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Educating Students in Real-world Sustainability Research: Vision and Implementation

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Abstract Readers are invited to imagine students helping to solve real-world sustainability problems brought to them by societal stakeholders and simultaneously learning about and contributing to sustainable changes in society. Effective sustainability research education engages students in just that. Higher education institutions are implementing this vision of education in entire curricula, individual courses, and extracurricular research activities. In this article, we build on the literature to describe a vision of sustainability research education and present an evaluative scheme for measuring its effectiveness. We apply the scheme to two sustainability research-education projects in Switzerland to test its applicability and to identify achievements of the projects and the areas where improvement is needed. Areas for improvement include collaboration between academics and practitioners, joint problem definition, and the guidance of students to participate successfully in collaborative, real-world projects.

Key words Sustainability research education · Participatory research · Transformative learning · Interface management · Evaluation

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In an article published in *Science* in 2007 Debra Rowe, the President of the U.S. Partnership for Education for Sustainable Development, described an ideal situation for sustainability research education:

> Imagine what might happen if students were regularly assigned actual sustainability problems that were brought to higher education by cities, businesses, non-profit organizations, and other institutions. If classroom exercises produced workable contributions to solutions, students would understand they can have a positive impact on the world through their academic learning (p. 324).

However, there is a gap between good intentions and actual implementation: "Most of our higher education institutions include somewhere in their mission statements goals for preparing students to help create a better society, yet this ideal is often not fully implemented" (Rowe 2007, p. 324). These visionary words inspired us to translate them into a framework for the ideal sustainability research education.

In this article, we first describe sustainability research and provide examples of higher education institutions that have incorporated sustainability research into their curricula. We then draw from the literature to substantiate and describe the steps and requirements necessary to realize Rowe's (2007) vision of sustainability research education. Third, we present an evaluative scheme that can be applied to design or evaluate educational programs in sustainability. Finally, we describe the challenges to implementing Rowe's (2007) vision of sustainability research education. In so doing, we respond to the call for further studies on "the benefits of community-university partnerships and the features of partnerships that contribute to these benefits" (McNall et al. 2009, p. 327) and for studies on "how to integrate sustainability effectively into higher education and, in particular, into the curriculum and the design of research projects" (Sammalisto and Lindhqvist 2008, p. 222).

We apply the evaluative scheme to two projects from the *Seed Sustainability* initiative of the Swiss Federal Institute of Technology (Eidgenössische Technische Hochschule) in Zürich (ETH Zürich). Seed Sustainability was founded in 2004 as a non-profit spin-off of ETH Zürich; and it has supported collaboration among students, academics, and practitioners in more than 40 sustainability research education projects (Kueffer 2006; Wiek et al. 2010a). In these projects, students together with practitioners have addressed real-world sustainability problems in government, businesses, and non-profit sectors. Collaborations aim to generate scientifically sound and practical solutions while also meeting students' educational needs. Seed Sustainability allows students to conduct their semester projects and/or their final theses (e.g., master's theses) or dissertation projects as sustainability research projects.

Sustainability Research and Curricula

Sustainability research has often been described as problem- and solution-oriented and equally committed to scientific rigor and social relevance (cf. Robinson 2008; van Kerkhoff and Lebel 2006; Wiek 2007). The kinds of complex problems that sustainability research addresses, including climate change, poverty, violent conflicts, and overuse of natural resources, are critical problems that display specific features. Climate change exemplifies the characteristics of a sustainability problem: its social, economic, and environmental causes and effects are interrelated (across societal sectors); it is a global phenomenon with specific regional and local causes and impacts (across spatial scales); its consequences will affect future generations (inter-generational); its impact is harmful to a large number of people; and the need for solutions is urgent (risk of irreversibility).

Students educated in sustainability research are able to address these complex sustainability problems and develop solutions to them. Because students need to learn how these problems matter to people “on the ground,” how they are caused, and where potential intervention points are, sustainability research education needs to take place in real-world settings that go “way beyond the classroom” (Calder and Clugston 2005, p. 8) and connect the classroom with the real-world (e.g., Calder and Clugston 2003; Corcoran and Wals 2004; UNESCO 2003).

Over the last decade, higher education institutions have introduced sustainability research education as an “add-on” to disciplinary curricula (e.g., geography, environmental sciences), built genuine sustainability science curricula (e.g., University of Tokyo n.d.; Lund University, Maastricht University, Arizona State University School of Sustainability n.d.), or initiated practical sustainability research activities on campus (e.g., University of British Columbia n.d.; Western Michigan University n.d.).[1] However, these initiatives have mostly been implemented *within* the collegiate institution: the majority of studies have been conducted *in* the classroom and have dealt predominantly with problems presented in the literature or identified by researchers. Some initiatives exist that to connect the classroom with the real-world and train students to solve sustainability problems: the Transdisciplinary Case Studies for Sustainable Development at the Swiss Federal Institute of Technology Zürich and at other European universities (Scholz et al. 2006; Stauffacher et al. 2006; Steiner and Posch 2006) and the Sustainability Learning Classroom Model initiated across four academic institutions in Vancouver, Canada (Holden et al. 2008) are two such initiatives. These programs have successfully engaged students, faculty members, and stakeholders in large-scale projects addressing real-world sustainability problems. Yet small-scale projects conducted by small groups of students, faculty members, and stakeholders to increase students’ activity, responsibility, and accountability are still rare.

