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Sustainability, Science, and Higher Education

The Need for New Paradigms

By Pim Martens,[1,2] Niko Roorda,[1] and Ron Cörvers[1,3]

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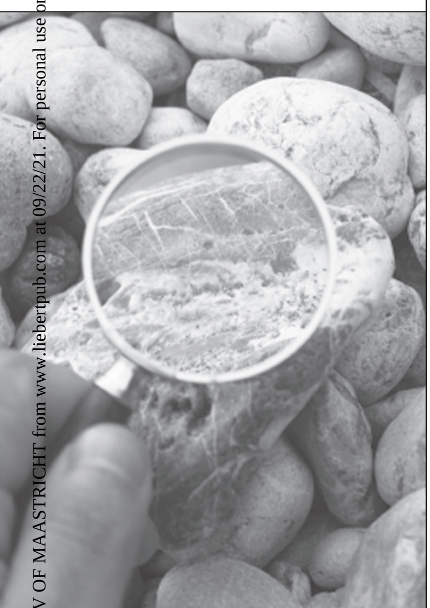

A number of fundamental barriers and practical obstacles have to be taken into account in translating the concept of sustainable development into science and education.

Abstract

In translating the concept of sustainable development into science and education, a number of fundamental barriers and practical obstacles have to be taken into account. However, there are also interesting opportunities and attractive challenges to make sustainable development "researchable, teachable, and learnable." New paradigms, or at least a shift in dominant paradigms, are required. Transition of the old curricula into more "sustainability-oriented curricula" means that the limited mono- and multidisciplinary approaches need to be replaced by full multi- and interdisciplinarity. This educational transition, which took place in several Dutch universities in the past two decades, and shifts in paradigm changed the educational system, which is now based on ideas from problem-based learning, project education, internationalization, multi- and interdisciplinarity, and competence-based education.

Introduction

During the World Summit on Sustainable Development in Johannesburg, South Africa, in 2002, it was agreed that a United Nations Decade of Education for Sustainable Development would be organized, spanning the years 2005–2014. Already in 1992 at the United Nations Conference on Environment and Development in Rio de Janeiro, Brazil, it was affirmed in Agenda 21 (Chapter 36) that education is essential for making progress toward sustainable development. The United Nations Educational, Scientific and Cultural Organization (UNESCO), as the declared lead agency to promote the Decade and expected substantive implementer of Education for Sustainable Development (ESD), envisions ESD as a "dynamic concept that encompasses a new vision of education that seeks to empower people of all ages to assume responsibility for creating and enjoying a sustainable future."

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In its information brief on Education for Sustainable Development, UNESCO identified four major thrusts in a new vision of education: promotion and improvement of basic education; reorienting existing education at all levels to address sustainable development; developing public understanding and awareness of sustainability; and training. In addition to this general plea for ESD, UNESCO claims in its Information Brief on Higher Education for Sustainable Development that universities (and probably other institutions of higher education, such as colleges in the United Kingdom, *hochschülen* in Germany, and *hogescholen* in the Netherlands) should particularly address the following issues in promoting sustainable development:

- Increasing the relevance of teaching and research for the societal processes leading to a more sustainable development and discouraging unsustainable patterns of life,
- Improving the quality and efficiency of teaching and research,
- Bridging the gap between science and education, and traditional knowledge and education,
- Strengthening interactions with representatives outside the university, in particular with those in local communities and businesses,
- Introducing decentralized and flexible management concepts.

Notwithstanding these ambitions, a number of fundamental barriers and practical obstacles have to be taken into account in translating the concept of sustainable development into science and education. Yet, there are also interesting opportunities and attractive challenges to make sustainable development researchable, teachable, and learnable. Therefore new paradigms, or at least a shift in dominant paradigms, are required.

Sustainability Science

In the academic world, there is a strong call for more integrated approaches to support the political and societal process toward sustainable development. Questions as to exactly how such integration—underpinned by scientific research—

should be conceived and put into effect have so far been the preserve of a select group of scientists.

