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**Transdisciplinarity in the class room? Simulating the co-production of sustainability knowledge**

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**Abstract.** Despite its many advantages, teaching transdisciplinary is a costly enterprise. Transferring diverse theoretical, methodological, and practical skills may require several teaching staff; developing meaningful stakeholder interaction is time-intensive; and managing the research process demands significant efforts in logistics and coordination. This article seeks to make two distinct contributions. Conceptually, it introduces a framework for distinguishing between soft, inclusive, reflexive, and hard transdisciplinarity, based on the notion that there are diminishing returns to all features of the practice. Empirically, it examines a classroom simulation – the Sustainable Development Indicator Exercise (SDIE) – as an example of soft transdisciplinarity. In the SDIE interdisciplinary student groups play the role of policy advisers. Building on a concrete transdisciplinary research project, they explore their understanding of sustainability, develop a multi-criteria decision making method for assessing sustainability criteria and indicators, elaborate and present their results, and reflect on their experience. All aspects of the exercise follow the logic of role playing: organizing group interaction, distributing responsibilities, interacting with their political principal, presenting their findings, and evaluating their progress. Experience from the simulation reveals insights into ways students address and express concerns with objectivity, transparency, deliberation, and balancing sustainability; it also points to ways for moving beyond soft transdisciplinarity.

## 1. Introduction

During recent decades transdisciplinarity has become an important paradigm of knowledge production to address complex problems under uncertainty in intercommunicative and action-oriented ways. Published work has focused on debating defining characteristics (Balsiger, 2004; Wickson et al., 2006; Russell et al., 2008), exploring evaluation approaches (Bergmann et al., 2005; Guggenheim, 2006; Klein, 2008a; Pohl, 2011), defining research principles and guiding research practice (Lang et al., 2012; Pohl et al., 2007; Hirsch Hadorn et al., 2008), reviewing research practice (Brandt et al., 2013), and illustrating transdisciplinary research by means of case studies, often brought together in edited volumes or journal special issues (e.g. Lawrence and Després, 2004; Maasen et al., 2006; Hirsch Hadorn et al., 2008). The proliferation of such work has significantly raised the profile of transdisciplinary research and generated more refined understandings among researchers, policy makers, and funding agencies.

In comparison to transdisciplinary research, teaching has received less attention, even though transdisciplinarity has long been understood to include the field of teaching (Centre for Educational Research and Innovation, 1972). At the outset, teaching-related concerns centred more broadly on the educational system, especially the linear structure of universities and their failure to serve the needs of society (Jantsch, 1972). According to Klein (2008b), transdisciplinarity soon appeared in numerous educational settings in the United States and Europe. Under the auspices of initiatives such as the International University Reforms Observatory, the Centre International de Recherches et Études Transdisciplinaires (CIRET) and <td-net>, a wealth of educational and teaching resources has become available (Klein, 2008a). Additionally, members of the transdisciplinary case study movement in countries such as Switzerland, Austria, and Sweden have produced numerous guides and scientific publications detailing their experiences (Muhar et al., 2006; Scholz et al., 2006; Stauffacher et al., 2006; Hansmann et al., 2009).

Even a cursory survey of accounts suggest that teaching interdisciplinarity and transdisciplinarity is a costly enterprise. In the very first issue of the journal *Issues in Integrative Studies*, Benson (1982) identified the relatively high cost of the typical integrative studies course as one of five overlooked, but serious criticisms of interdisciplinarity. Since teaching transdisciplinary research skills should add interactions beyond the academic world to the interdisciplinary curriculum, costs are even higher. Like interdisciplinarity, the sound teaching of transdisciplinary research may necessitate proficiency in a range of theoretical, methodological, and practical skills, which may require team-teaching. Furthermore, the development, implementation, monitoring, and evaluation of transdisciplinary research in concrete settings entails participation by a wide range of stakeholders. Extensive time is required to establish relations, convince external actors of the benefits of a transdisciplinary research project, and make themselves available at all stages of knowledge co-production. Finally, regardless of the research setting, efforts dedicated to research management tasks such as logistics and coordination are typically demanding.

While teaching transdisciplinary research raises tough questions about possible constraints, it also encourages the search for alternative approaches. To this end, the article makes two distinct contributions. First, it proposes a conceptual framework for distinguishing between different varieties of transdisciplinarity. The approach builds on widely used criteria for defining transdisciplinarity—integration, evolving methodologies, collaboration. Introducing the notion of "limits of transdisciplinarity," the resulting heuristic differentiates between four varieties of transdisciplinarity. Its purpose is not to designate what is transdisciplinary or not, but to facilitate the identification of means to make teaching—and research—more transdisciplinary with available resources, and/or to strengthen the case for devoting more resources to teaching.

