or, more broadly, the order of learning, doing, and reflecting) needs to be considered carefully.

<table>
<thead>
<tr>
<th>LEARNING OUTPUT</th>
<th>KNOWLEDGE</th>
<th>SKILLS</th>
<th>COMMITMENT + ATTITUDE</th>
<th>SOCIAL ROLE + AGENCY</th>
</tr>
</thead>
<tbody>
<tr>
<td>MODE 1: FACTUAL LEARNING</td>
<td>basic engineering and SD knowledge acquired</td>
<td>(cognitive skills acquired)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MODE 2: PRACTICAL LEARNING</td>
<td>(know-how acquired)</td>
<td>disciplinary engineering skills acquired</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MODE 3: COLLABORATIVE LEARNING</td>
<td>(know-how acquired)</td>
<td>interdisciplinary skills acquired</td>
<td>(strengthened)</td>
<td>(envisioned)</td>
</tr>
<tr>
<td>MODE 4: AUTHENTIC LEARNING</td>
<td>(know-how and know-who acquired)</td>
<td>transdisciplinary skills acquired/strengthened</td>
<td>strengthened, tried out</td>
<td>acquired, tried out</td>
</tr>
<tr>
<td>MODE 5: REFLECTION + RE-POSITIONING</td>
<td>re-assessed and adjusted</td>
<td>re-assessed (and adjusted)</td>
<td>re-assessed and adjusted</td>
<td>re-assessed (and adjusted)</td>
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</table>
Curricula incorporate learning phases, all of which can serve as a starting point. Traditional science curricula adopt a learning sequence we call “additive learning” (see figure) that starts with mode 1, adding further modes later on (cf., e.g., Grün 1994). Others strive to encompass elements that reflect real-world contexts and problems from the outset (we call this sequence “reflective learning”, cf. the OUNL example and the figure). The question of whether to start with disciplinary (mode 1) or inter- and transdisciplinary learning (modes 3 to 5) has been a topic of discussion ever since the importance of interdisciplinary and transdisciplinary skills was recognized. While experience alone has proven to be a poor teacher (Kelly 2006), and starting with factual knowledge helps to avoid this problem, such an additive learning sequence can be criticized for several other shortcomings, in particular for postponing the putting of acquired knowledge into practice in one’s own professional actions and for neglecting the opportunity to set the taught content against a real-world context. If starting with modes 3 to 5 and subsequently integrating packages of modes 1 and 2 in an appropriate form, inter- and transdisciplinary learning is no longer a mere add-on to disciplinary education, but allows for reconsidering specialized knowledge and for re-positioning oneself within the engineering field. One disadvantage of this reflective learning approach is that the students might refrain from specialisation and stay on a rather superficial scientific and engineering level.

An emphasis on the modes 3 to 5 also triggers a second major effect: besides changing the output of education, it alters the selection patterns of engineering schools. De Graaff (2006) argues that the point of entry to a learning cycle is adopted either for “thinkers” by commencing with concrete and passive observations, for “doers” by commencing with concrete and active experiences, for “deciders” by commencing with abstract and active concepts and experiments, or for “dreamers” by commencing with abstract and passive conceptualization. These different learning styles need to be taken into account in the design of education programs. Referring to our list of learning modes, starting with modes 3 and 4 would more readily attract young people who are interested in problem-solving and societal commitment to EE (cf. also Beder 1989). In contrast to the rather one-sided learning types presented by De Graaff (2006), these students would ideally favor a combination of styles, as has been captured by the picture of the “reflective practitioner” (Schön 1983).

Assessing the Balance Between the Different Learning Modes and Outputs

Besides the sequence of learning modes provided by educational programs, it is the overall spectrum of modes, their intensity, and their quantitative proportions that are of key relevance for the advancement of EESD.

The representation of modes 1 to 4 in different curricula can easily be assessed: Our rough analysis is based on equating (monodisciplinary) lectures with mode 1, (monodisciplinary) practical courses with mode 2, collaborative and interdisciplinary seminars with mode 3, and practical courses in a real-world context with mode 4. This analytical scheme was tested in an international expert workshop, leading to interesting results and discussions: Assessments of traditional educational curricula according to the scheme showed that mode 1, and later on mode 2, are most commonly represented, while modes 3 and 4 – although frequently praised and promoted – are all too easily neglected, less well established, or less valued in the final assessments of the students’ (and scientists’ and engineers’) abilities. As a consequence, the establishment of mode 5 also becomes less likely. The analysis of a human ecology curriculum at the University of Vienna gives the following results: 108 to 194 credit points for mode 1, 129 to 205 credit points for mode 2, 7 to 57 credit points for mode 3, and 5 to 55 credit points for mode 4 courses (depending on students’ choices). According to this scheme, the acquisition of disciplinary knowledge and disciplinary practical skills is to some extent guaranteed, while the (further) development of commitment, attitudes and expertise relating to social roles and agency is possible but optional, as is any critical reflection in an inter- and transdisciplinary setting. Students thus have a variety of options, and a segregation according to different types of students is likely (e.g., the categories described by De Graaff 2006). These groups will then need type-specific supervision and careers advice.

