



Changing requisites to universities in the 21st century: organizing for transformative sustainability science for systemic change

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Sustainability science aims to enhance our understanding and increase our repertoire of action on urgent complex problems of how to reconcile our societal metabolism with the bio-physical carrying capacity of the earth. Sustainability science thus requires new forms of interaction between the natural and social sciences and between science and society. Universities across the globe are re-thinking their mission accordingly. This paper summarizes changing conceptions of science, knowledge and practice and on this basis it identifies a set of requisites to learning, teaching and research in universities that aim to foster systemic change. This set structures the overview on the fourteen contributions to this special issue on how leading universities across five continents stage transformative learning opportunities. These contributions are developed from a wide range of perspectives from diverse academic disciplines and practice.

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Today's society is not the first, and questionably not the last human civilization facing existential problems due to growth in population, expansion of urban settlements, overuse of natural resources, inequity, and violent conflicts. The present situation is unique in that no civilization before us has faced these challenges at a similar scale. The land-use practices and societal metabolism jeopardize the stability of the entire planet's ecological life support system. The complex problems societies face in the 21st century invite to re-frame, un-learn, and re-learn fundamentally how humans relate to each other and the environment. Re-framing progress in terms of regenerative

sustainability opens up new opportunities to reimagine what makes life worth living [1], and to re-organize interactions between society, economy, environments and research and education accordingly, at the scale of entire societies, whilst respecting planetary limits. Sustainability can then be reconceived as an emerging property of a societal conversation, in which traditional notions of progress are replaced with a striving for sense-making and the consideration of interdependent social, technological and systemic innovation and change.

One requisite for engaging in such a conversation productively is the individual and societal capacity for transformative social learning. Transformative social learning describes a scalable learning process that is able to critique current and imagine new ways of life. A first step is to rethink how new knowledge is co-created in collaborative processes and how social innovation comes about. Traditional disciplinary fields of science can play only a limited role in addressing complex problems of sustainability, especially considering the prevailing rift between the natural and the social sciences on the one hand, and between communities of scientific knowledge and practical knowledge on the other [2,3]. Calls to develop knowledge platforms for such co-creative research abound [4–6,58]. Increasingly sophisticated conceptions of transformative sustainability science are being developed and put into practice [7,8^{**},9–12,24^{**}]. Recent analyses of the literature on sustainability and higher education have noted that society requires more diverse spaces and guidance for implementation for such research-based learning processes [13,14]. Universities have an obvious role to play in addressing this need. However, drawing on diverse knowledge from academia, professional and lay practice to transform interactions between humans and the environment is fraught with challenges. Overcoming these challenges requires education and capacity building of a special sort. Traditional teaching and research approaches will need to be reconceived for universities to fully embrace this new role.

This special issue provides new perspectives on how universities are establishing opportunities for students, researchers, and citizens to learn how to engage in transformative learning for sustainability. The main objective is to provide guidance to engaged staff in universities and policy-makers and decision-makers shaping university curricula and strategy, on how to develop transformative learning opportunities. This issue highlights that thinking

about integration of sustainability into the curriculum may not be suffice, but that innovation and systemic change is required to allow for more transformative learning to take place at the system level [15,16].¹ In this view, internal and external stakeholders need to consider the university and higher education at large from a systems thinking perspective, collaborate on the development of scenarios and future visions and engage in transformative learning to achieve greater coherence between goals in universities and more sustainable societies [17*]. This special issue will discuss both the role of disciplinary fields of knowledge, and the need to embed new approaches to knowledge co-creation across diverse disciplines and practice in the core activities of universities, in order to contribute to transformative social learning and systemic change.

To set the scene for the special issue, this introductory paper first briefly maps changing conceptions of science, knowledge production processes and their relation to practice and place. This leads to a conception of sustainability science as a social learning process. Second, it characterizes requisites for transformative and social learning to occur in university settings; this presents the theoretical basis to compare how universities stage transformative learning opportunities with the goal of fostering systemic change. Third, it provides a brief overview on the fourteen papers describing initiatives at universities to organize transformative learning for sustainability.

Changing conceptions of the relation between science, knowledge and practice

With the recognition of science as a social institution [2,3,18,19], some of the limitations of knowledge production in disciplinary silos were highlighted. Common practice of ‘normal science’ in a disciplinary silo usually leads to reduced recognition of complexity, uncertainties, and value pluralism; a drive towards abstract rather than situated knowledge; and a reliance on peer review and career reward systems in a way that suppresses divergence and contradictions [2]. Furthermore, the resulting dynamic leading to the fragmentation of fields of knowledge impedes the making sense of complex systems. It also undermines the processes of quality control through peer review.