The second, more practical contribution is an examination of a teaching exercise carried out in a graduate seminar on sustainable development, which serves as an illustration of what I will call 'soft transdisciplinarity.' The Sustainable Development Indicator Exercise (SDIE) contains numerous transdisciplinary elements, even though it was not conceived as such. The SDIE is a classroom simulation involving role plays of small student groups working on a task that mirrors a concrete transdisciplinary research project. Educational simulations are experiential exercises that transport students (and teachers) to another world, where they apply their knowledge, skills, and strategies in the performance of their assigned roles. Simulations can not replace interactions in concrete settings with real stakeholders facing complex problems. However, they can offer students insights into the 'surface structure'

(observable mechanisms, including the setting of the simulation) and the 'deep structure' (psychological mechanisms, including the nature of interactions between the learners and the task, and between students) of collaborative thinking and action (Gredler, 1992).

An analysis of the SDIE experience as a cost-effective approximation of a transdisciplinary setting thus permits a reflection of the limits of transdisciplinarity as well as the means to address them in a teaching context. Section 2 of this article is devoted to the conceptual argument. Section 3 provides an overview of the SDIE. Section 4 discusses key aspects of the SDIE, especially its implications for objectivity, transparency, deliberation, and understandings of sustainability. Section 5 concludes the article by reconsidering the SDIE from the perspective of moving beyond soft transdisciplinarity.

## 2. Varieties and limits of transdisciplinarity

Transdisciplinarity has obtained a prominent place among responses to widespread demands for transforming knowledge production, especially in the context of complex problems related to human-environment relations (Lawrence and Després, 2004). As Maasen and colleagues (2006) noted in their introduction to a recent special issue, previous research on transdisciplinarity has frequently focused on programmatic, epistemological and conceptual questions. Although much work has since produced insights into the practice of transdisciplinary research, defining transdisciplinarity in relation to other forms of knowledge production remains a prominent subject.

Several reasons account for the continued interest in differentiating forms of knowledge production. If traditional, disciplinary-based research is no longer considered adequate to grapple with problems such as climate change, health, or poverty, it is necessary to define and outline cross-disciplinary or supradisciplinary alternatives for bridging the "applicability gap" (Lawrence and Després, 2004:398). A second reason relates to the promotion of such alternatives, including by various types of funding agencies needing criteria for identifying and evaluating proposals (e.g. Mobjörk, 2010). A third reason concerns the pedagogical consequences, as new forms of knowledge production require new sets of skills (Klein, 2008b).

Efforts to characterize the changing knowledge production landscape have generated numerous typologies and definitions (Huutoniemi et al., 2010), but the majority of these center on the differences between multidisciplinarity, interdisciplinarity, and transdisciplinarity on the one hand, or the identification of different varieties of the first two. Multidisciplinary research, for instance, has been been categorized as "encyclopedic" (juxtaposed sub-projects loosely linked by a topical focus), "contextualizing" (cognitive interaction that is limited to the problem setting) or "composite" (modular combination of expertise from different fields) (Huutoniemi et al., 2010). Interdisciplinary research has been categorized as "wide" or "narrow" with respect to the distance between participating fields (Kelly, 1996); "empirical," "methodological" or "theoretical" with respect to employed research components (Huutoniemi et al., 2010); or "exogenous" (instrumental) or "endogenous" (conceptual) with respect to research goals (OECD, 1982).

By contrast, few scholars have attempted to go beyond the recognition that transdisciplinarity has multiple meanings and propose a conceptual framework for distinguishing varieties. Max-Neef (2005) talks of "weak" and "strong" transdisciplinarity. In his assessment, weak transdisciplinarity is "a practical way of tackling problems in a more systemic way," whereas

strong transdisciplinarity is "an unfinished project […], a different manner of seeing the world, more systemic and more holistic" (Max-Neef, 2005:15). Mobjörk (2010) proposes a more pragmatic approach, differentiating between "consulting transdisciplinarity" and "participatory transdisciplinarity." Following Wickson et al. (2006), Mobjörk defines problem-solving, evolving methodology, and collaboration as the core features of transdisciplinarity. Consulting transdisciplinarity falls short with respect to the degree of involvement from actors outside academia, whose roles are limited to responding and reacting to research carried out by researchers. In participatory transdisciplinarity, by contrast, "societal actors are fully included in the knowledge production process and their knowledge is equally valuable to scientific knowledge" (Mobjörk, 2010:870).

This dearth of conceptual frameworks for categorizing varieties of transdisciplinarity stands in marked contrast to the growing consensus on the characteristics of transdisciplinarity. Mobjörk's categories provide a useful start, but is limited to the element of collaboration. In addition to the features identified by Wickson et al. (2006), Pohl and Hirsch Hadorn (2007) suggest that a transdisciplinary approach can grasp the complexity of problems, take into account the diversity in life-world and scientific perception of problems, link abstract and case-specific knowledge, and develop knowledge and practices that promote what is considered the common good. Depending on the purpose for which a conceptual framework is to be used, combining any two key features in a matrix would be a step in the right direction.

