10 Research Integration

A Comparative Knowledge Base

Julie Thompson Klein

Integration is widely regarded as the primary methodology of interdisciplinarity. In the chapter on interdisciplinary studies (IDS) in the *Handbook of Undergraduate Curriculum*, Klein and Newell (1997) called integration the "acid test" of IDS (p. 404). In his textbook *Interdisciplinary Research: Process and Theory*, Allen Repko (2008) called it the distinguishing feature of IDS. And, in the defining chapter on integration in the *Handbook of Transdisciplinary Research,* Pohl, van Kerkhoff, Hirsch Hadorn, and Bammer (2008) called it "the core methodology underpinning the transdisciplinary research process" (p. 421). Three organizations have also made integration a cornerstone of their work. The Association for Integrative Studies promotes integration as the primary methodology of interdisciplinary studies. The Swiss Academies of Arts and Sciences Transdisciplinarity Research network (td-net; see http://www.transdisciplinarity.ch;) devoted a recent international conference to the topic, and the Australian-based Integration and Implementation Sciences network (http://www.anu.edu.au/iisn) provides an academic base for synthesizing pertinent knowledge, concepts, and methods in order to address complex problems (Bammer, 2005).

This chapter provides a comparative overview of approaches to integration in interdisciplinary and transdisciplinary research (IDR and TDR). It presents a historical context for the idea of integration, compares major

AUTHOR'S NOTE: I thank the following for permission to adapt parts of previous material: Matthias Bergmann and Engelbert Schramm, for J. T. Klein (2008). Integration in der inter- und transdisziplinären Forschung. In M. Bergmann & E. Schramm (Eds.), *Transdisziplinäre forschung: Integrative forschungsprozesse verstehen und bewerten,* (pp. 93–116). Frankfurt, New York: Campus Verlag; and *td-net for transdisciplinary research,* for J. T. Klein's keynote address, "Taking Stock of Integration at the Century Mark," at the *td-net* international conference "Integration in Inter- and Transdisciplinary Research," Berne, Switzerland, November 19, 2009.

approaches, and defines four principles that emerge from the overview. In the course of discussion, the chapter also situates Repko's (2008) model of IDR process for student research within the wider literature on integration. Awareness of the variety of approaches will help students in three ways. First, during and after working with Repko's guide to interdisciplinary research process, they can draw on complementary concepts, methods, tools, and models. Second, they can think more systematically about similarities and differences in forms of interdisciplinarity, including the current heightened importance of transdisciplinarity. Third, in their future careers and community lives, they can apply insights from the literature on collaborative IDR and TDR to working with others on problems of professional practice and societal needs. Integrative capacity and the ability to work in teams are coupled increasingly across all sectors of our lives, making comparative understanding of best practices all the more crucial.

Historical Beginnings

The etymology of a word is always a good place to start for definition. The *Oxford English Dictionary* (1971) traces the English word *integration* back to the Latin word *integrare,* meaning "to make whole." Over the centuries, the idea of integration has been associated with holism, unity, and synthesis. The foundation, though, differed over time. For the ancient Greeks, philosophy was the seat of a broad synoptic view of knowledge based on the study of forms and their relationships. In the medieval era, the Christian *summa* was the source of synthesis. Leaders of the Enlightenment movement in the 18th century placed their faith in the concept of universal reason. For members of the famed Vienna Circle in the 1930s, logical positivism was the foundation for the unity of science. In 20th-century physics, the search for grand unifying laws guided the search for scientific synthesis. E. O. Wilson's (1999) theory of "consilience" also stirred new hope for uniting separate ideas and methods, although Wilson favored biological reductionism as the primary ground for synthesis. Today, the ancient quest for simplistic unity grounded in one theory or method has largely been given up, though the online journal *Integral Review* provides a forum for transdisciplinary and transcultural models and metatheory (http://integral-review.org/index.asp).

The earliest notable uses of the term *integration* in the modern era appeared in the late 19th century, in Alexis Bertrand's theory of integrated instruction and in books on principles of psychology by Herbert Spencer and William James. The idea of integration was also linked with the role that schools play in promoting social unity and the Herbartian movement's *doctrine of correlation*, which supplemented the *doctrine of concentration* by recognizing "natural relations" among subjects (Ciccorico, 1970, p. 60). Over the course of the 20th century, the meaning of the term expanded. At the postsecondary level, integrating disciplines and developing the "whole" person were core values in the general education movement, although proponents

differed on whether the whole was located in the content of texts within a prescribed curriculum or in a process of knowing and understanding contemporary problems. At the primary and secondary levels, during the 1920s integration was associated in the U.S.A. with the Progressivists' social democratic vision of education centered on students' personal and social concerns, and the term *integrated curriculum* was also linked with the project approach. During the 1930s, it appeared in conjunction with the core curriculum movement. In the 1940s and 1950s, it was aligned with problem-centered cores as well as a broad-fields approach; skills across subjects; and child-centered, activity-based, and experience-based curricula (Beane, 1997, pp. 2–3, 28–29; Ciccorico, 1970, p. 62; Klein, 2002, pp. 5–6).

