Title
Transdisciplinary training in health research: Distinctive features and future directions

Author
Stokols, Daniel

Publication Date
2011

Peer reviewed

In M. Kirst, N. Schaefer-McDaniel, S. Hwang, & P. O'Campo (Eds.), Converging disciplines: A transdisciplinary research approach to urban health problems. New York: Springer, 2011.

Chapter 10
Transdisciplinary Training in Health Research: Distinctive Features and Future Directions

Shalini Misra, Daniel Stokols, Kara Hall, and Annie Feng

The malaria and AIDS epidemics, rising cancer, diabetes, and obesity rates are but some of the tremendously complex global health challenges of the twenty-first century. Since these challenges do not lie in the domain of any one academic discipline, many scholars have recognized that if they are to be tackled effectively, a new generation of scientists and health promotion practitioners must be trained to ensure that they have the requisite conceptual, methodological, and interpersonal skills to enable them to bridge traditional discipline-based, regional, and cultural boundaries (Nash, 2008; Nash et al., 2003; National Academy of Sciences, 2003; von Ruschkowski, 2003). In recent years, several transdisciplinary (TD) training programs have been initiated at undergraduate, doctoral, and post-doctoral levels with the aim of producing scholars capable of integrating and transcending theoretical and methodological boundaries of disciplines in a variety of problem areas (Fuqua, Stokols, Gress, Phillips, & Harvey, 2004; Nash, 2008; Nash et al., 2003; Stokols et al., 2003; Stokols, Hall, Taylor, & Moser, 2008). For example, in 2002–2003, the Canadian Institutes for Health Research funded 85 5-year nationwide TD training programs from undergraduate to post-doctoral level, entitled the Strategic Training Initiative in Health Research (STIHR). The foci of the programs spanned a wide range of areas including partnering in community health research, inner-city health, tobacco research and control, addictions and mental health policy services, cancer research and technology transfer, and molecular oncologic pathology just to name a few.

Whereas the educational and societal benefits of TD training have been heralded by many scholars, little empirical research is available on the short- and longer-term outcomes of TD as compared to unidisciplinary training (Lattuca, 2001; Nash et al., 2003; Younglove-Webb, Gray, Abdalla, & Purvis Thurow, 1999). There is little consensus about what constitutes TD training and on which dimensions it differs from unidisciplinary (UD), multidisciplinary (MD), and interdisciplinary (ID) approaches to education. How might effective TD training programs be designed and implemented at various educational levels (e.g., within undergraduate, graduate,

S. Misra (✉)
School of Social Ecology, University of California, Irvine, CA 92697, USA
e-mail: shalinim@uci.edu

M. Kirst et al. (eds.), *Converging Disciplines*, DOI 10.1007/978-1-4419-6330-7_10,

and/or post-doctoral programs)? What challenges and opportunities are associated with TD training? What criteria should be used to evaluate the processes and outcomes of TD training? The ensuing discussion provides an overview of the state of knowledge pertinent to these questions. Specifically, we focus on: (1) the distinguishing features and goals of TD training as compared to UD, MD, and ID training models; (2) distinctive characteristics of TD training models and programs at the undergraduate, doctoral, and post-doctoral levels; (3) new methods and metrics developed for evaluating TD training; (4) challenges encountered by TD programs as compared to discipline-specific ones; and (5) emerging issues for future investigation that pertain to the most effective strategies for designing, implementing, and evaluating TD training programs.

TD Training: Distinguishing Features and Goals

Nash (2008) conceptualizes different approaches to crossdisciplinary (CD) training in terms of the degree to which they synthesize conceptual and methodological perspectives spanning multiple academic disciplines (e.g., genomics, psychology, and political science) and levels of analysis (e.g., biological, individual, societal). Accordingly, UD training promotes the least amount of integration across boundaries of disciplines and analytical levels whereas TD training encourages the greatest degree of integration. Nash suggests that MD training programs tend to be primarily discipline specific but many of them also include components that encourage students to work with researchers from multiple fields. ID training models aim to prepare students to have functional knowledge of the conceptual frameworks and methodologies of several disciplines. TD training programs are distinctive, relative to UD, MD, and ID approaches, in that they embrace the explicit goal of training scholars who are able to integrate and transcend 'disciplinary'[1] boundaries and multiple levels of analysis within a given problem area.

TD training, ideally, incorporates not only a substantive scientific focus bridging two or more fields, but also a *value-added, process-oriented component* that introduces participants to the unique qualities and requirements of CD collaboration. For instance, trainers and trainees can be educated about the powerful contextual forces that may alter the pace, quality, and impact of collaborative outcomes,[2] the subtle but tangible links between social and intellectual integration that are evident within several arenas of TD collaboration, and the availability of practical strategies (e.g., regular retreats and brainstorming sessions) that can be used to enhance the success of TD research and training initiatives.

---

[1] The term 'disciplinary' in the context of this chapter refers to 'academic disciplines.'

[2] Collaborative outcomes of TD training programs include *process oriented outcomes* such as changes in intellectual values and interdisciplinary attitudes and behaviors as well as *product-oriented outcomes* such as the transdisciplinary scope and qualities for research papers, grant proposals, theses, and dissertations. Longer-term outcomes of TD training programs include the transdisciplinary orientation of trainees' future career plans and goals (Misra et al., 2009).