Before suggesting one such approach, it is useful to address the question why it matters whether and how transdisciplinarity is variegated. As in the case of interdisciplinarity, there are important epistemological concerns having to do with knowledge production for increasingly complex problems. Similarly, but at a more practical level, funding agencies devoted to promoting transdisciplinarity need tools to evaluate proposals. Perhaps more important, however, is that the lack of a nuanced understanding of varieties permits but one, not very helpful question: is a certain practice transdisciplinary or not? By contrast, a conceptual distinction between different types can suggest that some forms of transdisciplinarity are appropriate in some contexts but not others. Furthermore, such a framework can serve as a tool to identify ways for moving from one type to another as circumstances change (e.g. when new opportunities for collaboration appear). Ultimately, a conceptual framework can also help recognize that there are *limits of transdisciplinarity*.

Such recognition is implicit in the work of many authors but remains to be synthesized (but see Lang et al., 2012, for an overview of challenges of transdisciplinary research). While a concise and comprehensive synthesis is beyond the scope of this article, a few illustrations serve to illustrate the point. In essence, raising the idea of limits of transdisciplinarity is another way of saying that amplifying any of the core features is subject to diminishing returns with respect to the goals that are being sought. The concept of diminishing returns is not be understood in purely economic terms, although material costs play an important role, both in research and teaching. Instead it is meant to cover the range of direct and indirect benefits attributed to transdisciplinarity.

A first set of limits can be identified with respect to collaboration or participation. Referring to "procedural questions," for instance, Maasen et al. (2006) note the organizational challenge of coordinating complex tasks between different people and institutions. As long as a research project is managed within a single organization, they suggest, working procedures "may be handled tacitly. As soon as different actors with different understandings of work become involved, work procedures have to become negotiated […] and [o]rganizing the research

process becomes an object of close attention in itself, much to the disadvantage of the research process proper" (Maasen et al., 2006:397). Similarly, Mobjörk (2010:872) argues that "achieving a joint knowledge production process with a huge variety of actors with 'equal' roles is definitely more demanding than a process that distinguishes some actors as consultants that indirectly affect the process." Elzinga (2008:356) points to the same dynamic when differentiating between "real physical" and "virtual" participation of external users or practitioners as well as between "effective" and "token or symbolic" participation.

A second set of limits concerns integration, which refers to crossing boundaries between disciplines (or fields, see Balsiger, 2004) and between research and practice. Pohl et al. (2008: 412) note that "[w]hen taking plural relevant perspectives in the knowledge society on complex practical issues into account, linking and restructuring concepts, methods and results from heterogeneous bodies of knowledge becomes inevitable." The integration of knowledge, which is a the heart of all cross- or supradisciplinary enquiries, has long been recognized as a difficult task (Klein 1990; Weingart and Stehr, 2000). This has led some to argue that transdisciplinarity always remains an incomplete ideal (Max-Neef, 2005); others emphasize that integration is not "a value in itself, but a methodology for responding adequately to societal knowledge demands" (Pohl et al., 2008). Both imply that there are limits to integration, but few have taken the next step and asked how much integration is appropriate under what circumstances, or at what point does more integration undermine progress in responding to societal knowledge demands.

In a related reference to possible limits of integration, Benson's analysis of arguments against interdisciplinarity places the ambiguous nature of the term at the top of the list, in part because "the kind of borrowing suggested in the proposed account of integrative studies already occurs routinely within the framework of most disciplinary activity" (Benson, 1982:40). More recently, Jacobs (2013: 196) made a similar point in his defense of disciplines, suggesting that "[i]n most practical contexts, the term 'integration' must be seen as a relative term." These contentions apply to integration between disciplines and between research and practice.

The brief discussion of collaboration and integration raises but two examples of how transdisciplinarity can be subject to limits. Any feature of transdisciplinarity could be discussed in similar terms; any two features could be combined into a matrix to develop varieties of transdisciplinarity. For the purpose of this article, integration and collaboration shall serve to make the point (Figure 1).

**Figure 1:** Varieties of transdisciplinarity

| | | **Collaboration** | |
|---|---|---|---|
| | | *narrower* | *broader* |
| **Integration** | *shallower* | soft transdisciplinarity | inclusive transdisciplinarity |
| | *deeper* | reflexive transdisciplinarity | hard transdisciplinarity |

The varieties of transdisciplinarity in Figure 1 are to be understood as analytical categories. As many observers have noted, research is too complex to be categorized with simple

typologies; in practice, transdisciplinarity may vary across research phases, and participants will interpret there experiences differently. A second caveat concerns the categorization of integration and collaboration, which is not to imply a dichotomy, but as continuum along which specific instances of transdisciplinary practice (teaching or research) can be situated and compared. Finally, the terms 'soft' and 'hard' are used to avoid confusion with Max-Neef's strong and weak transdisciplinarity.