On a global scale, great progress has been achieved, within the framework of the international Global Change research program, in the integration of previously separated scientific disciplines. Fifteen years ago, atmospheric chemists and biologists were not sharing their knowledge of atmospheric change, despite the fact that biological processes are an important factor in regulating the composition of the atmosphere and that chemical changes in the atmosphere might have an impact on biological systems. Nor was either discipline well integrated with other disciplines, such as atmospheric physics, oceanography, or climatology. Today, these disciplines are much more closely linked, and together, through integrated research and comprehensive risk analyses, they form the core of our knowledge about global climate change.

The international research community concerned with global change has made huge progress in coupling various relevant natural sciences disciplines with specific themes, such as climate change, and, more recently, biodiversity. Unfortunately, despite this commitment at national and international levels, there has been far less progress in understanding the complex interactions between nature and mankind or environment and society. To meet the high level of expectations from different agents from government, business communities, and civil society, a new research paradigm is needed that reflects the complexity and multidimensional character of sustainable development.[1] The new paradigm must be able to encompass different domains (ecology, economy, social, cultural) and dimensions (time and space), different magnitudes of scales (time, space, and function), multiple balances (dynamics), multiple actors (interests), and multiple failures (systemic faults).

This new paradigm emerges from a scientific subcurrent that characterizes the evolution of science in general—a shift from mode-1 to mode-2 science (Table 1).[2] Mode-1 science is completely academic in nature and monodisciplinary, and the scientists themselves are mainly responsible for their own scientific performance. In mode-2 science, which is at the core both inter- and transdisciplinary, the scientists form a heterogeneous network. Their scientific tasks are part of an extensive process of knowledge production, and they are responsible for more than merely scientific production. Another paradigm that is gaining influence is known as post-normal science. As it is impossible to eradicate uncertainty from decision-making processes, it must be adequately managed through organized participatory processes in which different kinds of knowledge—scientific knowledge, but also knowledge from practitioners—come into play.

Table 1. Properties of Mode-1 and Mode-2 Science

Mode-1 science	Mode-2 science
Academic	Academic and social
Monodisciplinary	Trans- and interdisciplinary
Technocratic	Participative
Certain	Uncertain
Predictive	Exploratory

The research program that is beginning to emerge from this movement is known as *sustainability science*.[3] Sustainability science, however, is not an independent profession, let alone an academic discipline. It is rather a vital area in which science, practice, and visions from different parts of the world (North and South) meet one another, with contributions from the whole spectrum of the natural sciences, economics, and social sciences. To create a branch of knowledge for sustainable development that is taught and researched at universities, sustainability science is organized through a number of research principles. Here, "shared" implies a broad recognition by a growing group of practitioners who—in a steadily extending network—are active in the field of sustainability issues. The core ideas and principles of sustainability science are:

- Inter- and transdisciplinary research,
- Co-production of knowledge,
- Co-evolution of a complex system and its environment,
- Learning through doing and doing through learning,
- System innovation instead of system optimalization.

Simply stated, this new approach promoted by sustainability science can be represented as *co-production, co-evolution,* and *co-learning*. The theory of complex systems can be employed as an umbrella mechanism to bring together the various different parts of the sustainability puzzle.

Toward Integrated Sustainability Science

The new paradigm for sustainability science has far-reaching consequences for the methods and techniques that need to be developed before an integrated analysis of a sustainability issue can be carried out. The new methods and techniques required can be characterized as follows:

- From supply- to demand-driven;
- From technocratic to participant;
- From objective to subjective;
- From predictive to exploratory;
- From certain to uncertain.

The new paradigm for sustainability science has far-reaching consequences for the methods and techniques that need to be developed before an integrated analysis of a sustainability issue can be carried out.

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Sustainability science has to promote integration of knowledge on a larger geographical scale in order to get beyond the artificial division between global and local perspectives.

In short, the character of original approaches and accompanying tools in the field of integrated analysis is changing. Whereas previous generations of integrated approaches were considered as "truth machines," the current and future generations of integrated analysis will be seen more as heuristic instruments, that is, aids in the acquisition of better insight into the complexity of sustainable development. At each stage in an integrated sustainability analysis, new methods and techniques need to be used, extended, or invented. The methodology that is used and developed by the integrated assessment community is highly suitable for this purpose. There are three different kinds of methods in the integrated assessment field of study: analytic methods, participative methods, and managerial methods.