Framework for Sustainability Research Education

Expanding upon Rowe’s (2007) definition of sustainability research education, we constructed a framework for an ideal setting in which to deliver such education. The framework consists of seven components that are derived from the literature (Fig. 1).

Actual Sustainability Problems

Sustainability problems such as climate change, extreme poverty, and epidemics severely impact our society (Kates et al. 2001). These so-called “wicked” problems, which are urgent, long term, and highly complex, cannot be solved by simple remedies such as “technical fixes” (Funtowicz and Ravetz 1993; Liu et al. 2007). Higher education institutions recognize that these problems are important. They have begun to redirect their research and educational focus to balance basic research with applied research to solve such “wicked” problems (Corcoran and Wals 2004; Cortese 2003; Elder 2008). Society is

[1] For details about these efforts, please see: http://www.ulsf.org/resources_sust_degrees.htm, http://sustainabilityscience.org/curriculum.html, http://schoolofsustainability.asu.edu/degrees/index.php, http://www.sustainability.k.u-tokyo.ac.jp/, http://www.lucsus.lu.se/html/education_at_lucsus.aspx, http://www.icis.unimaas.info/education/must/, http://www.sustain.ubc.ca/.

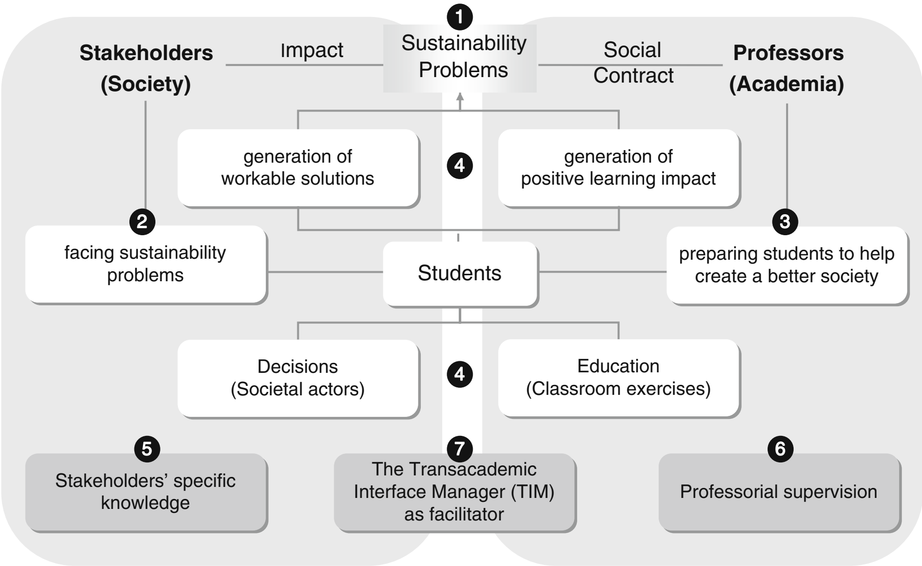

Fig. 1 Framework of requirements for sustainability research education as derived from literature

beginning to demand that academic institutions engage on an equal and structured basis with entities outside of academia to address the problems perceived to be most relevant and urgent. Dealing with *actual* sustainability problems takes students beyond theoretical understanding and helps them develop practical competence, commitment, and the skills needed to disseminate their research (Alvarez and Rogers 2006; Holden et al. 2008; Wals and Jickling 2002).

Stakeholders Facing the Sustainability Problems

Stakeholders and decision-makers need to solve sustainability problems; therefore, they often request help from researchers. Stakeholders' and decision-makers' willingness to adopt and implement solutions increases when they are the ones who initiate the problem-solving process. Stakeholders can also take ownership of a sustainability problem if academics invite them to identify and solve it *collaboratively* (Hirsch Hardon et al. 2006; McNall et al. 2009; Muhar et al. 2006; Wiek et al. 2007).

Preparing Students to Help Create a Better Society

Many institutions of higher education have as part of their mission the goal of preparing students "to help create a better society" (Rowe 2007, p. 324). This goal is echoed by the business sector when it calls for graduates able to act as "change agents" for sustainability (Martin 2005). Thus, sustainability research education must ground students' scientific expertise in competencies that promote stewardship and help students to unite "the disparate parts of personality: intellect, hands, heart" in their academic work (Orr 1992, p. 137). Wiek et al. (2010b) reviewed different sets of competencies in sustainability (Elder 2008; Fien 2002; Grunwald 2004; Sterling 2004; Wals and Jickling 2002), and grouped them into four categories: problem-oriented and conceptual knowledge, methodological knowledge, ability to "link knowledge to action", and interpersonal and collaborative skills.