As a conceptual tool, the typology can help to highlight specific aspects, including the direction in which a certain practice can shift. Starting from soft transdisciplinarity, which is characterized by relatively shallow integration and narrow collaboration—as outlined below in the case of the SDIE—a given practice can intensify its collaborative dimension and move towards *inclusive transdisciplinarity*, for instance by increasing the number of stakeholders, or move towards *reflexive transdisciplinarity*, that is strengthen integration of concepts and methods from different disciplines, fields, or communities of practice, for instance by achieving cognitive synthesis rather than simple cross-disciplinary borrowing. Balanced intensification of collaboration and integration designates a move towards *hard transdisciplinarity*, which is similar to the ideal-typical transdisciplinary research process described by Lang and colleagues (2012). Conversely, a practice that is considered as an example of hard transdisciplinarity can regress along one, two, or both dimensions and thus become a softer type of transdisciplinarity.

## 3. The Sustainable Development Indicators Exercise

Education has played an important role in the global dialogue on sustainable development for more than 40 years. The 1972 United Nations Conference on the Human Environment in Stockholm asserted the primacy of education as a means to foster sound environmental management, and its declaration specifically called attention to the younger generation. Institutions of higher education have been singled out as an especially appropriate site for communicating and promoting sustainable development by virtue of its influence on society and academic freedom to explore ideas (Davies et al., 2003; Sherren, 2006). Accordingly, over the course of the last two decades, education for sustainable development (ESD) has become a new field of study as well as a worldwide movement (Irandoust, 2009; Osano and Corcoran, 2009).

The relevance of ESD beyond the classroom is consistently highlighted. Steinfeld and Mino (2009: 1) suggest that the goal of sustainability education is "to equip the younger generation with leadership skills, management capabilities, and the broad knowledge needed to create the new systems that can lead to global sustainability." ESD emphasizes collaborative, process-oriented work and experiential or action-oriented learning. Wals and Corcoran (2004, p. 224) contend that sustainability in education "can be regarded as both the collaborative creation of an ever-evolving product and as an engaging, creative process involving a variety of different actors," while Irving et al (2005) advocate a process-driven, rather than a content-driven approach.

Collaborative learning also relates to how students communicate in collective settings, whether such settings are conducive to debate and argumentation, and the degree to which the settings resemble democratic processes in the larger polity. Englund, Öhman, and Östman (2008, p. 75) argue that "one important aspect of democracy in the classroom is the possibility for students to develop values and opinions in a democratic way." Östman (2010, p. 75)

highlights that "classroom analyses of socialisation – both its content and processes – are important in order to acquire knowledge about the moral and democratic aspects of ESD." All of these ESD principles are also central to the transdisciplinary case study movement (Hansmann et al., 2009; Scholz et al., 2006).

The Sustainable Development Indicators Exercise is part of a graduate-level seminar on concepts and assessments of sustainable development offered at the Department of Environmental Sciences at the Swiss Federal Institute of Technology Zurich (ETH). The semester-long course consists of three modules, each taught by one instructor. The first module introduces students to historical, conceptual, and ethical dimensions of sustainable development; the second module (in which the SDIE is carried out) focuses on legal, political, and administrative aspects; and the third module addresses sustainable development from a corporate perspective.

The students are from various majors, including environmental sciences (with minors in atmosphere and climate; human-environmental systems; forest and landscape management; human health, nutrition, and environment; or ecology and evolution); environmental engineering (with minors in water resources management; ecological systems design and waste management; or soil protection); mechanical engineering; geomatic engineering and planning; and management, technology and economics. In total, 15 groups involving 71 students completed the exercise during the three years 2008-2010. In 2010, 28 graduate and doctoral students from 16 different major/minor combinations registered for the course.

The overall objective of the group exercise is to design and carry out a sustainable development indicator selection process based on a real situation; this context was provided by the project "Sustainable Land-Use Practices in Mountain Regions: Integrative Analysis of Ecosystem Dynamics under Global Change, Socio-economic impacts and Policy implications" (Mountland, http://www.cces.ethz.ch/projects/sulu/MOUNTLAND), a multi-institutional research initiative implemented within the ETH domain.

All aspects of the exercise are suffused with the ethos of role playing: organizing procedures for group interaction, distributing tasks and responsibilities, coordinating meeting times, interacting with their political principal (the instructor), defending their findings to a peer audience, and monitoring and evaluating their process. Experience from the simulation reveals broad insights into ways in which students address and express concerns with objectivity, transparency, deliberation, and balancing sustainability. The assignment is designed to engage students' creative and analytical abilities as well as team working skills. It simulates a 'multi-criteria decision analysis' which students may encounter in their future professional careers. Group discussions generated by this type of exercise are meant to facilitate the integration of information, knowledge, and opinions of the participants.