The first category, analytic methods, mainly looks at the nature of sustainable development, employing, among other approaches, the theory of complexity. An example is an integrated assessment model that allows one to describe and explain changes between periods of dynamic balance. This kind of model consists of a system-dynamic representation of the driving forces, system changes, consequences, feedbacks, and potential lock-ins and lock-outs of a particular development in a specific area.

The second category, participative methods, can be distinguished by the fact that non-scientists, such as policy makers, representatives from the business community, social organizations, and sometimes even civilians, play an active role in the research. In these methods, negotiation processes between participants are mimicked in so-called policy exercises, whether or not supported by simulations. An example is a multi-stakeholder approach in which scientific analysis is enriched by the integration of knowledge possessed by participants from diverse areas of expertise.

The last category, managerial methods, is used to investigate the policy aspects and controllability of a societal process toward sustainability. An example is the method of transition management that consists of the following steps: envisioning (developing a long-term vision on sustainable development and common agenda at the macro-scale), experimenting (formulating and executing a local experiment in renewal that could perhaps contribute to the transition to sustainability at the micro-scale), evaluating, and finally, learning (putting together the vision and strategy for sustainability based on what has been learned from the experiment).[4]

Now that the first steps toward an integrated sustainability science have been taken, there is the prospect of making some major leaps forward. Sustainability science needs to be above all an integrative science, one that sets out to break down the barriers that divide the academic disciplines of "normal science," or mode-1 science. It will have to promote the integration of different scientific disciplines, such as earth sciences, ecology, economy, social sciences, and technology, to build a knowledge domain for sustainable development. The same can be said for virtually all policy approaches in society in which closely linked aspects of human activity, such as energy, agriculture, health, and transport, are still dealt with as separate entities.

The most significant threats to sustainability appear in certain geographical regions, with their specific social and ecological characteristics. Sustainability science, however, has to promote integration of knowledge on a larger geographical scale in order to get beyond the artificial division between global and local perspectives. Regardless of what spatial scale is found most suitable for an integrated assessment of any particular sustainability issue, gaining insight into the linkages between events on both the macro-scale and the micro-scale is one of the major challenges facing sustainability science. Finally, sustainability science must ensure the integration of different styles of knowledge creation in order to bridge the gulf between science, politics, and practice.

Education and Sustainable Development

The growing knowledge domain for sustainable development is not only a field of study for researchers, but also an area for teaching and learning. The educational system has the ambition to prepare children and young adults for functioning in future society. Education can be described as an institutionalized process aimed at realizing defined learning objectives for defined target groups. The learning objectives comprise disciplinary, social, cultural, and economic items. The target groups can be divided according to age and the level of prior education or development. The educational system tries to provide contexts that support the learning of individuals. Learning can be described as the result of the process of continuous interaction of an individual or a group with its physical and social environment.

The most important factors in the learning process are the individual learner and its learning environment. For the learner, the learning process contributes to the formation of social identity in which the individual can recognize him- or herself as a valuable individual with respect to others. The format of the learning environment depends on age, prior knowledge, and social activity and therefore changes continuously during the lifelong learning process.[5] The learning environment can be formal (within the educational system), nonformal (e.g., training on the job), and informal (family life, leisure time, museum visits). It is calculated that on average 5–10 percent of the lifelong learning process takes place in the

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formal learning environment. So, for lifelong learning the informal and nonformal learning environments are much more important.

In the traditional educational system, learning facts gets much emphasis, which is in line with the classical ideals of erudition and scholarship. In this classical approach, ordering of knowledge within specific domains or academic disciplines plays an important role. The objectives of the learning process are often described starting from these disciplines. An analysis of the objectives must give insight in the optimal conditions to realize the learning objectives. Starting from theoretical concepts of learning, it creates a set of conditions favoring the individual learning processes: the learning environment is designed, the learning content is structured, the learning process is supervised, and the results are tested.