Generation of Workable Solutions and Positive Learning Impact

Sustainability research education should enable students to analyze a sustainability problem *and* to develop response and mitigation strategies collaboratively with stakeholders (extended peer review).[2] Stakeholder support of solution strategies increases the likelihood that the strategies are workable and will actually be implemented after the research project ends, therefore increasing the likelihood of leading to real-world changes. Sustainability research education as "academic learning" should stimulate "transformative" or "second-order" learning in students (Mezirow 2000; Sterling 2004): students should be able to reflect explicitly and critically on their tacit assumptions, perspectives, and preferences. This should increase the likelihood that the project promotes changes in mindsets.

So called "transacademic" research settings address these criteria. "Transacademic" research means that scholars and laypersons (stakeholders) collaboratively conduct research (cf. Mushakoji 1978, p. 183). Transacademic settings allow students to join and contribute to a collective problem-solving process that integrates the best available knowledge from different sectors (Gibbons et al. 1994; Grunwald 2004; Hirsch Hardon et al. 2006; Robinson 2008; Scholz et al. 2006; Wiek 2007). In these settings, students recognize that they are not only "subjects of education," but also real-world stakeholders who—with their decisions—contribute to shaping the present and future of society.

Stakeholders' Specific Knowledge

Stakeholder collaboration in research supports development of credible and feasible solution strategies. It also helps overcome the "order, deliver, and pick up" model, in which stakeholders "order" a service and "pick up" the solution provided by scientists (Grunwald 2004; McNall et al. 2009; van Kerkhoff and Lebel 2006; Robinson 2008; Wiek 2007). Since sustainability research integrates place-based knowledge, preferences, and practical experiences, stakeholder involvement is indispensable. By working with stakeholders in the research process, students learn how to synthesize different forms of knowledge, cope with conflicting perceptions ("facts") and values, and build partnerships and trust. The ideal sustainability research education activity would involve stakeholders throughout the entire research process.

Professorial Supervision

Sustainability research depends to a significant extent on regular academic skills such as critical thinking, effective writing, and the skilled presentation of research results (Fien 2002; Healey 2005; Wiesmann et al. 2008). Professors should enhance students' critical-thinking abilities (e.g., help students evaluate the structure, coherence, and consistency of the ideas they read, hear, and talk about), foster basic academic skills (e.g., designing research, reviewing literature, writing, presenting), and supervise students' academic performance (e.g., jointly identify objectives, encourage reflection, provide feedback). Such efforts require that professors be flexible and adaptive and willing to go beyond disciplinary boundaries (Stauffacher et al. 2006). In return, professors may increase their own sustainability knowledge from their interactions with students and in particular with practitioners from the real-world.

[2] A peer review process is common practice in academia to ensure credibility of an academic contribution. The "extended peer-review" refers to the same process, but it includes non-academic experts such as stakeholders and decision-makers in the review process to ensure credibility, legitimacy, and salience of the academic and practical contribution.

The Transacademic Interface Manager as Facilitator

Transacademic research poses institutional and organizational challenges including, for example, matching schedules and working cultures of scholars and practitioners, balancing research and project management, and conducting extended peer review of the academic papers and other final products produced by students. We introduce the Transacademic Interface Manager (TIM) as a neutral person who facilitates the transacademic collaboration between and among students, their professors, and stakeholders and thereby mediates the interface between science and practice. The TIM facilitates the integration of so called "facts" with values, deals with power relationships, and mediates differences in the perspectives and aspirations of academics and practitioners (McNall et al. 2009; Miller 2001; Moll and Zander 2006; van de Kerkhof and Wieczorek 2005; Wiek 2007). The TIM takes on the roles of facilitator (mediation, translation), coach for students (interpersonal skills, project management skills), and project manager (coordination, administration, resources, schedules). Ideally, the TIM frees project participants to apply themselves to problem-solving and to their genuine tasks and competencies, for example students conducting research, professors mentoring students, and stakeholders informing the research process with their expertise.

Evaluation of Two Sustainability Research Education Projects

We translated the above framework into an evaluative scheme to assess whether and to what extent a particular sustainability research education project fulfills requirements for the ideal educational setting. The evaluation criteria and related guiding questions are listed in Table I.

We used this scheme to evaluate two representative projects of the Seed Sustainability initiative at ETH Zürich. In accord with the goals and procedures of this initiatives, both projects promoted collaboration among students, professors, and practitioners. The introductory meeting of each project team, which consists of students, their professors, and stakeholders, focuses upon joint problem identification and framing of the overall research question. The topics for students' master's and bachelor's theses arise from this discussion. At the final meeting team members consolidate results, review the solutions, and discuss how they will be implemented, and evaluate collaboration. Participants are jointly responsible for funding the project. As academic mentoring is part of the faculty member's responsibility, the supervising professor provides time in-kind paid for by the university. A grant from ETH Zürich covers the fixed costs of Seed Sustainability, e.g., for office space, web site, and administration. Practitioners pay Seed Sustainability for the TIM's project facilitation. There are no costs for students.

To evaluate the two projects, we analyzed process documents and observations of interactions (minutes of meetings, personal notes); student material (conceptual papers, presentations); and results of the exit surveys, which are completed by all project participants and are designed to evaluate the quality of the process and outcomes. One of us, Katja Brundiers, served as the TIM for both projects. Thanks to her role, we had access to the informal, and usually inaccessible, observational data that the TIM records in internal memos of meetings and interactions, e.g., on project participants' performance.