In groups of 4-5, students are asked to assess a set of 50 sustainability indicators and identify a 'balanced' selection of 15 indicators for sustainable natural resource management in Swiss mountain regions; the 50 indicators represent an arbitrary number of indicators identified through an exhaustive literature search in the Mountland project, while the 15 indicators to be included in the final set represent an equally arbitrary number intended to reflect policy makers' preference for a shorthand tool. Students are told that the combination of individual and group efforts would be instrumental for obtaining sound results.

Students were given complete freedom in designing the method for evaluating the indicators, both individually and collectively, as well as in defining what constitutes a balanced set. Leading up to the group exercise, students are offered a general introduction to criteria,

indicators, and sustainability assessments, as well as a guest lecture by a senior representative of Switzerland's Federal Office of Spatial Development on the country's national sustainable development strategy. In addition, students are provided with a number of general resources they could consult if they wished.

The SDIE was developed and implemented prior to the elaboration of the TD typology introduced in this article. Nevertheless, since the exercise incorporates multiple forms of collaboration and integration, as outlined in the following sections, it can serve as an illustration of one of the four types of the TD typology (soft transdisciplinarity).

### *3.1 Defining sustainable development through transdisciplinary group learning*

The SDIE incorporates several transdisciplinary features highlighted in ESD and directly or indirectly linked to the elements collaboration and integration used in the typology (Wals and Corcoran, 2004; Steinfeld and Mino, 2009). Consistent with the overall philosophy of the course, which evolves around the juxtaposition of different takes on sustainability and sustainable development, the SDIE does not provide students with a fixed definition but requires them to collaboratively (re)negotiate their own vision. The only normative stance that may be inferred from the design of the exercise is that sustainable development somehow needs to balance environmental, economic, and social concerns. This stance was at the same time mitigated, however, through the presentation of Switzerland's sustainable development strategy, which follows the notion of "sensible sustainability" and refers to the possibility of substituting capital stocks provided the offsetting is transparent, not systematically detrimental to the same sustainability dimension, and does not compromise the biosphere's overall carrying capacity. The outcomes of the group exercises reveal that students indeed negotiated quite varying concepts of sustainability, which they were free to do as long as they justified their view.

A second transdisciplinary feature of the SDIE is interdisciplinarity, both in the sense that students had to work outside their areas of specialization (Parker, 2010; Sibbel, 2009), and, as Parker (2010, p. 328) argues, that "in promoting interdisciplinarity we are also promoting the need for inter-agency, inter-professional collaboration and partnerships as well as raising questions of the learning process in these contexts." These two aspects are directly linked to integration; the second also concerns collaboration. The potential to advance interdisciplinarity through a relatively short group exercise is necessarily limited. Although students encountered different disciplinary ontological and epistemological traditions in a very concrete context, however, learning unfolded beyond the confines of substantive knowledge. The SDIE confronts students' self-understanding of their disciplinary tradition, precisely because they are required to define and operationalize a 'balanced' view of sustainable development that includes dimensions not necessarily of relevance to their training.

Another central aspect built into the SDIE concerns uncertainty. Students have to assume the role of experts through a simulated environment. In a relatively short period of time, decisions have to be made with imperfect knowledge. Students have experienced this as one of the most challenging aspects. On the one hand, traditional sustainability assessments often resemble environmental impact assessments in that the object of the evaluation is a specific project such as a recreational park, or a new housing estate. In this case, the exercise lacked this level of concreteness. On the other hand, uncertainty appeared with respect to the indicators

students had to rank, particularly concerning ranking criteria such as measurability, data availability, or consistency with international practice. As in real contexts, students had a wealth of information at their disposal but needed to balance the trade-offs of knowledge depth and breadth.

Finally, the SDIE places great emphasis on communication. Aside from the traditional context of a course, students have to communicate sustainability to each other while keeping a broader audience in mind, which relates to collaboration and integration (integrating non-expert . In the SDIE, the students' task involves the communication and discussion of findings with their peers and instructors, which simulates the transdisciplinary feature of bringing results to fruition, as students finalized their reports after the presentation of their findings in two of the three years the SDIE was taught.

### *3.2 Sustainability from a student perspective*

Since students have complete freedom in developing a method for assessing the set of indicators and aggregating individuals' results to a group outcome, the ratings of individual indicators cannot be compared directly across groups. Instead, the following discussion is based on the frequency with which individual indicators were selected for the final set of 15. Giving students free methodological range gave rise to a broad variety of approaches. Offering an in-depth overview of this range would be beyond the scope of this article. In general terms, students had to grapple with whether and how they rated the evaluation criteria (relevance, soundness, etc.), whether and how they weighed the indicators on the basis of their criteria ratings, and how they aggregated individual results to the group outcome. As elaborated below, the students were keenly aware of, and sensitive to issues of (and trade-offs between) objectivity, transparency, and deliberation. Accordingly, the groups varied considerably in the degree to which their outcomes started out from a mathematical model or a deliberative process.