This approach can be effective in domains that are characterized by independent learning objectives, but it is less satisfying in situations characterized by a more integrated, complex set of learning objectives. For the educational design of learning environments, a starting point in a specific discipline mostly implies a learning process in a relatively closed system. For the individual learner, it means that the formal learning process takes place in a learning environment that is relatively shielded from society and that the application of knowledge in vocational or societal practice only occurs after the formal learning process has finished. One may wonder if this way of teaching and learning is still "in harmony with modern society."[6]

Problems of sustainable development are typically complex, and perspectives on the nature and solution of these problems are likely to vary with national, cultural, and disciplinary background. This diversity of perspectives seems inevitable, given the global scale and complexity of sustainability problems and the many uncertainties that surround them. In an increasingly globalized, open, and pluralistic society, a key competence for practitioners in the field of sustainable development is therefore the ability to think, communicate, and work across the boundaries that divide the various perspectives. Major examples of boundaries to be crossed in this respect are those between disciplines, ideologies, and nations or cultures.

The ability to communicate and collaborate across the boundaries of nation, culture, and discipline can be described as "transboundary competence."[7] Transboundary competence is essential to support sustainable development processes. To determine how transboundary competence can best be developed in the context of higher education, one can apply the insights of competence-based learning experts into the elements that constitute powerful learning environments. Powerful competence-based learning environments are those that combine actual practice ("learning by doing") and reflection on what and how to learn from this practice ("learning by reflection").[8] Based on these principles, the ideal learning environment for sustainable development would be one that provides students with actual experience in interdisciplinary, international, or intercultural project work in teams.[7,9]

Competences for Sustainable Development

Today's students will be the business leaders, scientific researchers, politicians, policy makers, artists, and citizens of tomorrow. So what should we expect from the new graduates: what kind of knowledge, skills, and attitude do they need if we want them to lead us toward a more sustainable world? In other words, what kind of competences should the graduates have? Many scholars and developers of ESD have made attempts to formulate such a set of competences. Although they differ in details, the basic ideas are comparable. One such set is:

- "*Openness*, because the existing stock of knowledge has proved to be subjective and relative.
- *Reflexivity,* because subject and object underlie dynamic changes that may only be grasped by a higher level reflexivity.
- *Future viability,* because in the increasing dynamic of global change, only those who have learned to responsibly cope with insecurities and risks will remain functionable."[10]

Competences such as these remind us of a set of more general competences of higher education graduates, the so-called Dublin descriptors, accepted as guidelines for the graduate qualifications in the European Higher Education Area (EHEA). When these descriptors were formulated, between 2001 and 2004,[11] sustainable development was not specifically in the minds of the designers. Nevertheless, some relevance to sustainable development can be found in them, which may be illustrated by two of the "descriptors" for the Master's level, which demand that the graduates have:

- The ability to gather and interpret relevant data (usually within their field of study) to inform judgments that include reflection on relevant social, scientific, or ethical issues;
- The ability to communicate information, ideas, problems, and solutions to both specialist and nonspecialist audiences.

The relation between the Dublin descriptors and sustainable development has been made clearer by universities applying them. Some of the competences of a graduate should be that he or she:

- "Is able to analyze and discuss the social consequences (economical, social, cultural) of new

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developments in relevant fields with colleagues and non-colleagues.
- Is able to analyze the consequences of scientific thinking and acting on the environment and sustainable development.
- Is able to analyze and discuss the ethical and the normative aspects of the consequences and assumptions of scientific thinking and acting with colleagues and non-colleagues (both in research and in designing).
- Has an eye for the different roles of professionals in society."[12]

Other initiatives tried explicitly to integrate sustainable development into the academic qualifications in the EHEA, such as the Barcelona Declaration (2004) and the Graz Declaration on Committing Universities to Sustainable Development (2005), which was supported by UNESCO. These offer an even more explicit list of demands to the graduates:

- "Understand how their work interacts with society and the environment, locally and globally, in order to identify potential challenges, risks and impacts.
- Understand the contribution of their work in different cultural, social, and political contexts and take those differences into account.
- Work in multidisciplinary teams, in order to adapt current technology to the demands imposed by sustainable lifestyles, resource efficiency, pollution prevention, and waste management.
- Apply a holistic and systemic approach to solving problems and the ability to move beyond the tradition of breaking reality down into disconnected parts.
- Participate actively in the discussion and definition of economic, social, and technological policies, to help redirect society towards more sustainable development."[13,14]

Based on these and other sets of competences, we have made an attempt[15] to summarize and systematize them in an ordered set, called the RESFIA+D model (Table 2).