The purpose of applying the scheme to evaluate two projects was not to conduct a rigorous evaluation or produce representative findings, but rather to test the scheme's validity as a way to derive insights systematically so as to inform the vision of sustainability research education.

Table I Evaluative scheme comprising seven requirements for sustainability research education with corresponding criteria and guiding questions

Requirement/Feature	Criteria	Guiding questions to help assessing each criterion
(1) Actual sustainability problems	a. Long-term dynamics	a. Does the problem impact future generations?
	b. Cross-domain and cross-scale complexity	b. Does the problem feature tensions between social, economic, environmental domains as well as inter-linkages across global, national, local level?
	c. Cause-effect structure	c. Does the problem have multiple causes and impacts?
	d. Specificity	d. Is the problem spatially and temporally embedded (place-based)?
	e. Urgency	e. Is the problem pressing because it is quickly getting worse, even irreversible?
	f. Harmfulness	f. Does the problem result in harm that threatens socio-ecological viability and integrity?
(2) Stakeholders facing the sustainability problems	a. Initiation	a. Do stakeholders approach researchers to address the problem?
	b. Problem ownership	b. Does a process of collaboration and negotiation lead to joint ownership?
(3) Preparing students to help create a better society	a. Corresponding specific and generic sustainability knowledge	a. Does the project allow for acquiring knowledge that is valid beyond the specific problem situation?
	b. Link knowledge to action	b. Does the project allow for acquiring knowledge that links various forms of knowledge and ultimately leads to substantiated and tested recommendations for change?
	c. Problem-solving techniques	c. Does the project allow for exploring problem-solving tools and techniques?
	d. Interpersonal skills	d. Does the project allow for acquiring communicative and collaborative skills?
(4) Generation of workable solutions and positive learning impact	a. Salient, extended peer reviewed products	a. Does the project result in theses and other products that include strategies, plans, or recommendations for action agreed upon by all relevant stakeholders?
	b. Generic transformative "impacts"	b. Does the project induce changes in knowledge, attitude, decision-making, or behavior towards sustainability?
(5) Stakeholders' specific knowledge	Two-way interaction	Does the project involve stakeholders during all research phases in a way that goes beyond extraction and exchange of information? Do stakeholders and scholars jointly negotiate, revise, and synthesize knowledge, and take decisions?
(6) Professorial supervision	Academic supervision	Do the professors advise students' academic thinking (e.g., structure, coherence, consistency), convey basic academic practices (e.g., research design, literature review, research techniques, scientific writing, presentations), and supervise their academic performance (e.g., jointly identifying objectives, providing feedback)?
(7) The Transacademic Interface Manager (TIM) as facilitator	Transacademic interface management	Does a TIM provide the services of translation of scientific knowledge and integration of scientific with practical knowledge, coaching, and project management that is satisfying for all parties involved?

Project 1: Sustainable Quality Management of Nanomaterial Production

Project Profile

The team for this 18-month project included four master's students, one bachelor's student, and the five supervising professors. They came from three Swiss universities: ETH Zürich, the University of Zürich, and the University of St. Gallen. The participating stakeholders were HeiQ, a Swiss nanotechnology company, and Mammut, a Swiss mountain sports equipment manufacturer. The research goal was to assess the risks of using HeiQ's antimicrobial silver composites for coatings, textile finishes, or plastics, through the entire production process. A second goal was to develop a quality-management strategy that took public perception of nanoparticles into account. Nanoparticles enable new product features and thus increase profit potential, but they are also associated with human and environmental health problems (Fleischer and Grundwald 2008). The big research question was broken down into smaller questions for students' individual theses. Three students contributed to the risk assessment of nanoparticles. Student 1 investigated what happens when nanoparticles leave the manufacturing plant and enter the water system. Student 2 explored whether workers in a manufacturing plant are exposed to health hazards from nanoparticles. Student 3 researched whether nanoparticle intake caused health problems (e.g., does a nanoparticle-coated plastic wrap leak nanoparticles into the sandwich and does it affect human health). Student 4 conducted an anonymous email survey of Mammut's registered customers to elicit opinions related to nanomaterial, outdoor clothing, and risk perceptions. The survey was also accessible to the public through Mammut's web site. Student 5 selected and analyzed case studies that used ingredient branding in order to create recommendations for Mammut and HeiQ.[3]

HeiQ was represented by its two founders, the inventor of the antimicrobial silver composite (a scientist) and the CEO. A sales executive represented Mammut. Additional stakeholders including company representatives from the insurance and chemical industries, and the Federal Office of Public Health participated in specific meetings. The first part of the project (months 1–6; theses 1–3) consisted of two meetings involving the students, professors, and stakeholders and additional scientists and professionals from industry and public administration. Participants in the second part of the project (months 7–16; theses 4 and 5) wanted to engage more to understand one another's viewpoints and values and learn from each other. Therefore, they needed more time than did those in the first part. Since the topics of the five theses had been derived from the main research question and defined in relation to each other, students were encouraged to attend all project meetings so as to learn from others and to support the synthesis of all projects. However, only the two students working on theses 4 and 5 attended most of the meetings.