Although the results are presented here with a view to making them comparable, it is important to recognize that the comparison as such does not serve to identify a 'right' or 'wrong' approach or set of indicators. Sustainable development is not a final state that can be communicated, but a learning process in which communication plays a central role.

The diversity of student and group views is reflected in the fact that only 3 of the total of 50 indicators did not appear in any of the group's final selection: area under irrigation, watercourse interference, and phosphorous efficiency (all indicators from the environmental dimension). No single indicator was selected by all 15 groups. The most favored indicator is 'forest area' (13 groups), closely followed by 'farm and forestry employment' (12 groups) and 'use of forest growing stock' (12 groups). Although the smaller number of social and economic indicators from which students could choose inflates the value of their selection frequency, it is noteworthy that the top three indicators come from the three different sustainability dimensions. Table 1 presents the 15 most frequently selected indicators and compares these with the five most selected indicators per sustainable development dimension. It shows that overall the top indicators are distributed fairly evenly across the three sustainable development dimensions.

**Table 1.** Most frequently selected indicators, student assessment

| Economic dimension | Environmental dimension | Social dimension |
|---|---|---|
| • Use of forest growing stock (12)<br>• Agricultural GDP per capita (11)<br>• Payments for ecosystem services (10)<br>• Farm & forestry income (9)<br>• Firm closures in agriculture & forestry (5) | • Forest area (13)<br>• Protected area (10)<br>• Agricultural area (7)<br>• Water contamination (7)<br>• Soil erosion (7)<br>• Grassland area (6)<br>• Energy use (6)<br>• Renewable energy consumption (6) | • Farm and forestry employment (12)<br>• Forest area for protection of settlements and infrastructure (9)<br>• Training & education (8)<br>• Income distribution (7)<br>• Integrated water management (6) |

In spite of this apparent balance between sustainable development dimensions, the groups on average picked 7.5 indicators from the environmental dimension for their final selection, compared to 3.8 from the economic and 3.7 from the social dimension. This breakdown varied between groups who interpreted 'balanced' as requiring the selection of five indicators from each sustainable development dimension, to groups that picked just one indicator from the economic dimension or one from the social dimension. By contrast, while two groups identified as many as 11 environmental indicators for their final set of 15, no group selected more than six economic or social indicators.

Some interannual patterns were evident but not consistent. Groups in each of the three years identified social indicators at the same frequency, but they varied with respect to economic and environmental indicators. Whereas Year 2008 and Year 2010 groups 'over-identified' environmental indicators and 'under-identified' social and economic indicators by a wide margin, Year 2009 groups selected much more evenly. Differences in the way collective feedback was organized in the three years may account for this interannual pattern. On the one hand, one entire class period was reserved for group work in each of the three years. These provided an opportunity for groups to work on their exercise together and exchange experiences, as well as for the instructor to facilitate the exercise with substantive or process-oriented support. On the other hand, while 2008 groups simply turned in their report, 2009 groups turned in their report *after* presenting their preliminary results to their peers, and 2010 groups were asked to provide an informal status report during the in-class work period. Since the more formal presentations in 2009 attracted more students than the informal briefings in 2010, it is possible that students in 2009 adjusted their views of what constitutes a 'balanced' set of sustainable development indicators on the basis of their peers' presentations.

## 4. Simulating soft transdisciplinarity in the class room

The SDIE simulation offers an opportunity to familiarize students with the concept of sustainable development through a concrete context and foster collaborative learning. With its emphasis on problem-solving (contribution to a societal knowledge demand), evolving methodology (complete freedom to design and modify approaches as the exercise progresses), integration (interdisciplinary student groups as well as work on a problem that goes beyond academia), and collaboration (role play), the SDIE incorporates key transdisciplinary features, but within the constraints of a relatively short assignment. As proposed by Östman (2010), it nevertheless enables teachers to observe the dynamics of the learning process (surface

structure) through participant observation, and analyze these dynamics through the critical reflections (deep structure) students are asked to include in their final report.

Several elements contained in these reflections point to the greater significance of communicating sustainability through teaching, including objectivity, transparency, deliberation, and understandings of sustainability. They also reinforce the transdisciplinary character of the SDIE. While these elements were identified inductively from a close reading of the student reports and observation of the group processes, they also relate to the elements of collaboration and integration that underpin the TD typology proposed above. The issues of objectivity and evolving methodology directly relate to integration because in selecting a given methodology, students essentially made a normative statement on the differentiated integration of different fields of knowledge and value systems into what they still desired to be an objective assessment of SD indicators. To the extent that student groups became aware of, and addressed this tension, their particular SDIE experience was already beyond the shallow end of the integration spectrum.