Even with differences in individual approaches, a major shift in meaning occurred during the 1930s and 1940s that lies at the heart of Repko's (2008) emphasis on integration as a *process*. Integration, Repko explains, does not derive from a predetermined pattern. It is something we must create. It also, he cautions, does not supply a universal template that is necessarily applicable beyond the specific problem, issue, or question being addressed in a particular course. The shift in meaning emphasized process over content and preexisting formulas for integration. At a 1935 meeting sponsored by the National Education Association, and in the 1937 book *Integration: Its Meaning and Application*, participants in both forums concluded that complete unity is impossible. They proposed thinking in terms of *unifying*, not *unified*, approaches. At a 1948 workshop sponsored by the Foundation for Integrative Education, participants further distinguished *content integration*, in bridging physical sciences with arts and letters, from *process integration*, in the interplay of an individual and an environment. They also distinguished *integration* as synthesizing accepted postulates from *integrative* building of new conceptual modes capable of producing a holistic experience (Ciccorico, 1970, pp. 60–61; Taylor, 1969, p. 130).

In the latter half of the 20th century, two other notable developments occurred that reinforced the new emphasis on process and expanded the contexts for integrative thinking. In the first development, writers on social science research and higher education contrasted *interdisciplinary* generalizing and connecting of current knowledge formations with constructing new *integrative* concepts that raise new intellectual questions. In some cases, such as the concepts of "area" and "gender," they have even led to the formation of new interdisciplinary fields beyond the disciplines (Beane, 1997, pp. 15–18; Klein, 1990, pp. 24–25). In the second development, the Association of American Colleges and Universities (http://www.aacu.org) and the Carnegie Foundation for the Advancement of Learning also joined forces in promoting a new Integrative Learning movement that aims to bridge multiple divides, including high school and college, general education and the major, introductory and advanced levels, theory and practice, disciplines and fields, and academic and other forms of knowledge. "Interdisciplinary studies" is a subset of integrative learning that fosters connections among disciplines and interdisciplinary fields. Yet, it also intersects with and sometimes directly

complements other integrative approaches to education, such as collaborative learning, feminist pedagogy, learning communities, multicultural pedagogy, team teaching, theme- and problem-based curricula, inquiry- and discovery-based teaching, and performance-based teaching (Huber & Hutchings, 2004; Klein, 2005a).

Transdisciplinarity and the Shift to Complexity and Problem Solving

Interdisciplinarity is defined conventionally as a synthesis of ideas, data and information, methods, tools, concepts, and/or theories from two or more disciplines aimed at answering a complex question, solving a complex problem, or producing new knowledge or a product of knowledge. In contrast, the term *transdisciplinarity* is often associated with the idea of unified knowledge. The term is traced conventionally to the first international conference on interdisciplinary teaching and research, cosponsored in 1970 by the Organization of Economic Cooperation and Development (OECD). It denotes a common system of axioms that transcends the narrow scope of disciplinary worldviews through an overarching synthesis, such as anthropology conceived as a comprehensive science of humans and their accomplishments (OECD, 1972, p. 26). Over time, a variety of overarching frameworks became linked with the idea of transdisciplinarity, notable among them general systems theory, structuralism, Marxism, feminist theory, phenomenology, policy sciences, and sociobiology. Holistic in intent, these initiatives aimed to reorganize the structure of knowledge, although they differed in the role accorded to disciplines (Miller, 1982, p. 21). Other metatheoretical approaches also emerged, including a model informed by the new worldview of complexity in science developed by the Centre International de Recherches et Études Transdisciplinaires (http://perso.club-internet.fr/nicol/ciret).

In recent decades, a new connotation has emerged that aligns both inter- and transdisciplinarity more strongly with problem solving and complexity. This development was anticipated in 1982, when the OECD announced that the weight had shifted from *endogenous university interdisciplinarity* to *interdisciplinarity exogenous to the university*. *Endogenous interdisciplinarity* is based on production of new knowledge with the aim of achieving the unity of science. In contrast, *exogenous interdisciplinarity* originates in real problems of the community, supplementing and enriching the *endogenous* form while calling into question its limits (OECD, 1982, p. 130). The core premise of this shift within the new connotation of transdisciplinarity is that complex problems in the *Lebenswelt*—the "life-world" in German and the "real world" in English—need to frame research questions and practices, rather than disciplines. The participation of stakeholders in other sectors of society is also assumed, requiring cooperation and integration beyond academic boundaries. This development was apparent in Europe in the late 1980s and early 1990s in Swiss and German contexts of environmental research, and by

the turn of the century, case studies were reported in all fields of human interaction, with natural systems and technical innovations in Europe and in partnerships for development with countries in the southern hemisphere (Klein, Grossenbacher-Mansuy, Scholz, & Welti, 2001).

Not all problems are the same. One strand of problem solving in TDR centers on collaborations between academic researchers and industrial/private sectors for the purpose of product and technology development. A different type arises when academic experts and social actors with local knowledge and contextual interests cooperate to achieve democratic solutions to complex problems, such as sustainability and risks deriving from technological modernization such as nuclear power plants. Together, though, the cumulative literature on TDR provides a rich knowledge base for integration aimed at improving problem solving and decision making. It is anchored in guidelines and case studies illustrating the roles of concepts and abstract ideas; quantitative and qualitative models; methods and tools; organizing frameworks; and products such as a technical device, database, regulation, exhibition, medical treatment, or a plan for sustainable development. The 2007 book *Principles for Designing Transdisciplinary Research* presents a synthesis of principles, concepts, and methods (Pohl & Hadorn, 2007). The 2008 *Handbook of Transdisciplinary Research* provides a state-of-the-art overview of theory and practices, with a closing chapter on the topic of integration (Hirsch Hadorn, et al., 2008). And the 2009 book *Research Integration Using Dialogue Methods* is a "methodological toolkit" of 14 dialogue methods that is useful for both IDR and TDR collaborative process (McDonald, Bammer, & Deane, 2009).