Moreover, TD training can combine mentorship provided by scholars based in academic disciplinary departments and interdisciplinary university centers with the mentorship provided by community professionals who interact with trainees in non-university field settings. Such TD training programs expose trainees not only to interdisciplinary (academic) collaborations but also to "inter-professional" (and often non-academic) partnerships, as is the case with cross-sector action research (Stokols, 2006) and experiential learning programs that bring together university scholars and community professionals and decision-makers.

TD training strategies can be applied within several arenas of scientific collaboration and at multiple levels of TD training within each arena. For instance, three major arenas of TD research and training are: (1) *intra-center collaborations*, especially the TD research and training processes experienced by the members of a particular research center; (2) *multi-center collaborations* emphasizing the sharing of scientific information and training strategies among the members of two or more research centers; and (3) *research center-community collaborations* involving the TD exchange of information among scientists, community leaders, and policy-makers. Similarly, collaborative processes can be viewed at both intra- and inter-institutional levels–that is, as they occur within the context of a particular institution (e.g., a university, research agency, or foundation, each of which includes multiple research centers) or, alternatively, as they connect and integrate the activities of multiple institutions and their respective members.

Within each arena of collaboration several levels of TD training can be identified. This includes researchers' collaborative exchanges of information: (a) among themselves (i.e., among fellow senior scientists), as well as with (b) *pre-doctoral trainees*, (c) *postdoctoral trainees and new investigators*; and (d) *community leaders and decision-makers*. The levels of TD training emphasized within each arena of collaboration vary according to the composition and programmatic goals of the collaborative enterprise. Thus, some collaborations might incorporate all four training levels whereas others (e.g., the research center-community arena of collaboration) might include only a subset of those levels (e.g., some inter-investigator and scientist-policy maker collaborations may not include pre-doctoral or post-doctoral trainees).

TD training programs aim to nurture a number of *scientific*, *intrapersonal*, and *interpersonal* qualities in their trainees. In addition to the goals of UD training programs (e.g., instilling in trainees strong conceptual and methodological competencies), there are several *scientific* goals that are unique to TD training. One such goal is to foster trainees' capacity to extend and integrate scientific findings, theories, and methods from multiple fields. Additional aims of TD training are to enable trainees to work closely with community-based practitioners and stakeholders (Bammer, 2008), develop novel practice-oriented theoretical and methodological frameworks drawing on the perspectives of multiple fields, and translate scientific knowledge into evidence-based policies, community interventions, and clinical practices. Ideally, the scientific competencies of TD scholars and practitioners should be supplemented by effective interpersonal communication, leadership,

and administrative skills, all of which are essential for achieving and sustaining collaborative success among scientists and their community partners.

Whereas ID training programs encourage trainees to become conversant with different disciplinary perspectives and acquire the ability to coordinate with community groups and health practitioners, they do not necessarily teach them how to integrate the perspectives of multiple fields as TD training programs do (Nash et al., 2003; Stokols et al., 2003). Thus, another goal of TD training is to enable trainees to bridge disciplines along *horizontal* or *vertical* dimensions and across a *narrow* or *broad* range of fields (Stokols et al., 2003). *Horizontal integration* occurs when trainees bridge different disciplines at the same level of analysis (i.e., the societal level of analysis is shared by political science, sociology, and anthropology; whereas the biological level of analysis is common to fields such as biochemistry, pharmacology, and virology). *Vertical integration*, on the other hand, occurs when the disciplinary perspectives bridged are at different analytical levels (i.e., linking sociological, psychological, and genetic analyses of disease susceptibility). *Narrow range* TD training encompasses fields whose disciplinary perspectives are relatively similar and thereby ostensibly more easily combined (i.e., molecular biology and neuroscience). *Broad range* TD training encompasses disciplines whose perspectives may be more difficult to integrate because their conceptual and methodological assumptions are divergent (i.e., integrating the qualitative ethnographic methods of medical sociology with the quantitative assays used in genetics and pharmacology research) (Stokols et al., 2003).

As noted earlier, TD training aims to foster certain intrapersonal and interpersonal skills as well as scientific competencies. At the *intrapersonal level*, it is important to cultivate a "TD Ethic" (Bradbeer, 1999; Stokols, 1998), which broadly construed encompasses: (1) the cognitive flexibility to move between various levels of analysis, scientific worldviews, and methodological perspectives; (2) inclusive rather than exclusionary ways of thinking; (3) broad-gauged contextually oriented theorizing as opposed to circumscribed reductionist thinking; (4) the ability to develop creative solutions to intractable real-world problems; (5) open-mindedness, tolerance, and respect toward diverse disciplinary perspectives and scientific worldviews; (6) egalitarian values and a culture of sharing; (7) an appreciation of and interest in collaborative work; (8) optimism about the scientific and societal outcomes of collaboration; (9) the perseverance, determination, and stamina to overcome and learn from situations of conflict and dissent inherent in TD work; and (10) the ability to adapt to changing circumstances, remain open to new perspectives, and challenge existing assumptions and practices.