Transparency and collaboration explicitly relate to collaboration. Because collaboration was mainly limited to the interactions among students and between students and the instructor, the SDIE has to be considered at the narrow end of the collaboration spectrum. Democratic deliberation concerns integration (of perspectives) and collaboration (logistics and procedures), hence changes in the form of deliberation can shift the SDIE along either of the typology's two axes. As in the case of previous feature, the relatively limiting context of the simulation situates the SDIE at the narrower end of the collaboration spectrum; at the same time, the fact that groups were self-selected meant that students who knew each other because they came from the same master's program were likely to band together, thus limiting also the degree to which different knowledge fields and normative stances were integrated. Finally, while the issue of balancing sustainable development dimensions is raised primarily to give some flavor of the student's views of SD, it also centrally relates to integration. In sum, two features analyzed below primarily concern integration, one primarily collaboration, and one has implications for both collaboration and integration.

### *4.1 Objectivity and evolving methodology*

Almost all groups in some way experienced the tension between striving for objectivity, prioritizing a democratic process, and believing in knowledge as the ultimate arbitrator. One way in which objectivity came up in many groups was with respect to the decision whether individuals should define their own weights for the indicator evaluation criteria, or whether the group should first agree on a common set of weights. Many groups felt that the former would make it difficult to compare individuals' results and thus found consensus on a common weighting system first, with relevance and data availability generally considered most important. Few groups refrained from weighting evaluation criteria altogether.

Almost all groups identified uncertainty or lack of knowledge as a critical issue. Some groups dealt with this by actively acquiring additional knowledge, for instance by studying criteria and indicator sets used by international organizations. For other groups this "veil of ignorance" facilitated the completion of the exercise within the given time constraints. As one group noted in its reflections, "in real life experts participating in the evaluation would have all the necessary information available."

### *4.2 Transparency and collaboration*

Since the majority of students taking part in the SDIE were being trained in natural science disciplines or engineering, it should come as no surprise that they consider transparency – interpreted as the requirement that results can be reproduced – as an important norm. Transparency was also raised with respect to the dimension of collaboration in the overall assignment. Many groups correctly remarked that the set of indicators they were asked to work with had shortcomings. Whereas some groups took issue with the fact that the initial set contained more environmental than economic and social indicators (some groups in fact decided that their resulting set of 15 had to reflect that ratio), others focused on flaws in the categorization or inadequacies in examples for measuring the indicators. Some groups went a step further and questioned how the initial set was developed in the first place. Although groups were free to adjust it, almost no group actually did so. Here, the classroom context presented a clear limitation for transdisciplinarity, as students had only a limited opportunity to co-define the research problem together with policy makers, even though the instructor was involved in elaborating the initial set.

### *4.3 Democratic deliberation*

The SDIE is a group exercise and group discussion inevitably makes students aware of the challenges and opportunities of defining and communicating sustainability in such contexts. Overall, the usefulness of democratic deliberation was recognized by all groups, both on practical and ethical grounds, even by those groups whose members did not interact much.

Almost all groups claimed that the make-up of the group determined the final outcome and that previous academic training was the most important factor. Since many groups were made up of students in environmental science, they were more familiar with data availability of environmental than other indicators, which explains the higher rating of environmental indicators. Diversity among group members was seen as both an asset and a challenge. Indeed, many groups analyzed the divergence of opinions for each indicator and prioritized their deliberation on those indicators which generated the most disagreements.

Deliberation among group members was seen as key for rendering group results better than individual results; as one group commented, “ranking the provided indicators was not as straightforward as we had anticipated.” In some cases, groups suggested that deliberation was necessary because the chosen method for rating the indicators yielded many indicators with equal scores. In other cases, broader reasons were mentioned. One group explicitly raised the tradeoff between transparency, objectivity and deliberation: “Our method derives from the ethical problem that each group member should have equal weight but in a discussion some key members are often able to persuade and influence the others more efficiently.” Another group suggested that “the key concern was to ensure that everybody’s thoughts had the same overall importance.”

Ultimately, many groups felt that even though they set out with the intention of developing an objective and transparent method, “clearer results could be reached with less calculating and a more vivid discussion.” The overwhelming majority of groups thus realized that their method had inherent biases and developed their conclusion through processes of deliberation, or in the words of one group, “by means of a political process of debate and bargaining.”

### *4.4 Balancing sustainable development dimensions*

Almost all groups recognized that economic and social indicators would be under-represented if they determined their final selection solely on the basis of a mathematical approach. In particular, low-ranking indicators such as 'training and education' and 'participatory landscape development' were included because they are "regarded to be of extraordinary importance for successful sustainable development processes."

Many groups did not apply a strict numerical balance of sustainable development dimensions, opting instead for a more or less pronounced bias toward the environmental dimension. On the surface, this bias may simply be a reflection, voiced also by some of the students, of the fact that the course is offered in a department of environmental sciences. Although this department also contains a contingent of social scientists, the substantive orientation of their curriculum is clearly focused on environmental problems.