With respect to the sustainability problem part of the research question, the students working on thesis projects 1–3 found no evidence of critical impact on human health or river systems from HeiQ's nanomaterial production. Available measures such as respiratory filters and sewage treatment were found to control risks sufficiently. With respect to the

[3] Ingredient branding is a marketing concept. It means that an ingredient or component is added into an existing product (e.g., GoreTex in outdoor clothing; NutraSweet in diet soft drinks). The ingredient brand has its own brand identity to promote its special features. The inclusion of an ingredient in an existing product improves the existing product. The question then is how to market the improved product. In general, companies strive to relate the ingredient brand to the brand of the initial product to market the improved version. In doing so they hope to tap into customers' brand awareness of the initial product and of the ingredient.

marketing aspect, students working on thesis projects 4 and 5 concluded that joint ingredient branding would be beneficial for both HeiQ and Mammut. Because both companies share core values including manufacture in Switzerland, environmental stewardship, quality, and accountability, a shared system of ingredient branding could help both companies positively influence the public perception of nanoproducts.

We did not evaluate theses 3 and 5 because thesis 3 was designed as a disciplinary study with some stakeholder consultation and for personal reasons the student working on thesis 5 was unable to complete it.

Evaluation Results

In this section we evaluate each component of the framework introduced above (see Table I).

Actual Sustainability Problem—Not Achieved

Only thesis 1 addressed the *long-term dynamics* of nanomaterial lifecycle. However, the thesis failed to anticipate how risks associated with nanomaterial could play out over 25 years, which is the minimum time period that can be considered inter-generational. All of the theses concluded that their research problem had implications from *local to regional scales* and *across social, economic, and environmental domains*. However, no thesis *analyzed* those cross-domain implications, and only thesis 1 outlined a cross-scale systemic analysis by comparing a local with a regional watershed. None of the theses explored the generic issues of *complexity,* such as indirect feedback loops or surprises (e.g., what unintended consequences might arise from nanoparticle emission). All theses addressed the interplay between human actions and social structures that cause the problems and the adverse effects of these interplays on the environment, society, or economy. The degree of depth and rigor with which students analyzed these interplays varied. Theses 1, 2, and 4 were place specific. Theses 1 and 4 concluded that the problem was not pressing or critically harmful. In thesis 1 the problem refers to the environmental impacts of nanoparticles on the river; in thesis 4 the problem refers to whether public perception of nanoparticles is harmful to the economic performance of the company. Thesis 2 was inconclusive about the harmfulness of the silver composite nanoparticles on human health.

Stakeholders Facing the Sustainability Problems—Fully Achieved

HeiQ had initiated the project by approaching ETH Zürich. The theses research questions were derived from the main problem as presented by HeiQ. A process of negotiation led to joint ownership of the problem-solving process. Student 4 defined the problem collaboratively with his professor *and* the stakeholders. However, students 1 and 2 defined the research problems themselves in working with their professors. Afterwards, they consulted with the stakeholders to get their feedback.

Preparing Students to Help Create a Better Society—Partially Achieved

Although the project made it possible to derive generic knowledge valid beyond the specific problem situation, only student 4 seized that opportunity. Students 1 and 2 only outlined how their concepts could be adapted to other situations. All students linked knowledge to action by developing a system model, but with varying degrees of depth and rigor. Only the two students (1 and 2) writing their theses in environmental science also took the next steps to construct scenarios (anticipatory knowledge) and address value conflicts related to the problem and its solution (normative knowledge). However, they did not produce recommendations for the stakeholders (strategic knowledge). Student 4 writing his social-science thesis did formulate actor-specific recommendations. The project allowed students to engage in interdisciplinary teamwork and to develop their interpersonal, organizational, communicative, and collaborative skills; but only student 4 chose to seize those opportunities and sought to bring all project participants—professor, stakeholders, fellow students—to the meeting table. The student's professor highlighted the value of interdisciplinary and transacademic skills for a career. Although the TIM offered support, students were not interested in additional coaching in the interpersonal and professional skills listed.

Generation of Workable Solutions and Positive Learning Impact—Partially Achieved

Students and stakeholders collaborated in all stages of the project and engaged in "extended peer review" processes. Students 1, 2, and 4 discussed their findings, implications, and suggestions individually with the CEOs of both companies and other interested parties. Given the lack of team efforts, students did not produce a synthesis report. Therefore, the project could not create overall, actor-specific strategies. HeiQ was interested in incorporating information from the project into strategic planning to improve its sustainability performance, specifically, information related to potential damages and thresholds as derived from theses 1 and 2. HeiQ and Mammut wanted to account for the information from thesis 4 related to risk perception in their ingredient branding strategy. These interests indicate that the problem-solving process contributed to a change in stakeholders' mindsets.

Stakeholders' Specific Knowledge—Fully Achieved

Thesis project 4 involved stakeholders during all phases of research, while thesis projects 1 and 2 involved them during only some stages. All stakeholders were satisfied with their involvement: in communications with the TIM; and through the exit-survey, which had been completed by all project participants, all indicated that they felt they had been appropriately included in the process, adequately informed, and prepared for decision-making.