In the United States, a separate but parallel initiative arose in the late 1990s. In programs of the National Cancer Institute, TDR was defined as a collaborative form of "transcendent interdisciplinary research" that is generating new methodological and theoretical frameworks for defining and analyzing social, economic, political, environmental, and institutional factors in health and well-being (Rosenfield, 1992; Stokols, Hall, Taylor, & Moser, 2006). The areas of concern include cancer, heart disease, obesity, violence, and the environment. The emphasis is on scientific discoveries, educational outcomes, and translation of scientific findings into new clinical practices and public policies. Multiple stakeholder groups are targeted, including scientists and trainees, funding organizations, policymakers, and partners in clinical settings and community organizations. Direct participation of stakeholders is not prominent, as it is in the European formulation of TDR. Yet, this initiative has enriched the knowledge base for integration. Results of and reflections on a groundbreaking 2006 conference, "The Science of Team Science," appear in a special issue of the *American Journal of Preventive Medicine* devoted to theory and practice, definitions, social and cognitive dynamics of collaboration, assessment and evaluation, leadership, training, and case studies in health sciences (Stokols et al., 2008). An April, 2010 conference explored next steps in TDR team science (http://cancercontrol.cancer.gov/brp/scienceteam/index.html; http://cancercontrol.cancer.gov/BRP/scienceteam/ajpm.html; http://scienceofteamscience.northwestern.edu/agenda).

The primary focus on integration in the U.S.-based initiative has been the personal, social, and institutional dynamics of collaboration. Collaboration readiness and antecedent conditions are crucial. The more contextual factors and institutional supports are in place at the outset, the greater the prospects for achieving integration and collaboration. Key factors include leadership skills and styles of research administrators, shared office and laboratory space, electronic connectivity, and team members' experiences working together on previous projects. Key factors in the quality and scope of IDR and TDR integration in both collaboration readiness and antecedent conditions include development of integrative conceptualizations, methodological approaches, commitment to team research, mutual learning, negotiation of shared meaning, resolution of conflicts, and interactions in collaborative activities such as attending meetings with co-investigators and trainees to share and integrate ideas, as well as developing partnerships with community organizations (Stokols et al., 2008).

Means of Integration

In describing the process of integration for student research, Repko (2008) highlighted three sources of conflicts among disciplines: assumptions, concepts, and theories. The key integrative activities in his model are comparing and contrasting disciplinary insights, creating common ground, and creating a new and more comprehensive understanding of a problem. The key integrative techniques are redefinition, extension, organization, and transformation. Two or more of the four may also be combined. Others have identified similar and additional means of achieving integration. In their chapter on integration, Pohl et al. (2008) highlighted four primary means that foster integration: mutual understanding in collaboration, theoretical concepts, models, and products. Along with Pohl and Hadorn (2007), they also call attention to the importance of language and add the role of frameworks.

Language is central to integration in both IDR and TDR. The same terms may be used in different ways, underscoring the importance of focusing on conflict in Repko's (2008) model. By not dealing with conflicts, students run the risk of privileging some definitions over others or using an ambiguous mix of meanings. Bilingualism is a popular metaphor of interdisciplinary work. However, mastery of two complete languages rarely occurs. New and redeployed terminology form the basis of a working interlanguage or metalanguage likened to two concepts from linguistics. A "pidgin" is an interim tongue, providing a trade language between groups with different languages. A "creole" is a new first language among members of a new social and cognitive community (Klein, 1996, p. 220). When research problems and questions fall within the scope of interdisciplinary fields, students have an additional obligation to learn the creoles of those fields, such as feminist theory, general systems, sustainability, and cultural analysis. In collaborative

work, negotiation of common meanings is also crucial. Everyday language has a role to play. "Interdisciplinary discussions," Gerhard Frey (1973) found, typically occur at a level similar to popular scientific presentations. They become more precise as individuals acquire knowledge of other disciplines, combining everyday and specialist language. Everyday language is especially important for integrating nonacademic stakeholders into the research process.

Concepts play prominent roles in integration for both individuals and groups. Repko (2008) cited the differing meanings of the concept of "efficiency" for economists, biologists, and political scientists. Comparably, Miller (1982) cites the concept of "role." It is widely used in social sciences but alternatively framed in the market model as the role of the consumer, in sociology's structural-functional model as the individual's role playing in social structure, in history as a person's role, and in one conceptual model in sociology as a role model (pp. 17–18). Both individuals and groups need to uncover different meanings in order to work toward common ground. These are other *bridging concepts* play a productive role in this process, transferring notions between fields and fostering adaptations in new contexts. In a TDR project, for instance, the bridge concept of the syndrome approach classified global change problems on the basis of indicators (symptoms) that were analogous to disease patterns (syndromes). The bridge helped to generate solutions for problems such as overcultivation of marginal land (Sahel syndrome) and uncontrolled urban growth (favela syndrome; Pohl & Hirsch Hadorn, 2007, p. 29).