Since the 1990s new conceptions of the relation of science, knowledge, practice and progress are being advanced, including ‘post-normal science’, ‘Mode 2 science’, and the ‘co-production of science and social norms’ [4,20–22]. Diverse conceptions of sustainability science have emerged from these perspectives. Sustainability science relies on problem-driven interdisciplinary research focusing on the interaction between nature and

society, and takes account of complexity and uncertainty by adopting a systems perspective and a close link to practice [7,12,23,24**]. To ensure the future orientation of such research and to be able to consider the normative dimensions of the concept of sustainability and its implications more explicitly and from diverse perspectives, a process-oriented and pluralist view of collaborative research is required. Similar views on research are increasingly taken up in leading environmental research journals, as reflected in the revision of scope of journals like COSUST [25]. Research projects and platforms that aspire to embrace this co-creation logic fully are being developed and are growing in scale and ambition, as illustrated the Future Earth platform [5].

If universities choose to embrace sustainability science and an ensuing new dimension to their role in society, two conceptions of science will have to co-exist in universities: Science as a commodity and science in and for community [15]. The natural tension arising from co-existence of such disparate conceptions of science brings many challenges. However, of most interest to this special issue is the particular challenge that these two forms of science rely on very different conceptions of learning, teaching, research, and practice, and how they relate to each other.

New requisites to learning, teaching and research

Putting sustainability at the heart of university education in science involves fundamentally new conceptions of and requisites to learning, teaching and research and how they relate to each other. The conception of learning in the literature on sustainability education is usually that of ‘transformative’ or ‘triple loop’ learning for sustainability (e.g. [13,26]). Transformative learning is a term derived from adult education in the US that is also associated with instilling the curiosity and building the capacity for life-long learning (e.g. [27]). This form of learning can be juxtaposed to transmissive learning that is information-based learning about pre-supposed cause and effect relationships and which occurs within accepted boundaries [26,28]. This paper identifies a set of attributes of learning which are conceived in an entirely different manner in the two cultures of learning (Table 1): Purpose and scope of learning; learning processes; teaching, and tools and artifacts used; the role of learning environments; outcomes, impacts; and evaluation. Each attribute is explored in more detail below. This set of attributes also presents the basis of an analytic framework developed, which allows comparison of diverse approaches by universities to stage learning for sustainability.

Purpose and scope of learning. Purpose depends on local framings of sustainability challenges and possible solutions, which can range from seeking technological change, awareness raising to respond to information deficits, social

¹ <http://www.lnc.be/themas/natuur-en-milieueducatie/algemeen/edo/docs/inaugurele-rede-prof.-dr.-ir.-arjen-wals>.

Table 1

Comparing two cultures of learning

	Transmissive learning	Transformative learning
Purpose and scope	Understand defined cause and effect relationships	Personal transformation in contribution to systemic change
Process	Transfer of information from experts	Action-oriented development process
Teaching	Teacher defines meaning	Teaching facilitates negotiation and construction of meaning in diverse groups
Learning environments	Classroom or laboratory	Emergence of new knowledge from interaction with complex real world learning environments in diverse groups
Outcomes and impacts	Efficient reproduction	Shared actionable knowledge, transformed perspectives and environments
Assessment and Evaluation	Standardized testing	Self-evaluation and critical support

Personal adaptation building on [26,28].

adaptation and resilience building, to more fundamental social and systemic innovation including value changes (see also [29]). Regardless of which understanding of sustainability challenges and solutions prevails, the purpose and scope of transformative learning is often posited as the co-creation of actionable knowledge to address complex sustainability challenges in diverse groups; addressing such problems often requires systemic change. This broader conception of learning fundamentally reframes the question of *who learns and what for*. In order to embrace uncertainty, complexity and the unknowable we need to draw on plural rationalities and contradictory behavior. Transformative learning relies on collective learning in diverse groups, organizations or networks. It considers influences on learning across diverse levels of social organization including individuals, organizations and larger systems in which they are embedded, in terms of situated learning and systemic change [17,30].

The learning process: In line with Sterling [31], we consider transformative learning in individuals as a life-long iterative process, doors to which may be opened through engagement in projects that integrate education, research and civic engagement, and which is a requisite to systemic learning and change. In sustainability education emphasis is placed on the fact that transformative learning engages learners in *a process for active knowledge construction* that involves rethinking and acting upon how societies and individuals interact with their environments, questioning governing assumptions and values, and investigating alternative ways of doing and thinking. Transformative learning has been considered as an ‘opening up to diverse ways of knowing’ and interacting in a new manner with others and the world around you’ [27]. Building on John Dewey’s learning theories [32], parallels between learning and scientific inquiry and benefits of experiential learning and its close connection to actual practice are highlighted.