Professorial Supervision—Partially Achieved

Since part of the TIM's role is to mediate and facilitate interaction, the TIM observed interactions between students and their professors at meetings and questioned students and professors individually about the supervising relationship. All professors supported their students in their academic thinking. However, professors expected students 1 and 2 to find their own ways to excel in the areas of academic practices. Student 4's supervising professor explicitly encouraged him to enhance his interdisciplinary and transacademic skills in addition to the regular academic skills. She contacted the TIM to request support for herself and the student.

The Transacademic Interface Manager as Facilitator—Partially Achieved

The project participants for theses 1 and 2 requested that the TIM's role be limited to facilitating the framing of each thesis and providing only bilateral support for students and stakeholders when needed. These limitations caused some failures, e.g., inadequate problem definition because projects did not take into account the expertise and perspective of the stakeholders; restricted coaching of students' in preparing for meetings; and project management problems related to coordination, limited teamwork, and mutual learning. For thesis project 4, the TIM fulfilled all roles (translation, integration of knowledge, coaching, and project management). All parties indicated in the exit survey their satisfaction with the TIM's performance. Yet, theses teams 1 and 2 took only baby steps towards the goals of sustainability research education, which strives for equal collaboration, two-way communication, and integration of knowledge and skills among students, professors, and stakeholders. The challenge remains to create awareness among project participants about how the TIM's role exceeds common project management functions.

Project II: Swiss Federal Council's Sustainable Development Strategy: Guidelines and Action Plan 2008–2011—Enhance Effective Communication

Project Profile

The second project lasted 12 months. The project team included three master's students, one undergraduate, and the four supervising professors. They came from three Swiss universities: ETH Zürich, the University of Zürich, and the Lucerne University of Applied Sciences and Arts. The stakeholder was the Swiss Federal Office for Spatial Development (SFOSD). This office coordinates the Swiss Interdepartmental Sustainable Development Committee (SISDC), which includes representatives of all federal offices. The committee drafted the *Sustainable Development Strategy: Guidelines and Action Plan 2008–2011* on behalf of the Swiss government (Federal Office of Spatial Development 2008).[4]

The project goal was to identify and assess the networking and communication patterns among public and private agencies involved in disseminating and implementing the *Strategy* and then to recommend how to improve these activities to enhance its effectiveness. The project focused on *effective communication* of the sustainability issues included in the *Strategy*. It did not evaluate the sustainability issues themselves; therefore, it addressed sustainability issues only *indirectly*.

In addition to the Office of Spatial Development, other stakeholder groups participated in the project to varying degrees. Representatives from the Swiss Interdepartmental Sustainable Development Committee (SISDC), the Federal Office of Energy, and the Federal Office for the Environment played an important role in framing the entire project. Students individually also interviewed representatives from municipalities, media, and business to gather additional information for their thesis projects. The project process included five team meetings of students, their professors, and the stakeholders. The sixth meeting was only for students so as to prepare a synthesis report and final presentation.

The research questions for students' individual theses were derived from the general problem. Thesis 1 identified communication patterns among public and private agencies in the "actor network," the network created by all agencies involved in disseminating the *Strategy*. Communication patterns were considered critical because they can either hamper or improve efficient implementation of the federal strategy. Thesis 2 revealed that communicating the federal strategy conflicts with the communication agenda and

[4] For details, see http://www.are.admin.ch/dokumentation/publikationen/00014/index.html?lang=en

workload of federal offices and their specific issues. Thesis 3 addressed why provincial [state] and local agencies were dissatisfied with federal support aimed at enhancing their communication of the federal strategy. Thesis 4 identified reasons behind the media's lack of interest in reporting on the federal strategy. The synthesis report, coordinated by the TIM, highlighted the four actions recommended by all of the theses: 1) to strengthen the federal activities for sustainability of the various federal offices by clarifying the role of the SFOSD and the SISDC, 2) to improve collaboration between the SFOSD and the other federal offices by accounting for their context and relations with their respective target groups at the state and municipal level, 3) to stop communicating general sustainability concepts and instead share existing projects as examples of what can be done, and 4) to encourage and challenge key players (business and media) also to contribute to sustainability.

Evaluation Results

Actual Sustainability Problems—Partially Achieved

The project dealt with the problem of ineffective communication and only *indirectly* addressed an actual sustainability problem. It analyzed the Swiss government's strategies to address sustainability issues. The project evaluation assessment showed that the Strategy is *long-term oriented* and recognizes the *cross-domain* and *cross-scale complexity* of sustainability. The *Strategy* calls for improving coordination between and among policy areas and for fostering partnerships across all sectors and scales to address local and global change. However, it does not anticipate *non-linear developments* or *surprises* that might result from implementation. The *Strategy* acknowledges the *interplay of human actions and social structures* that cause sustainability problems and their potentially adverse effects on human and environmental systems and provides for policies and tangible actions that deal with these interactions. The *Strategy* embeds sustainability issues in *specific* settings by focusing spatially on Switzerland, and it also accounts for Switzerland's international context. It lists "high-priority-areas" to guide actions, e.g.: combat global warming, decouple resource and energy consumption, and alleviate poverty. The prioritization indicates that these problems have been identified as *urgent and harmful*.