Table 2. Professional Competences for Sustainable Development: The RESFIA+D Model

Competence R: Responsibility A sustainable professional takes responsibility for his/her own work. *i.e., The sustainable professional can…*	Competence E: Emotional intelligence A sustainable professional projects him/herself on the values and emotions or others. *i.e., The sustainable professional can…*
R1. Make a stakeholder analysis R2. Take personal responsibility R3. Render personal account to society R4. Critically evaluate own actions	E1. Recognize and respect values of him/herself and of other people and cultures E2. Recognize and respect action perspectives of him/herself and of other people and cultures E3. Listen to opinions and emotions of others E4. Distinguish between facts, presumptions and opinions
Competence S: System orientation A sustainable professional thinks and works from a systems vision. *i.e., The sustainable professional can…*	Competence F: Future orientation A sustainable professional thinks and works from a future-oriented perspective. *i.e., The sustainable professional can…*
S1. Cooperate in an inter- and transdisciplinary way S2. Think in systems, zoom in and out, i.e. alternately think analytically and holistically S3. Think function oriented, innovative, creative, out of the box S4. Think chain oriented	F1. Recognize and understand nonlinear processes F2. Think in varying timescales; distinguish between short and long term approach F3. Estimate consequence reach and consequence period of decisions F4. Think future oriented, anticipate
Competence I: personal Involvement A sustainable professional dedicates him/herself personally for sustainable development. *i.e., The sustainable professional can…*	Competence A: Action skills A sustainable professional acts decisively and competently. *i.e., The sustainable professional can…*
I1. Consistently involve sustainable development in own work as a professional (sustainable attitude) I2. Keep own knowledge and expertise up to date, even outside of the discipline I3. Work with passion on dreams and ideals I4. Apply own conscience as the standard	A1. Weigh unweighable aspects and make choices A2. Act when the time is ripe, not against the flow: "do without doing" A3. Deal with uncertainties A4. Make decisions
Plus: Disciplinary competences for sustainable development (varying per education program or professional group).	

The RESFIA competences (named after their initials) and their subcompetences do not mention any specific sustainability-related subjects, such as climate change, deforestation, poverty eradication, or stakeholder participation. Topics like these are too specialized to be mentioned in a set of competences that should be applicable to all academic disciplines. That is why disciplinary competences are only mentioned at the bottom of Table 2, and therefore the model is called RESFIA+D.

As with other sets of competences for sustainable development, the RESFIA+D model may seem abstract. How can the acquisition of such competences be measured with individual learners or graduates? For the answer to this question, many sectors of higher education introduced the so-called competence-based education, which not only implies new educational methodologies, but also new ways of evaluating the students' progress and achievements. In many organizations for higher education, this evaluation is an assessment in which the student has to prove acquisition of the desired competences at a certain level of expertise. Such an assessment usually takes the form of a student interview by one or more teachers. In this interview the student describes and defends a report, or a file of reports, of the activities that the student did to acquire, exercise, and prove the competences on the desired level. For this aim, sets of competence levels have been designed (for an example, see Table 3). The competences and subcompetences of RESFIA+D have been described in operational terms, so they can be assessed.

Table 3. Competence S1: Cooperate in an Inter- and Transdisciplinary Way
Level 1: *Apply*
• In your professional activities, you consider aspects of other disciplines, i.e., in a multidisciplinary approach.
Level 2: *Integrate*
• You carry out these activities as a member of an interdisciplinary team.
Level 3: *Improve*
• You involve stakeholders, including those who do not represent a specific professional discipline, actively in the activities, thus creating a transdisciplinary approach.
Level 4: *Innovate*
• You enlarge the target area of the activities to new kinds of stakeholders and/or cultures.