Teaching, tools and artifacts: For fostering transformative learning, teaching must be sensitive to ‘positionality’ of the learner and how personal perspectives are formed by

linking to personal experience. Learners, including teachers, need to be challenged by the experiences and perceptions of others in a dialectical manner. There is a slow emergence of new literature on problem-based and project based learning (and a more recent form of solution-oriented sustainability learning [43,54,60]). Successful learning interventions need to be managed to ensure that experiential situated knowledge from diverse communities of practice is made explicit, communicated and understood by others. And there are new requisites to how such learning is organized and supervised [33], for it involves awareness and balancing of diverse perspectives. In this special issue we argue that the field of sustainability education can still benefit from recent research from learning and developmental sciences, in particular on the relation between learners and experts and the use of tools and artifacts and learning environments [34].

Learning environments give direction to learning and how learning often occurs at the defined boundaries of such environments is key. Given that the individual embedding across diverse levels of social organization matters for giving direction to learning, there is a new focus on learning environments, including on the hidden curriculum that may be conveyed through values manifested in the design of social, institutional, and physical structures that an organization is embedded in. For informal teaching the campus can thus also be used as a resource and as a subject for a neutral discussion forum which allows bypassing disciplinary silos [35].

Learning outcomes and impacts include the production of shared actionable knowledge on complex problems, and that learning can be mediated by practice [31,36,37]. Some experts describe a shift in the goals of learning from content-driven to competences-driven. Three main sets of competences are usually cited as learning outcomes: first, Collaborative systems thinking and understanding interdependencies; second, to collaboratively see the future and develop shared visions that can shift the system; and third, normative and strategic competences to identify leverage points for change. Building

such collaborative and normative competences requires instilling a concern with values, and interpersonal competences to motivate groups to assume new responsibilities, and the capacity to mediate in situations of value conflict [38,39]. Other scholars critique the focus on competences as a too reductionist and utilitarian framing again directing attention at what may be countable, rather than considering learning as emergent property of actively in groups changing relations to the social and the environment [29,40]. Transformation can also be related to transformed relations between humans and their environment and transformations of the physical environment itself (e.g. retro-fitting of buildings for energy-saving, improved waste sorting or recycling infrastructure, renewable energy systems, etc.). These can be considered impacts.

Assessment and evaluation: Guided self-evaluation for learning plays a critical role in transformative learning. Relational changes are key for systemic change are however also a particular challenge for evaluation of impacts and outcomes of research and teaching for sustainability [41*].

Diverse approaches by universities to engage on sustainability challenges

Universities across the world have started to experiment with different approaches to institutionalizing transformative learning opportunities for sustainability. The central pillar of the special issue are fourteen papers covering a range of different approaches. The attributes of transformative learning for sustainability described in Section 'New requisites to learning, teaching and research' above are the basis for a set of guiding questions the authors of the case papers were asked to develop:

- (1) How is sustainability and/or sustainability science framed, what are the main themes or goals associated with sustainability at the University or in the department, and derived therefrom, what is the purpose of learning?
- (2) What is the structure and content of the research and study programme? How is learning conceived in terms of process or pathways, roles of experts and novices, tools/artifacts/resources, and the role of (scientific) inquiry in teaching and learning?
- (3) What are useful design attributes of learning environments (physical, virtual, or institutional)?
- (4) What are criteria for judging success and metrics for individual learning and for success of the study programme? What outcomes are established? How are outcomes measured and evaluated? What indicators might help to track curriculum change for sustainability at the level of universities?

While these questions are all interrelated, and most if not all are addressed in the various contributions to this

special issue, the individual papers all have different points of emphasis. A first set of papers focuses on learning processes and pathways and highlights learning outcomes. A second set draws attention to the role of learning environments; and the last set focuses on learning as relational change for systemic change. We provide a brief outline of each of these three sets in turn.

The first set of papers presents diverse conceptions of learning pathways and outcomes and how these may be embedded in curricula. Marcus *et al.* [42] present the University of British Columbia's long-term vision to embed sustainability in all teaching programs for undergraduates. Sustainability learning pathways are defined as any combination of salient curricular experiences. Students can choose from ranges of options that are flexibly embedded in programs and departments. Four 'Student Sustainability Attributes' help frame this sustainability learning. The Arizona State University's School of Sustainability's closely related goal is to enable students to acquire competence in collectively solving sustainability problems. Solution-Oriented Sustainability (SOSL) Programs allow students to contribute to transformative research projects in public or private organizations or cities, building place-based knowledge and relationships are a core aspect of this programme. However, Wiek *et al.* [43] also pragmatically highlight the resource intensity of such programs and the resulting challenges of scalability and reach. McGibbon and Van Belle's [44] paper then elaborates one specific example of how reflective practice enables awareness building and empowerment looking at the example of embedding a carbon foot-printing exercise within the Information Systems undergraduate curriculum. Lippuner and Bratrach [57] showcase the Sustainability Summer School at the ETH Zürich, a programme, which changes its setting each year to look at sustainability challenges in a different cultural and environmental setting with a diverse and changing international group of students and contributors from academia and practice. A set of critical and independent thinking competences constitutes the core learning objectives of this experiential learning programme.