Models vary along a spectrum, spanning quantitative and qualitative as well as ideal versus field-based approaches. They also have different intellectual foundations. Some are based in operational theory and others in studies of human behavior; sociocultural and sociotechnical theories of group interaction; communication theory; decision theory; and hybrid psychologies of social, cognitive, educational, organizational, and industrial concerns. Repko's (2008) stage model prescribes steps in a process, though he acknowledges that individuals might begin at different points and compress steps, depending on the immediate task. Newell (2007), Sjolander (1985), and Szostak (2002) have also designated steps in a sequence. Maurice DeWachter's (1982) model of an interdisciplinary approach to bioethics bridges the gap between ideal models and the realities of practice. The ideal model assumes that individuals will suspend their disciplinary/professional worldviews from the beginning, in favor of a global question grounded in the problem to be solved. Realistically, though, they are usually unwilling to abstain from approaching a topic in terms of their worldviews. The best chance of succeeding lies in starting by translating a global question into the specific language of each participating discipline, then working back and forth in iterative fashion, constantly checking the relevance of each answer to the bioethical problem at hand. That way, no single answer is privileged. Likewise, Klein's (2005b) generic model of an interdisciplinary approach to

problem solving replaces linear sequence with an iterative movement back and forth across types of knowledge, approaches, and stages. All of these approaches, it should be added, share a belief in best practices and iteration.

Methods (and techniques) of integration vary as well. Some are well-known, including systems theory and modeling, integrated environmental assessment and risk management, Delphi and scenario building, simulation, concept mapping, and computer synthesis of data and information flow. Other proven methods facilitate communication and common understanding, including mental mapping of stakeholder views, consensus conferences, collaborative learning, and collaborative workspaces. New methods also emerge in the process of performing IDR and TDR. The Natural and Social Science Interface of the Swiss Federal Institute of Technology in Zurich developed the TIPS approach in a case study and teaching project on sustainable regional development. Standing for Transdisciplinary Integrated Planning and Synthesis, TIPS embeds formal, scientific, integrated planning in a real-world setting, facilitating mutual learning among scientists and stakeholders through interactions. It also utilizes other successful methods such as systems analysis and scenario constructions (Walter, Wiek, & Scholz, 2008, p. 174; Pohl & Hirsch Hadorn, 2007, p. 56).

Frameworks are overriding "idea tanks" that help to integrate different disciplinary perspectives and organizing clusters of insights while structuring the core issue of a project or program in a systematic process (Ulli-Beer, Kaufmann-Hayoz, & Schwaninger, 2008, p. 170). In describing the field of policy analysis, Joel L. Fleishman (1991) illustrated the integrative character of frameworks. Policy analysis incorporates only a fraction of the contents of participating disciplines. Policy analysts construct an integrative lens and analytic framework that fit around a particular problem, choosing portions of disciplines that appear relevant to solving it and adding useful elements from statistics, operations research, history, and ethics. The process starts where economics and political science leave off, building on disciplinary descriptions and inferences to formulate alternative solutions and project likely consequences (pp. 235–238).

Lessons From TDR Integration

Although Repko (2008) focuses on the solo researcher, parallel insights appear in the literature on IDR and TDR collaboration, while extending awareness of how social and cognitive integration are interwoven (O'Donnell & Derry, 2005, p. 60). Joint definition of a project is required, along with the core research problem, questions, research objects, and goals. Role clarification and negotiation help members assess what they need and expect from each other. Ongoing communication and interaction foster mutual learning and a sense of "teamness" and interdependence. The organizational framework should also provide for coordination of subprojects

and the main project with correlated inputs, progressive sharing, and interactive cross-testing of empirical and theoretical work. If individuals hold back during the early phase, the prospect of arriving at a shared or interfacing cognitive framework is jeopardized from the beginning. Teams must also grapple with differences in the status hierarchy of their members. A prestigious person or discipline may dominate, inhibiting others from speaking, impeding role negotiation, delaying communal work, and creating social and cognitive dependence.

In defining principles for TDR collaboration, Pohl and Hirsch Hadorn (2007) adopted Rossini and Porter's (1979) scheme from the IDR literature. The four major forms of collaboration are common group learning, negotiation among experts, integration by a leader, and modeling. Common group learning is a cooperative process among all participants: Subquestions are distributed to the most appropriate members of a larger group and then discussed by everyone and related to an overall question. The process repeats in recursive fashion, with progressive mutual learning and gradual shifting of individual responsibility for subanswers to the group as a whole. Negotiation among experts begins the same way but allots responsibility for subproblems to experts followed by a bilateral exchange, mutual adaptation of answers and subquestions, then a final stage of negotiation that leads to synthesis. Integration by a leader places responsibility with a designated individual or subgroup in charge of mediating exchange and integrating subresults at the end. Modeling is situated on a continuum between quantitative and qualitative frameworks or schema (Pohl & Hirsch Hadorn, 2007, pp. 52–54; Rossini & Porter, 1979, p. 74). The following two case studies provide complementary insights for students who are now doing IDR individually but will find themselves in the future involved in collaborative learning environments, workplace projects, and community forums where the lessons of IDR and collaborative TDR can be combined.