This example uses the terms multi-, inter-, and transdisciplinary, which by many authors are considered key aspects for sustainable development.[1,16] These terms form a central theme in ESD and can be defined as follows:

- ***Multidisciplinary:*** cooperation between various disciplines, but keeping intact every separate set of theoretical concepts and methodological approach.
- ***Interdisciplinary:*** cooperation between various disciplines, looking for a common methodological approach and theoretical fundament as a synthesis of the participating disciplines. Participants try to speak "one language."
- ***Transdisciplinary:*** not only cooperation between specialists of various disciplines, but also others are directly involved: users, problem owners, clients, stakeholders, etc. Transdisciplinary literally means "beyond the disciplines."

Competences like these can hardly be achieved by students in the traditional education style that was typical in most universities some decades ago. So the question arises, which educational methodologies have been developed in order to enable competence-based education, especially for sustainable development.

Methodologies for Education for Sustainable Development

Traditional educational methodologies can fulfill the requirements for ESD to a certain level. However, other educational methodologies have been designed that are more suitable to enhance ESD. One of them is problem-based learning (PBL), which was first introduced in medical studies in Canada. The problem-based approach focuses on the integration of knowledge and skills from different domains. During their studies, students are required to put the knowledge they learn into practice (for example, medical students have to analyze and gather information systematically from a real patient to make and discuss a diagnosis with a teacher). An advantage of this learning method is that students gain knowledge in a meaningful context, providing a connection between different kinds of knowledge that otherwise would have been provided separately.

In the Netherlands, PBL was introduced at the Medical Faculty of Maastricht University. From there, it spread across many universities, especially those of applied science.

According to De Graaff and Bouhuys[17] the characteristics of a PBL-based curriculum are:

- Integration of discipline and skills;
- Curriculum structure with thematic blocks;
- Learning oriented work in small groups;
- Self-directed learning.

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Ph.D. Program on Sustainability Science, Policy, and Practice

The new interdisciplinary Ph.D. program in Sustainability Science, Policy, and Practice (SSPP) at the Maastricht University Graduate School of Sustainability Science (MUST), ICIS (www.icis.unimaas.info) is designed to educate researchers, university teachers, and world leaders in the social, economic, and natural science disciplines that underpin sustainable development. Sustainability science is a new transdisciplinary approach to science that recognizes the limitations of traditional scientific inquiry in dealing with the complex reality of social institutions interacting with natural phenomena. The research produced by the program's doctoral dissertations will focus on integrative, interdisciplinary research that is needed to explore science and policy issues in sustainable development. Integrated assessment methods and concepts (e.g., transitions, modeling, scenario analysis) will be instrumental in providing answers to the central questions of sustainable development. Applicants should demonstrate an ability to pursue independent research through their prior work and academic distinction. Upon graduation, it is expected that the candidates will play an important role as scholars, policymakers, and professionals in their home countries and in the international community, taking leadership roles in government, international organizations, nonprofit organizations, and business.

The Ph.D. program is a four-year program of individual scientific research, individual supervision. and classes. The program is designed both to equip candidates with the skills required to undertake research for the Ph.D. thesis and to develop in them the breadth of knowledge and depth of understanding in their specific subject of research. The supporting institutes provide the Ph.D. students with advanced training modules, top research advice, innovative think-tank activities, excellent assistance, and supervision of the students. The objectives are:

- To familiarize the student with the main contemporary social, economic, and environmental theories and concepts related to sustainability science, policy, and practice;
- To introduce the student to the challenges, constraints, and interactions of the academic definitions, decision making tools, and practices of the principles of governance, sustainable development, and sustainability science;
- To provide the student with skills to be able to perform a quantitative/qualitative analysis of "sustainable development issues" by using a set of "Integrated Assessment" methods and tools;
- To get the student started on doing original research in the field of sustainability science, policy, and practice by solving existing puzzles and paradoxes, critiquing and modifying existing approaches, identifying ways to obtain developing new concept models, and deriving new policy implications and more relevant empirical evidence.