Stakeholders Facing the Sustainability Problems—Fully Achieved

The Office of Spatial Development had initiated and approached the academic sector to propose the project. All thesis problems were derived from the overall problem of ineffective communication. A process of negotiation including collaborative (all team members) and bilateral (students and stakeholder) participation fostered a sense of joint problem-ownership among students and stakeholders.

Preparing Students to Help Create a Better Society—Partially Achieved

The project made it possible to acquire generic knowledge that was valid beyond the specific problem situation, namely on communication patterns between and among agencies at the federal level as well as between federal and state/municipal levels. Theses 1 and 4 explored the linkages between specific and generic knowledge while theses 2 and 3 applied only generic knowledge to the specific problem situation. All theses linked knowledge to action by producing analytical and systemic knowledge, for example on processes and communication patterns. Together students and stakeholders produced normative knowledge about what makes a communication pattern ineffective or even dysfunctional and a high degree of action-oriented knowledge, namely insights on how to redesign the federal strategy. However, none of the theses generated anticipatory knowledge (e.g., elaborating upon strategic options to achieve alternative future states) or strategic knowledge (e.g., how to implement each of the recommendations). The project helped students to acquire interpersonal and organizational skills. In meetings, email and phone conversations, students performed very well in project organization and communication. Their collaboration on as an interdisciplinary team was moderate but sufficient.

Generation of Workable Solutions and Positive Learning Impact—Fully Achieved

An extended peer review led to the approval of all four theses and a synthesis report coordinated by the TIM. The project's transformative impact is reflected in the Office of Spatial Development's adoption of the project results and students' recommendations and their presentation of results and recommendations to the Swiss Interdepartmental Sustainable Development Committee. Thanks to the Committee's approval, the project significantly contributed to redesigning the plan for communication and implementation of this sustainability strategy: evidently, the process offered stakeholders new insights that led to a change in their mindsets and procedures.

Stakeholders' Specific Knowledge—Fully Achieved

All theses involved stakeholders throughout the research. All project participants stated, in the exit-survey and through personal communications with the TIM, that they appreciated the two-way communication that characterized the project process as well as the efficient project management. Stakeholders, in particular, emphasized that they appreciated the professionalism of students, which they attributed both to student personalities and the coaching provided by the TIM.

Professorial Supervision—Fully Achieved

All professors supported students in their academic thinking and practices. They encouraged students to request additional support from the TIM so as to enhance their interdisciplinary and transacademic skills. In the exit survey, all students reported that they were satisfied with the academic supervision. Although they felt challenged to perform well and with a high degree of autonomy, they felt supported and rewarded in this endeavor.

The Transacademic Interface Manager as Facilitator—Fully Achieved

All project participants asked for the TIM's help with facilitating the project. Students asked for coaching, and students and stakeholders asked for help with project management. The exit survey revealed a high degree of satisfaction with the TIM's performance. This achievement is interesting because all project participants were initially skeptical about this new type of transacademic collaboration and reluctant to engage in the project. From the outset, the TIM had to build trust among project participants and convince them that her services to mediate the collaboration between and among scholars and practitioners, as well as between and among the different disciplines, would benefit the project and prevent this new form of collaboration from failing.

Discussion

To address an "actual sustainability problem" was a challenging requirement. Project I did not meet most of the criteria for addressing an actual problem, and Project II addressed an actual problem only indirectly. The fact that sustainability research is still an emerging field with ambiguous definitions and demarcations makes it difficult to designate any particular problem as an "actual sustainability problem". The primary objective of the "actual sustainability problem" framework component is that students are able to understand what constitutes a sustainability problem, why it is different from other problems, and what knowledge and skills are needed to cope with it (Wals and Jickling 2002). Therefore, it is important that students reflect on how their thesis research relates to the overall project *and* to the concept of sustainability. Professors and the TIM should support students in this thought process.

The requirement that stakeholders bring the sustainability problem forward and develop ownership was met by both projects. Both projects aimed to define the overarching problem and students' individual research problems together, and each achieved this goal to a different degree. A more rigorous and joint problem-definition process between students, their professors, and stakeholders might complicate negotiations; but ultimately it will encourage ownership on the part of all parties because expectations, priorities, and needs will have been thoroughly addressed. This process would reveal the "true" sustainability challenge. Furthermore, defining the problem jointly improves the likelihood of achieving outcomes that are relevant and robust.