The second set of papers focuses more on the design of learning environments. Evans *et al.* [45] introduce the living laboratory framework as one approach to strategically coordinate a stream of highly visible sustainability science projects for continued transformation on and beyond campus. Living laboratories allow the bringing together of researchers, students, external stakeholders and the university estates and facilities functions in real world settings on or beyond campus to co-produce applied sustainability knowledge. Evans *et al.* [45] point out the high potential of the greater use of the web and virtual spaces for scaling up the living laboratory approach and extending its reach. Trencher *et al.* [46] describe projects and programs at the University of Tokyo's Kashiwa

campus that rely on collaboration between students and stakeholders in the municipality with the aim of systemic transformation. A template institutional form to frame interactions between universities and municipalities facilitates scaling and transfer of knowledge resulting from such projects between regions in Japan. McKormick and Kiss [47] describe the Malmö Innovation platform in Sweden as a unique learning environment for Masters students of Lund University to engage with the complexity of urban renewal in practice. This case highlights the need for iterations in the learning process to allow the seizing of complexity and to create room for reflection. The other two papers take a step back from the urgent problem of transformation in urban environments and provide broader reflections on the importance of developing a sense of place for attributing meaning to sustainability. Building on early recognitions of the relationship of landscape, sense of place and scholarly enquiry in Greek philosophy, Whitbread [48] explores the role of landscape as an agent for an integrated pedagogy for sustainability. In the empirically based case study on the Australia National University's School of Art Environment Studies, a field work course was designed with stakeholders to change university-community relations, also employing art. Young *et al.* [49] make an in-road into the much theorized about, but in practice under-researched area investigating the role of art and the humanities in helping us to develop new imaginaries of how we relate to our environment.

The last set of four papers puts the focus on relational change in transformative learning. Villsmaier and Lang [50] describe a learning module in the Masters programme in Sustainability Science at the University of Lüneburg, which allows students to understand differences between cultures of knowing and practice. Boundary work highlights differences in outlooks on life, priorities and challenges. The gained awareness on differences presents opportunities to think out-of-the-box and find new solutions, and to develop a culturally sensitive reflexivity. The paper claims that students can be thus equipped to contribute to shifts in landscape of knowledge and institutions. On a more practical basis, Rosenberg *et al.* [51] then focus of their investigation on partnerships and stakeholders set up between the municipality of Oberlin and Oberlin College. They analyze how students can significantly contribute to learning experiences for external partners. They introduce the concept of 'carrying capacity' of such partnerships, which defines the extent to which students can fruitfully engage in such projects. König [52] presents the Certificate in Sustainability and Social Innovation at the University of Luxembourg, which is unique in that it is open to professionals and students from any degree programme. A combination of core courses and peer group projects offer transformative learning experiences; participants can design their own learning pathways with different theoretical or practical points of emphasis. Programme evaluation with

contributing external stakeholders plays a key role to build the programme's transformative capacity at the systemic level. Wals *et al.* [29] highlight the need to strengthen transgressive learning and capacity building for systemic disruption in order to equip students to break away from maladaptive resilience of unsustainable systems. Four streams of research and practice are characterized that are emerging to do exactly that. This paper invites higher education to provide spaces to transgress taken for granted norms and ethical and epistemological imperialism.

Outlook

The fourteen papers presented in this special issue pursue a shared goal of sharing lessons on how universities can more effectively contribute to fostering systemic change, by embedding their learning opportunities for students in wider networks of stakeholders within and beyond the University. Across papers in this the special issue it is argued that more systematic adoption of innovative and context-sensitive pedagogies will help universities to respond to new societal requisites of the 21st century, as well as enhance the sustainability of education and research. Institutional, physical and virtual learning environments are strategically deployed for translation from universal to situated knowledge. In most presented cases, the relationship of the university and the community it is embedded in is critical for achieving a systems perspective on the problem. Some of the initiatives also think strategically about scaling up relational networks. However, a wide range of well-characterized challenges abound: within universities, between university initiatives and external stakeholders, and also the challenges relating to scaling for fostering change at the systems level [14,55]. This set of papers provides a strong basis for further reflection on and analysis of how universities can stage transformative learning opportunities and how greater coherence can be achieved between goals of universities and sustainable societies.

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