Other similar programs exist or are being developed at several (collaborating) universities worldwide: Arizona State University, United States; the University of Tokyo, Japan; Maastricht University, the Netherlands; Lund University, Sweden; Stellenbosch University, South Africa; Leuphana University, Germany; Technical University of Catalonia, Spain; Harvard University, United States.

PBL lends itself strongly to the integration of sustainable development in the curriculum. However, PBL has one important limitation: usually every PBL exercise is done within a couple of weeks, so it requires limited planning and scope. Therefore another method was introduced—project education. Such a project may be performed by a group of students of, say, 2 to 30 persons. The project time may vary between a few weeks and half a year or so, meeting perhaps one to five days a week. During this time period, lectures or other instruction may be given by the teaching staff, usually after the students have become aware that they lack certain knowledge or skills. Thus, the instructions are made available "just in time."

Depending on the time, equipment, and money available, project education may be performed through a search in the literature and the Internet, via online interviews with people in a developing country, or perhaps even with a visit to such a country. In the latter case, the students have to make extensive planning; although the exercise contains specified tasks and desired results, it leaves a lot to the fantasy and responsibility of the student group. If the group is made up of students from various relevant disciplines, an interdisciplinary approach is easily obtained. If other interested persons, such as some receivers of microcredits and employees of credit-donating banks are also members of the group, the project is even transdisciplinary.

The Ph.D. program described in the box above is one example of a program in which students travel the world over to contribute to sustainable development and at the same time enhance their personal knowledge and experience. This kind of program could never have been developed within a traditional curriculum. It is only possible thanks to one of the major changes that have been going in higher education—the internationalization process. This leads to cooperation between universities in all parts of the world, and also to cooperation of universities with companies, governments, and nongovernmental organizations across borders, and students working or studying for some time in a foreign country.

Students who spend a period of time abroad to study at another university have become a familiar phenomenon in many European countries over the past decades. For over 20 years, the European Commission has been stimulating physical mobility in its member states through the Erasmus program. The objectives of this international exchange program range from promoting a sense of European citizenship and the competence to cope with cultural diversity to improving access to high quality education throughout Europe and improving the quality of higher education through international collaboration and competition.[9]

The Erasmus program can be considered a success in that more than 1.5 million students have participated since 1987.[18] In fact, however, in each academic year less than 1 percent of the total European student population take courses at a university in another member state.[19] The European Commission is currently aiming to increase student mobility by 2012,[20] but it appears that these targets will not be achieved by physical mobility alone. Even if the campaign is successful, the large majority of students will not be internationally mobile, due to a variety of social, organizational, administrative, financial, and physical barriers.

For those students who are not able to be internationally mobile, an alternative has been suggested in the form of virtual mobility, that is, "using information and communication technologies to obtain the same benefits as one would have with physical mobility, but without the need to travel."[19] Recent reviews of virtual mobility initiatives list many actual or potential advantages and benefits at the student and teacher level, as well as the institutional level.[19,21] These range from better Europe-wide access to courses for students to an enriched, internationalized work environment for teachers, and a cost-effective expansion of the number of courses being offered by universities.

The integration of virtual courses into the curriculum can become an important new method for ESD, as it can provide students with actual experience in interdisciplinary, international, or intercultural project work in teams.[22] In a traditional educational setting, such a learning environment with cross-boundary contexts and group work as

major ingredients is difficult to achieve; it would require a high level of international student mobility to bring students from different disciplinary, national, and cultural backgrounds together at the same time and in the same place. Virtual mobility, using computer-supported collaborative learning environments, provides an innovative and almost ideal solution to this problem, as these learning environments allow communication and collaboration, independent of time and place, between internationally dispersed student teams at low cost.[9] An added advantage of virtual learning environments is that they provide better opportunities for structured group discussions as well as reflection processes, both individually and collectively.[23]

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Thus, although it might seem somewhat counterintuitive, virtual learning environments appear to be well suited to develop the transboundary competence required to effectively contribute to sustainable development. In addition to learning for sustainable development, international virtual learning environments are also major instruments in preparing students for the rapidly internationalizing labor market and for new ways of working, such as Internet-based collaboration in geographically dispersed teams. These educational considerations were the major reasons to develop new approaches for ESD at the course level and campus level. (See box on page 302.)