At a deeper level, however, the bias toward the environmental dimension also relates to asymmetries in disciplinary power when it comes to knowledge integration and the development of interdisciplinarities. Parker (2010, p. 332), for example, suggests that "disciplines and interdisciplinary clusters vary greatly in their degree of institutional and societal integration, the extent to which they are allowed or required to inform policy, and consequently in their degree of funding. These factors, Parker claims, contribute to the relative power of disciplines in interdisciplinary interactions, reflected in "historically established and/or politically popular existing interdisciplinarities seeking to expand their power base and funding to take on relatively new areas such as sustainable development" (p. 332).

### *4.5 Moving beyond soft transdisciplinarity*

The SDIE is presented as an illustration of soft transdisciplinarity. Several improvements could move the exercise in the direction of greater problem-solving orientation, integration (i.e. towards reflexive transdisciplinarity), and collaboration (i.e. towards inclusive transdisciplinarity). In line with the article's argument that specific types of transdisciplinarity are suited to specific contexts, any such move would need to be justified.

In the case of the SDIE, the collaborative dimension could be intensified in response to concerns that the case study is too abstract or that the initial choice of SD indicators is too limiting. For example, representatives of the research project in which the SDIE is embedded could be invited to discuss the concrete challenges with the students. More generally, since any such research project is of a limited duration, policy makers or representatives of public agencies or non-governmental organizations could play that role. These same persons could also be invited to the student presentations, although mobilizing external stakeholders twice within the context of one of three modules of a semester-long course may already by difficult. Collaboration could also be enhanced by switching to a more local sustainability context that would allow students to engage with external stakeholders. The growing practice of university sustainability strategies could offer such opportunity, as could a city's or region's sustainability practice. At the same time, such a shift would increase the preparation and coordination efforts of instructors, which itself is an important limit on teaching transdisciplinarity. On the other hand, instructors can gain from systematically drawing lessons from the role play experience and incorporating these lessons into the teach approach.

Each of these modifications would shift the SDIE from a soft transdisciplinarity towards inclusive transdisciplinarity.

Efforts to enhance integration could be made in response to concerns that the learning objectives of the course are jeopardized because the SDIE offers too many non-negotiable parameters, or because there is insufficient awareness of the tension between objectivity and democratic process. Integration could be enhanced by letting students work on the task without providing them with an initial set of sustainability indicators. This would require them to further reflect on their disciplinary differences and complementarities, while at the same time stimulating greater discussion of trade-offs between different conceptualizations and methodologies. The latter would also strengthen the evolving methodology dimension of transdisciplinarity. This modification would shift the SDIE from a soft transdisciplinarity towards reflexive transdisciplinarity. As in the case of problem-solving orientation, however, there are limits of time (and capacity).

## 5. Conclusion

This article set out with the contention that scholarly work on transdisciplinarity have focused much more on research than on teaching, and that recognizing the varieties and limits of transdisciplinarity could usefully contribute to better incorporating transdisciplinarity in teaching. Although the SDIE was not primarily conceived as a tool to teach transdisciplinary research, several of its features are in line with transdisciplinarity principles. At the same time, the practical constraints imposed by a classroom context highlight the limits of transdisciplinarity, while pointing to some opportunities for improvement. At the very least, the SDIE goes some way towards the 1997 Locarno Declaration to devote 10 percent of teaching time in each discipline to transdisciplinarity (CIRET, 2014).

The SDIE also corroborates the lessons identified in Klein's (2008b) overview of transdisciplinarity issues in education. The first of these concerns the "new quadrangulation of disciplinary depth, multidisciplinary breadth, interdisciplinary integration, and transdisciplinary competencies." Achieving all of these is a tall order and would require more time than the SDIE can afford. The second lesson relates to the reconceptualization of education as a dialogue of content and process, where content includes the knowledge, principles, and methods of different disciplines as well as inter- or transdisciplinary approaches, and the ability to analyze complex problems, and process designates organizing and participating in inter- or transdisciplinary processes and communicate across disciplines and with actors outside academia. Here, the limits of the SDIE mainly relate to the ability to interact with external stakeholders. The third lesson is the "intertwined relationship of transdisciplinary competencies," including "the ability to participate productively in reflective transdisciplinary communities," "mindsets and metacognitive skills that enable lifelong learning," and "concern about real world needs, manifested in a willingness to become an engaged citizen" (Klein, 2008b: 408). Other authors list additional skills, but conclude that "no transdisciplinary researcher, the authors advise, will be expert in all of these areas, noting that "other team and project members can be brought in to fill skill gaps" (Pohl et al., 2008).

As noted at the outset of this article, the designation of the UN Decade of Education for Sustainable Development (following on the heels of many earlier pronouncements) has signalled the importance of learning and teaching to making progress towards sustainable development. The SDIE casts students in a play that simulates a situation which most of

today's decision makers recognize as characterized by significant uncertainty, disciplinary chasms, communicative challenges, and time (and budget) constraints. Through their critical reflections, students have shown how policy makers' concerns are not unique to their practice, and have outlined ways in which these concerns can be addressed.

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