Neither project met the requirement that "academia prepares students to help create a better society" well. Forgoing the TIM's services limited interdisciplinary and transacademic learning opportunities in Project I. The exit surveys and the TIM's observations indicated that the nine professors involved in the two projects failed to convey sustainability skills to their students although they supported students in enhancing their regular academic skills. Faculty members are often unfamiliar with concepts of sustainability research education and how these concepts relate to their discipline. As Rowe (2007) has pointed out, most institutions promote sustainability research education in their mission statements, yet offer few incentives for faculty to explore how they could include sustainability research education in their teaching. Incentives such as a small scholarship, a TIM as go-to person, or an award, would surely help faculty members to address the challenge of including sustainability research education into their teaching. This would ultimately help higher education institutions realize the sustainability component of their missions (Corcoran and Wals 2004; Elder 2008; McNall et al. 2009). There is little academic recognition of research that explores how to link knowledge to action or to develop problem-solving techniques, but this kind of research is essential for sustainability research education (Grunwald 2004; Kates et al. 2001; Wals and Jickling 2002). Transacademic research is still new at many higher education institutions. Because such research may not be adequately rewarded, transacademic teaching and learning approaches often remain undeveloped. This situation leaves organizations like Seed Sustainability reliant on individual faculty members who are interested in innovation and therefore seize the opportunity to build their own sustainability research and teaching capacity.

The fourth framework requirement was that students would contribute to workable solutions through their academic learning. The requirement was fulfilled better in Project II than in Project I, where it was left to stakeholders to synthesize and apply findings from students' theses projects. Students in Project II drafted a synthesis report that included their recommendations on how to apply the results. The synthesis report was coordinated by the TIM, who played a key role in making sure that *joint* deliberation on research implications occurred, which is essential to enable real-world changes (Gibbons et al. 1994). In both projects, students realized that their research mattered beyond the classroom, and they were strongly motivated by that realization. They found that the design and structure of the collaborative process contributed to their research experience. A mid- and a long-term evaluation could substantiate the real-world outcomes of the projects, as well as the learning outcomes for students.

The framework requirement that stakeholders provide specific knowledge through collaboration was fulfilled by both projects. All stakeholders appreciated the opportunity to go beyond the “order, deliver, and pick-up” model, and all took an active role in the research projects. They engaged with students, arranged contacts with other experts, and set aside time to offer critical feedback. Most students seized the opportunity to develop their partnerships with stakeholders. They faced the challenge of synthesizing different forms of knowledge, which requires both academics and practitioners to reflect on and challenge each others’ positions (Wiek 2007). Students and stakeholders are usually unaware of the “room for negotiation”, created and mediated by the TIM, which allows for sound co-construction of sustainability knowledge.

The framework requirement that professors provide generic knowledge through academic supervision meant that professors were expected to ensure the scientific rigor of the research undertaken. In Project I, all but one professor expected students to enhance skills of critical thinking, writing, and presentation on their own. In Project II, the professors supported students in increasing their academic skills but complained that they spent more time on supervision than their budgets covered. This problem could be resolved by allowing professors to require their students to link project work to core courses, for instance a methods course; this combination would strengthen both course and project (cf. Brundiers et al. in press). Professors were reluctant to provide knowledge in accessible forms and to participate as learners themselves in “joint and mutual learning” processes with stakeholders. Students may therefore be exposed to contradictions in knowledge; and the TIM can only mediate contradictions when there is equal participation at team meetings of students, professors, and stakeholders.

Project II met the framework requirement that a transacademic interface manager facilitate the collaboration better than did Project I, but neither project entirely fulfilled it. The TIM’s facilitation is intended to allow students, professors, and stakeholders to pursue their own agendas and to work together to create sustainability solutions without the extra workload of coordination, integration, and mediation. To be successful, the TIM needs institutional support such as funding, mandate, and logistical support. In both projects, failures resulted partly from poor institutional mandates. The TIM needs to be pro-active in challenging and encouraging professors and students to engage in transacademic activities. In Project I, the TIM failed to explain and argue convincingly for her role and thus failed to overcome participants’ apprehension about collaboration. Finally, the TIM needs to employ credible methods for managing the collaboration between and among the students, professors, and practitioners so as to create a shared understanding of the problem and solution options and to ensure buy-in from all participants.

The data available was insufficient to evaluate the framework requirements, related to transformative learning outcomes of students and stakeholders (requirement 4b) and to the quality of mentoring experienced by students and provided by stakeholders and professors alike (requirements 3, 5, 6). The original design of transacademic projects at Seed Sustainability did not sufficiently provide for subsequent evaluations of project participants performance. The exit survey and observations by the TIM were the only sources of data on performance. Data collection was further restricted by the fact that the TIM had limited access to information about student-supervisor relationships. Obviously, additional methods to collect data need to be developed.

Conclusions

Higher education institutions develop programs and projects for sustainability research education. In this article we extended and transformed a vision of this kind of education (Rowe 2007) into an evaluative framework and scheme. We applied the scheme to two projects of the Seed Sustainability initiative at ETH Zürich. The evaluation results illustrate the challenges of sustainability research education. First, sustainability problems have special features that are often not considered. Second, higher education institutions need to develop stronger incentives for faculty and students to implement quality education in sustainability research. Third, research projects are more successful when a Transacademic Interface Manager facilitates collaboration among students, academics, and practitioners. However, to realize the potential of this support function, higher education institutions must endorse the TIM's role and encourage project participants to work with the TIM in order to educate students effectively in sustainability research. Our evaluation scheme may be used to guide efforts to bridge the gap between good intentions and implementation of sustainability research education. The framework needs to be tested on additional projects in order to substantiate its value and possibly revise it to be more effective. Future evaluations could produce more insights and stimulate continuous improvements.

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