Baccini and Oswald (2008) illustrated the role of bridging concepts and models in a TDR project involving a scientist and an architect with a common interest in sustainable urban development. Two tasks were crucial: learning each other's language and understanding differing perceptions of the same words, such as "landscape," "urban," and even "project" and "process." Focusing on an area in the Swiss lowlands, they took field trips that contributed to mutual learning. The process repeated when the project expanded to include others. One group (morphologists) was rooted in the culture of architecture and urban planning. The other group (physiologists) was composed of natural scientists, engineers, and an economist. Architects considered themselves urban planners and designers able to lead the project because of their competence as generalists. They viewed engineers, economists, and natural scientists as suppliers of facts, figures, models, and tools to support architectural blueprints. Natural scientists were also considered more interested in theories of cognition than a concrete project, and their methods were considered inadequate for dealing with complex urban phenomena and

creative synthesis. Two years of mutual learning resulted in a shared definition of "urbanity" in mixed groups of morphologists and physiologists. The bridging concept of Netzstadt ("net city") provided a common way of perceiving the agglomeration of lowlands as a network with connected knots or nodes, rather than a center. A new identity and shared convictions also emerged. In a second phase, new teams elaborated the Netzstadt model and methods along with the Synoikos method of generating cooperative majorities in participative processes.

Bergmann and Jahn's (2008) case study of an urban mobility planning project offers an extended illustration of the importance of tending to integration throughout all phases of a program's life cycle. Nearly 20 participants from various disciplines and city and transportation planners from two model cities participated in the CITY: *Mobil* project. The focus was a rising volume of motorized traffic that was generating ecological and economic problems. The challenge of *integration* was complex, spanning planning and technical aspects as well as economic, ecologic, and social goals. Cooperation was further complicated by the dispersed location of research institutes in Germany and Austria. Key integrative activities in the three-phase project are italicized in the following paragraph.

Phase A dealt with construction and description of the project and the team, *constitution of a common research object*, and analysis of the problem dimensions to be treated. Objects of TDR, Bergmann and Jahn (2008) emphasize, are not automatically specified. Constituting them at the beginning of the research process establishes a underlying "fundament" for *integration*. A detailed structuring plan also called for *close cooperation* between all subprojects and the main project with *correlated inputs*. A *coordinator was responsible for leading integration*. Contradicting disciplinary, scientific, and political claims had to be recognized and integrated into a research objective accepted as the *shared focus* for all participants, using a theoretically and methodologically *guided process of translating all single aspects* of the societal problem. The common focus was determined by *mutual agreement* on problem descriptions, resulting analytical questions, and definitions of related notions and concepts. The bridging concept of the term *mobility* functioned as a boundary object and overarching integrative term encompassing spatial mobility, socio-spatial mobility, and social mobility.

During Phase B, the emphasis was on subprojects and knowledge building, *mutual learning and linking between disciplines*, and *coordination* of researchers and project parts. A *common analytical question* had to be answered by all subprojects: "How can the strong coupling between mobility and 'auto-mobility' be decoupled?" The *interaction structure* enriched interaction and mutual learning while bringing integration down to the level of every subproject and thereby preventing a large conflict at the end of the project. Partnerships between researchers from different disciplines also facilitate *mutual control of the developing comprehensibility and integration potential* of results, publications, common systems or categories, and assessment criteria. Cognitive integration was facilitated by common foci in the main project.

The overall pathway in the main project encompassed an inventory of the transportation system and its ecological impacts, options and restrictions to mobility behavior as well as transportation infrastructure and city development, mappings of scenarios, an integrated impact assessment of strategies, an intensive phase of TD *integration*, and finally publication of a guide for communities and book of findings for the scientific community.

In Phase C, the focus was transdisciplinary integration, product/publication design, and transformation/innovation/implementation impulses. The final integration task was to integrate corresponding and differing findings from all project parts to form relevant conclusions for different target groups, the scientific community, and the urban communities. *Multiple instruments and measures* were used. Researchers in the planning perspective developed a computer learning model of the cities (MOBI*DYN*) combining three modules: transportation networks, allocation of people in different housing areas and work places, and mobility behaviour. Critical analysis of research questions and methods in traditional research on transportation planning led to development of a new approach to the ecology of transportation and analysis of traffic genesis. These approaches were investigated in four subprojects supported by a system of *coproduction*, *interfacing workshops, and exchange of findings with cooperation among members of several institutes and disciplines*. An empirical market research and marketing instrument targeted several groups with different mobility behaviors and attitudes; it aimed to shift them from the car to other mobility modes using a new focus and method called *mobility-style research* that supplies information to transportation planners and companies. A newly developed information system called Least-Cost Transportation Planning (LCTP) provided planners and politicians with comprehensive information about all expenses for the transport sector and its sources. A new integrated method of Action Impact Assessment facilitated ex-ante evaluation of transportation projects and their ecological, economical, and social impacts and the problems to be faced when putting them into public use.

Conclusion

Four principles of integration emerge from the comparative overview of IDR and TDR.

1. The Principle of Variance

No Universal Formula for Integration

There is no universal formula for integration because the contexts of IDR and TDR differ. The focus varies, from theoretical frameworks for integrating knowledge to specific themes, questions, and problems. Integration is also influenced by the goals of a particular program, the participants who are

involved, their disciplinary and professional backgrounds, and institutional settings. Scope and complexity vary as well, ranging from "narrow-gauged," "middle-range," and "horizontal" interactions among disciplines with compatible methods, paradigms, and epistemologies to "broad-gauged," "vertical," and "grand"-scale forms involving disciplines with divergent approaches (Kelly, 1996; van Dusseldorp & Wigboldus, 1994, p. 96). The type of inter- or transdisciplinarity being practiced is a further source of variance. Method- and theory-based forms differ in the purpose and means of integration.