Strategies for Change

An active internationalization policy supported by virtual courses to acquire competences for ESD is not the only condition for universities to integrate sustainable development in the education. Methodologies like problem-based learning and project

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Virtual Mobility for Sustainable Development: EVS and VCSE

The idea for a European Virtual Seminar on Sustainable Development (EVS) originated in 2001 at the Open Universiteit Nederland. Since then the EVS has been organized each year and the network of participating universities has gradually expanded; in 2008 14 universities from 11 European countries were involved in the EVS. The aim of EVS is to foster a dialogue on sustainable development issues in Europe. The educational format for EVS should therefore support computer-supported collaborative learning in geographically dispersed student teams, which is an educational approach in which students work in small groups to achieve a common goal, by using modern ICT and the Internet. The organizational model of EVS is a bottom-up network approach with distributed responsibilities, operating without external funding. The EVS has been widely acknowledged as a successful model and "best practice" in inter-institutional e-learning. Recent external quality assessments of educational programs in environmental sciences in the Netherlands and Belgium explicitly commended the EVS as an excellent example of internationalization.[24,25] A detailed description and discussion of EVS has been published.[26] (See also the EVS website: www.ou.nl/evs)

Inspired by the success of the EVS, a consortium consisting of EVS universities from Austria, Czech Republic, Greece, Germany, and the Netherlands has executed a project to expand from a single joint course (EVS) to a joint virtual campus for ESD. The first phase of this project involved the design of the virtual campus and the development of e-learning courses as its building blocks, such as EVS. The next phase involved the implementation of the virtual campus website, running the e-learning courses, active expansion of the virtual campus, and the dissemination of the virtual campus model to other interdisciplinary fields of study. The result of this project funded by the European Commission is the Virtual Campus for a Sustainable Europe (VCSE). The VCSE is organized as an open and flexible network with distributed responsibilities, offering high-quality e-learning opportunities on interdisciplinary topics that are ideally taught and learned in an international educational setting. An important objective of the initiators of the VCSE is to enlarge it, adding new partners, more students, and more e-learning courses on sustainable development. For a detailed description of this virtual campus and its e-learning courses, see the VCSE website (www.vcse.eu), where one can also download the VCSE Best Practice Guide.

education require a fundamentally different structure than that of the traditional curriculum. Transition of the old curricula into more sustainability-oriented curricula means that the limited multidisciplinary approach based on the integration modules needs to be replaced by a full multidisciplinarity by relating the curriculum parts to each other in several ways.

This educational transition is similar to what happened in the past two decades in most Dutch universities. Nearly all of these shifted in paradigm by applying changes in their educational system based on ideas from problem-based learning, project education, internationalization, multidisciplinarity, and competence-based education. Some experiments were done in the direction of inter- and transdisciplinarity, but there is room for improvement.

At present, the "walls" between the faculties or schools at most Dutch universities are still quite closed; another breakthrough is necessary. Of course, the introduction of ICT and the Internet and distance education has created new opportunities for learning, like the use of virtual classrooms, online learning materials, worldwide discussion forums, and serious games. Last but not least, the universities also received a strong impulse toward sustainable development through their intensive contacts with the professional field, urging them to integrate sustainable development and corporate social responsibility into education.

The Dutch higher educational system has seen many innovations and structural changes in the past 20 years. This illustrates that, wherever such fundamental innovation processes take place in a sector of higher education, these processes can effectively be used as a vehicle for the integration of sustainable development, that is, for the ESD development process to "sail on the winds of change." Probably, if such suitable situations occur, this is the best ESD strategy available, because it fits with the already occurring change processes and causes the least resistance.

In other situations in which suitable change processes do not take place, the integration of sustainable development into the education will not be possible through such an "evolution" strategy and success may only be gained through "revolution," in which the ESD forerunners have to have a proactive role, trying to set the desired change processes in motion. In these cases, the new paradigm that is necessary for ESD will have to come from the ESD developers, and not to them.

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