The new OUNL curriculum can also be compared against the five modes. The introductory course for the OUNL’s academic Bachelor’s and Master’s programs in Environmental Sciences, “Earth, Humans and the Environment – an introduction to the environmental sciences”, combines distance learning with face-to-face meetings between students and tutors. The students are assigned case-related learning tasks on the Biosphere 2 experiment, which are then followed by similar assignments relating to real-world problems (mode 3 and 4). To fulfill these assignments, students are provided with a “knowledge base book” on environmental sciences (mode 1) that helps them gain domain-specific knowledge (physics, geology, life sciences, energy, production technology, mathematical modelling, etc). In-depth scientific texts on basic topics in the environmental sciences are discussed. In this way, the learning of sound basic knowledge is embedded in the philosophy of competence-based learning, which is based on learning-by-reflection rather than on factual learning alone (De Kraker et al. 2007, chapter 5). Learning-by-reflection (mode 5) is used from the very beginning: the students set their own daily life experiences against the model Biosphere 2 experiment and against reality, the real biosphere of earth. Face-to-face meetings are aimed at conveying skills (mode 2) and at setting study goals according to the professional development aims of the lifelong learner.

OUNL students complete their BS thesis in the form of a collaborative and interdisciplinary research project as part of the “Virtual Environmental Consultancy” (VEC) course (De Kraker 2007, chapter 5). 4 Mode 5 is less easy to detect based upon the analysis of course type prevalence.

5 According to the European Credit Transfer and Accumulation System (ECTS).
et al. 2007, chapter 8). The VEC course lasts a full academic term and can be seen as a remote internship, in which learning and work experience have been fully integrated in a distance-learning environment. Students and tutors working on the VEC carry out real research projects at the request of real clients, and deliver authentic products such as consultancy based on scientific research (mode 4). A unique feature of the VEC is its focus on individual competence development in accordance with students’ personal development plans. Learning-by-reflection (guided by self-assessment and peer-assessments) in combination with learning-by-doing and learning-in-context (provided by the internship assignments from real clients) are effective in fostering trans-boundary competencies for SD (De Kraker et al. 2007). Similar examples are presented by Jansen (2010, in this issue).

Conclusions

EESD should address the individual knowledge, skills, and attitudes of engineering students, as well as their perceived societal role and their own professional agency. For this reason, it is important

- to reassess the current demands of engineering education against the background of complex global problems and a changing engineering landscape,
- to acknowledge the different modes of learning and their respective learning outputs,
- to ensure a balanced approach and to improve the sequence of modes of learning in favor of a sustainability-oriented education,
- to integrate the different modes of learning in a meaningful way, and
- to call into question the current boundary between university education and professional agency, by establishing acting-in-context as the norm at the university level (e.g., integrating students in professional work on a more regular basis) as well as ensuring learning-in-context at the professional level (e.g., establishing contexts of learning and reflection for experienced professionals).

This approach also implies obligations for the four main groups of actors: Students should reflect upon the learned contents and the possible relevance of acquired knowledge for SD; engineers need to re-evaluate the potential impacts of available technical solutions; individual educators are expected to draw the link between social challenges and engineering education and to prepare students for inter- and transdisciplinary work; and those in charge of designing engineering curricula have to bear in mind that it is not only understanding and know-how but also reflection, attitudes, and commitment that are at stake in education for SD. The case of the School of Science of the OUNL can be a starting point for further discussion about good practice. Additional methodological surveys of professional qualities contributing to SD are required, as are the further development of interactive and project-based didactic methodologies and an increased dialogue about quality criteria across institutions and curricula.

Although we have made every effort to refer to the most frequently used concepts and to acknowledge the most important approaches encountered within the EESD discourse, we are aware that we may have missed some and may not have constructed an all-embracing taxonomy. Moreover, we have not fully addressed two important aspects of the debate: the trade-off between educating specialists and educating generalists, and the relationship between general engineering education programs and elitist programs like the OUNL curriculum. Against these acknowledged shortcomings, the main purpose of this paper has been to point out the importance of EESD as a topic of research and debate, as well as the present conceptual disparity, and to help foster the contribution of higher education to a societal transition towards SD. We hope that the proposed assessment scheme allows for further analyses and discussions in the EESD community.

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References


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