2. The Principle of Platforming

Interaction Structure, Integration Potential, Fundament

Platforming is a set of actions aimed at building a foundation for integration. In collaborative work, it also entails putting into place the antecedent conditions and contextual factors crucial for both cognitive and social integration (Stokols et al., 2008). One of the most important lessons to emerge from the earlier Bergmann and Jahn (2008) case study of an urban mobility planning project was the need to tend to integration throughout the life cycle of a project or program. The *interaction structure* brought *integration* down to the level of every subproject, to prevent a large conflict at the end of the entire project. Partnerships also facilitated mutual control of the evolving comprehensibility of the task. The *integration potential* of emerging results, publications, systems, categories, and assessment criteria was also made visible.

Although the organizational management of the project was more challenging than most student projects, students trained in using Repko's (2008) model can appreciate several crucial points of similarity. They, too, must constitute a *common research object* and a *common analytical question,* to analyze the problem dimensions that will be treated within the scope of their individual studies. Bridge concepts and common foci serve as a *fundament* for integration, and the *integration potential* of each element needs to be assessed. Students also need to address conflict in contradicting claims and sources, *translating all single aspects* of the problem or question at hand.

3. The Principle of Iteration

Moving Back and Forth, Bootstrapping, Triangulation, Reflective Balance, and Weaving

Repko's (2008) step-by-step model unfolds in a linear sequence of explanation. Integration does not appear as a formal step until the 9th of 10 steps. Yet, he argues the process can begin at any step, may compress some steps depending on the task at hand, and may move back and forth between disciplinary part and complex whole as tentative syntheses are reformed. Others have depicted comparable movement in the process.

- Steve Fuller (1993) argues that the interdisciplinary process requires moving from lower-level translation of disciplinary perspectives by bootstrapping up to higher levels of conceptual synthesis (p. 42).
- J. T. Klein (1990) contends that the process requires achieving balance through ongoing triangulation of *breadth* of expert materials and approaches; *depth* in pertinent disciplinary, professional, and interdisciplinary fields; and *synthesis* of common ground elements tested throughout the process (p. 52; Klein, 1996, pp. 212, 214, 222–223).
- Veronica Boix-Mansilla (2006) emphasizes reflective balance and weaving together perspectives into a coherent whole. Options must be weighed in a "balancing act" that maintains generative tensions and reaches compromises in selecting and combining disciplinary insights and standards.

Together, these movements emphasize the importance of patterning and testing throughout the research process, modifying objectives and goals as new insights are generated.

4. The Principle of Communicative Rationality

Shared Language Culture, Social Learning, Translation-Negotiation-Mediation, Intersubjectivity

The quality of outcomes, Wilhelm Vosskamp (1994) suggested, cannot be separated from development and richness of a shared language culture. Moreover, Vosskamp exhorted, the agreement/disagreement structure necessary for all communication shapes the possibility of interdisciplinary dialogue. Consent/dissent (*Alteritaet*) requires accepting the unforeseeable and productive role of misunderstanding from the outset. A final case study provides a powerful reinforcement of the importance of language and conflict in integration in both IDR and TDR, in an urban planning project to retrofit residential neighborhoods built between 1950 and 1975 on the outskirts of Québec City, Canada.

In the case study, Després, Fortin, Joerin, Vachon, and Gatti (2008) demonstrate that scientific and academic knowledge alone cannot deal adequately with the complexity of subjects and problem domains such as revitalizing neighborhoods. Following Jurgen Habermas's *Theory of Communicative Action* (1987), instrumental, ethical, and aesthetic forms of knowledge are also needed. Rational knowledge comes out of not only "what we know" but "how we communicate" it, generating a form of "communicative rationality." Stakeholders enter into a process of negotiation, confronting the four kinds of knowledge in a series of encounters that allow representatives of each type to express their views and proposals. In the process, a fifth type of knowledge progressively emerges. It is a hybrid product, the result of "making sense together." Fostering "intersubjectivity," the

fifth type of knowledge requires an ongoing effort to achieve mutual understanding. Simply bringing people together and coordinating conversations is not enough. Mediation is required to define collectively what could and should be done. Each stakeholder expresses individual interests or views that are discussed and criticized by others. The role of the mediator is to extract this knowledge. As progressively shared meanings, diagnoses, and objectives emerge, individual interests and views are seen in different perspectives. Even individual students conducting solo research projects will need to be alert to the importance of communicating their results to different target audiences, requiring some awareness of their worldviews.

In closing, a set of core capacities emerges from the comparative overview of approaches to integration in IDR and TDR. Students, professionals, and citizens alike need to create an integrative framework and a more holistic understanding by comparing and contrasting multiple resources, discovering patterns, and making connections. The process is not algorithmic. It is heuristic and constructivist at heart. It also, Repko (2008) reminds us, requires analytical reasoning and creative thinking. Moreover, it requires reflexivity on the limits of the wholes they create. The emergence of a literature and networks focused in significant part on integration is an important historical development in both IDR and TDR. Skills of research integration, McDonald et al. (2009) assert, have become as essential as disciplinary skills, making competence and training in integration methods as crucial today as new digital literacies. This need is all the more important when disciplines are also undergoing tremendous change characterized by pluralistic practices, boundary crossing, openness to interdisciplinary developments, and the force of complexity and problem solving. We need integration experts as much as we need disciplinary, professional, and interdisciplinary expertise.

References

Baccini, P., & Oswald, F. (2008). Designing the urban: A transdisciplinary approach. In G. Hirsch Hadorn, et al. (Eds.), *Handbook of transdisciplinary research* (pp. 48–56). Berlin: Springer Verlag.

Bammer, G. (2005). Integration and implementation sciences, building a new specialization. *Ecology and Society*, *10*, 2, 6. Retrieved from http://www.ecology andsociety.org/vol10/iss2/art6//

Beane, J. (1997). *Curriculum integration: Designing the core of democratic education*. New York: Teachers College Press.

Bergmann, M., & Jahn, T. (2008). Transdisciplinary integration in sustainability research: The case of CITY: mobil. In G. Hirsch Hadorn, et al. (Eds.), *Handbook of Transdisciplinary Research* (pp. 57–68). Berlin: Springer Verlag.

Boix-Mansilla, V. (2006). Assessing expert interdisciplinary work at the frontier: An empirical exploration. *Research Evaluation, 15*(1), 17–29.

Ciccorico, E. W. (1970). "Integration" in the curriculum. *Main Currents in Modern Thought, 27,* 60–62.

Després, C., Fortin, A., Joerin, F., Vachon, G., & Gatti, E. (2008). Retrofitting post-war suburbs: A transdisciplinary research and planning process. In G. Hirsch Hadorn et al. (Eds.), *Handbook of transdisciplinary research* (pp. 251–259). Berlin: Springer Verlag.

DeWachter, M. (1982). Interdisciplinary bioethics: But where do we start? A reflection on epochè as method. *Journal of Medicine and Philosophy, 7*(3), 275–287.

Fleishman, J. L. (1991). A new framework for integration: Policy analysis and public management. In D. Easton & C. Schelling (Eds.), *Divided knowledge: Across disciplines, across cultures* (pp. 219–243). Newbury Park, CA: Sage.

Frey, G. (1973). Methodological problems of interdisciplinary discussions. *RATIO, 15*(2), 161–182.

Fuller, S. (1993). *Philosophy, rhetoric, and the end of knowledge*. Madison: University of Wisconsin Press.

Habermas, J. (1987). The theory of communicative action Vol. 2: Lifeworld and system: The critique of functionalist reason (T. McCarthy, Trans.). Boston: Beacon Press.

Hirsch Hadorn, G., Hoffmann-Riem, H., Biber-Klemm, S., Grossenbacher-Mansuy, W., Joye, D., Pohl, C. . . . Zemp, E. (Eds.). (2008). *Handbook of transdisciplinary research*. Berlin: Springer Verlag.

Huber, M. T., & Hutchings, P. (2004). *Integrative learning*. Washington, DC: AACU.

Kelly, J. (1996). Wide and narrow interdisciplinarity. *Journal of General Education, 45*(2), 95–113.

Klein, J. T. (1990). *Interdisciplinarity: History, theory, and practice*. Detroit, MI: Wayne State University Press.

Klein, J. T. (1996). *Crossing boundaries: Knowledge, disciplinarities, and interdisciplinarities*. Charlottesville: University Press of Virginia.

Klein, J. T. (2002). Introduction: Interdisciplinarity today: Why? What? and How? In J. T. Klein (Ed.), *Interdisciplinary education in K-12 and college: A foundation for K-16 dialogue* (pp. 1–17). New York: The College Board.

Klein, J. T. (2005a). Integrative learning and interdisciplinary studies. *Peer Review, 7*(4), 8–10.

Klein, J. T. (2005b). Interdisciplinary teamwork: The dynamics of collaboration and integration. In S. J. Derry, C. D. Schunn, & M. A. Gernsbacher (Eds.), *Interdisciplinary collaboration: An emerging cognitive science* (pp. 23–50). Mahwah, NJ: Erlbaum.

Klein, J. T., Grossenbacher-Mansuy, W., Scholz, R. W., & Welti, M. (Eds.). (2001). *Transdisciplinarity: Joint problem solving among science, technology, and society*. Basel: Birkhäuser.

Klein, J. T. & Newell, W. H. (1997). Advancing interdisciplinary studies. In J. Gaff & J. Ratcliff (Eds.), *Handbook of the undergraduate curriculum: A comprehensive guide to purposes, structures, practices, and change* (pp. 393–415). San Francisco: Jossey-Bass.

McDonald, D., Bammer, G., & Deane, P. (2009). *Research integration using dialogue methods*. Canberra: Australian National University. Retrieved from http://epress.anu.edu.au/dialogue_methods_citation.html

Miller, R. (1982). Varieties of interdisciplinary approaches in the social sciences. *Issues in Integrative Studies, 1*, l–37.

Newell, W. H. (2007). Decision making in interdisciplinary studies. In G. Morcol (Ed.), *Handbook of decision making* (pp. 245–264). New York: Marcel Dekker, CRC Press/Taylor & Francis.

O'Donnell, M. O., & Derry, S. (2005). Cognitive processes in interdisciplinary groups. In S. J. Derry, C. D. Schunn, & M. A. Gernsbacher (Eds.), *Interdisciplinary collaboration: An emerging cognitive science* (pp. 51–82). Mahwah, NJ: Erlbaum.

Organization for Economic Co-operation and Development. (1972). *Interdisciplinarity: Problems of teaching and research in universities*. Paris: Author.

Organization for Economic Co-operation and Development. (1982). *The university and the community: The problems of changing relationships*. Paris: CERI, Author.

Oxford English dictionary (Compact Ed.). (1971). Oxford, UK: Oxford University Press.

Pohl, C., & Hirsch Hadorn, G. (2007). *Principles for designing transdisciplinary research*. Munich: Oekom.

Pohl, C., van Kerkhoff, L., Hirsch Hadorn, G., & Bammer, G. (2008). Integration. In G. Hirsch Hadorn, et al. (Eds.), *Handbook of transdisciplinary research* (pp. 411–424). Berlin: Springer Verlag.

Repko, A. F. (2008). *Interdisciplinary research: Process and theory*. Thousand Oaks, CA: Sage.

Rosenfield, P. (1992). The potential of transdisciplinary research for sustaining and extending linkages between the health and social sciences. *Social Science and Medicine, 35*(11), 1343–1357.

Rossini, F. A., & Porter, A. L. (1979). Frameworks for integrating disciplinary research. *Research Policy, 8*, 70–79.

Sjolander, S. (1985). Long-term and short-term interdisciplinary work: Difficulties, pitfalls, and built-in failures. In L. Levin & I. Lind (Eds.), *Interdisciplinarity revisited: Reassessing the concept in the light of institutional experience* (pp. 85–92). Stockholm: OECD, Swedish National Board of Universities and Colleges, and Linköping University.

Stokols, D. B., Hall, K., Taylor, B. K., & Moser, R. P. (2008). The science of team science: Overview of the field and introduction to the supplement. *American Journal of Preventive Medicine*, *35*(2S), S77–S89.

Szostak, R. (2002). How to do interdisciplinarity: Integrating the debate. *Issues in Integrative Studies, 20*, 103–122.

Taylor, A. (1969). Integrative principles and the educational process. *Main Currents in Modern Thought, 25,* 126–133.

Uli-Beer, S., Kaufmann-Hayoz, R., & Schwaninger, M. (2008). A transdisciplinary modelling approach for policy learning and analysis: Steps and concepts of a case study. In G. Hirsch Hadorn, et al. (Eds.), *Handbook of transdisciplinary research* (pp. 160–173). Berlin: Springer Verlag.

Van Dusseldorp, D., & Wigboldus, S. (1994). Interdisciplinary research for integrated rural development in developing countries: The role of social sciences. *Issues in Integrative Studies, 12*, 93–138.

Vosskamp, W. (1994). Crossing of boundaries: Interdisciplinarity as an opportunity for universities in the l980s? *Issues in Integrative Studies, 12,* 43–54.

Walter, A., Wiek, A., & Scholz, R. (2008). Implementing regional sustainable development: The transdisciplinary case study research approach. In G. Hirsch Hadorn et al. (Eds.), *Handbook of transdisciplinary research* (pp. 174–194). Berlin: Springer Verlag.

Wilson, E. O. (1999). *Consilience: The unity of knowledge*. New York: Vintage.

distribution of resources and the politicized definitions of community. His current work on Los Angeles County is focused on leveraging multiple disciplinary perspectives to develop a metropolitan framework that integrates the fields of urban and suburban history.

Stuart Henry is Professor and Director of the Interdisciplinary Studies Program at the University of Texas at Arlington. He was formerly Director of the School of Public Affairs at San Diego State University and served seven years as the Chair of the Department of Interdisciplinary Studies at Wayne State University. He is a member of the executive board of the Association for Integrative Studies and has served as co-chair of their annual conference (2003 and 2010). He is the author or editor of 25 books and more than 100 articles, mostly on criminology, social control, and deviant behavior. His most recent books are *Essential Criminology* (2010), *Social Deviance* (2009), and *The Politics of Interdisciplinary Studies* (co-edited with Tanya Augsburg, 2009).

Julie Thompson Klein is Professor of Humanities at Wayne State University and has held visiting posts in Japan, New Zealand, and Nepal. She received the Kenneth Boulding Award for outstanding scholarship on interdisciplinarity, the Ramamoorthy and Yeh Transdisciplinary Distinguished Achievement Award, and the Joseph Katz Award for Distinguished Contributions to the Practice and Discourse of General and Liberal Education. Her authored and edited books include *Interdisciplinarity: History, Theory, and Practice* (1990); *Interdisciplinary Studies Today* (1994); *Crossing Boundaries* (1996); *Mapping Interdisciplinary Studies* (1999); *Transdisciplinarity* (2001); *Interdisciplinary Education in K-12 and College* (2002); *Promoting Interdisciplinary Research* (2005); *Humanities, Culture, and Interdisciplinarity* (2005); and *Creating Interdisciplinary Campus Cultures* (2010). She is also co-editor of *The Oxford Handbook of Interdisciplinarity* (2010).

Machiel Keestra studied philosophy and psychology in Amsterdam and Heidelberg. He was a staff member at the International School of Philosophy in the Netherlands and in the General Studies Department of the University of Amsterdam, where he now has a tenured assistant professorship at the Institute for Interdisciplinary Studies. He is involved with and teaches in the Interdisciplinary (Natural and Social Sciences) Bachelor, Brain and Cognitive Sciences Master, and Interdisciplinary Honours programs. His research ranges from the philosophy of tragedy to the cultural history of mathematics and currently focuses on the philosophy of the cognitive sciences, resulting in an interdisciplinary thesis: *Sculpting the Space of Actions: Mechanisms and Meanings, Causes and Contexts*. In addition, he is involved in building a European interdisciplinary network, and in 2008 he was appointed "International Liaison" by the Association for Integrative Studies.