At the *interpersonal level,* TD training should strengthen individuals' capacity to work effectively in teams. Toward that goal, certain competencies should be fostered including: (1) excellent communication skills that build and sustain cooperation among team members representing diverse disciplines and educational backgrounds; (2) the ability to manage and resolve interpersonal conflict; and (3) the ability to reach consensus around shared visions and goals and to reduce task-related uncertainties.

Effective TD training requires a sustained mutual exchange of information among trainers and trainees over the course of successive interactions, rather than a one-way episodic delivery of information by experts to non-experts. As such, the roles of trainer and trainee can change in the context of collaborative TD training, such that the trainer may be the trainee in the context of another domain at a different moment in time. Furthermore, TD scientific collaboration and training depend greatly on the establishment of shared terminology and common conceptual ground among participants who have been trained in different fields and are essentially "non-experts" outside of their specialty areas. The cultivation of common linguistic and conceptual understandings requires a greater degree of reciprocal information exchange and receptivity to unfamiliar approaches in TD, as compared to non-TD training arenas.

How can such skills and competencies be cultivated in trainees? What is the relative importance of each of these goals (scientific, intrapersonal, and interpersonal) at the various levels of TD training (e.g., undergraduate, doctoral, and post-doctoral levels)? What specific curricular components most effectively foster the requisite skills and competencies? The following section offers examples of various kinds of "formal" TD training programs and describes exemplars of those (at undergraduate, doctoral, and post-doctoral levels) in terms of their core curricular components.

TD Training Programs: Undergraduate, Graduate, and Post-doctoral Levels

Growing interest in ID training and education has led to the development of a number of undergraduate and graduate programs. Examples in the United States include the University of Southern California's Institute for Health Promotion and Disease Prevention Research, which provides mentorship to undergraduates in the area of health promotion and disease prevention (see http://ipr1.hsc.usc.edu/ipr/). At other universities such as UCLA and the Universities of Michigan, Oregon, Texas at Austin, and Wisconsin, undergraduate students are trained in MD topics such as biotechnology and society and environmental studies. Similarly, CD approaches to the study of health and illness such as the "biopsychosocial" model, cognitive neurosciences, and psychoneuroimmunology have been incorporated into undergraduate curricula at a number of universities. On the other hand, formal TD training programs are a relatively new endeavor and still few in number.

Based on Nash et al.'s (2003) conceptualization of CD training programs, TD training programs should incorporate certain key components regardless of the educational level at which they are conducted: (1) the teaching of ID courses using a team of instructors (multi-mentor model) or a single instructor trained in ID concepts and methods (single mentor model); (2) the establishment of forums for the frequent exchange of scholarly ideas between faculty and students; and (3) promotion of an institutional climate of openness, respect, and trust that encourages the examination of new ideas and experimentation with novel research methodologies. Some examples of TD training programs in North America include the CIHR

Strategic Training Initiative in Health Research (STIHR), the NIH Transdisciplinary Tobacco Use Research Centers (TTURCs), the Robert Wood Johnson Health and Society Scholars Program, the NCI Cancer Prevention Fellowship Program, the School of Social Ecology at the University of California, Irvine (UCI), and the NIH Interdisciplinary Summer Undergraduate Research Program (ID-SURE) at the University of California, Irvine (ID-SURE, 2004; National Cancer Institute, 2008; Robert Wood Johnson Foundation, 2008; UC Irvine, 2008). We discuss the curricular strategies of some of these training programs below.

TD Training at the Undergraduate Level: The Case of ID-SURE

UCI's ID-SURE program is one the few TD training programs developed to train undergraduate students in the field of health promotion and disease prevention (ID-SURE, 2004). The ID-SURE curricular strategy was guided by Nash et al.'s (2003) conceptualization of TD training outlined above. Specifically, (1) teaching was performed by a team of faculty representing a variety of disciplines such as health psychology, environmental health sciences and policy, psychiatry and human behavior, and cell and molecular biology, and medicine; (2) the training program instituted regular meetings providing a time and place for idea exchange among faculty and students in addition to weekly lectures; and (3) the program was jointly administered by the School of Social Ecology at UCI whose academic mission is to analyze research and community problems from a broad ecological perspective and encourage faculty and students to integrate disciplinary perspectives in their research, in collaboration with UCI's Undergraduate Research Opportunities Program, noted for encouraging undergraduate research (see http://www.urop.uci.edu/).

Undergraduates participated in a 10-week course titled "The Social Ecology of Health Promotion and Disease Prevention" and a 10-week summer research internship program that provided them training in integrative concepts, theories, and methods; exposure to diverse disciplines; opportunities to apply TD theoretical models and techniques to the analyses of community health problems and to collaborate with students in disciplines other than their own; and mentorship from faculty representing different disciplines. During the 10-week summer research internship period, students had the opportunity to work on laboratory or field research projects related to the broad field of health promotion and disease prevention under the guidance and supervision of a faculty mentor. Faculty mentors in the ID-SURE training program represented the Biological Sciences (e.g., biomedical engineering, pharmacology) and the Social Sciences (e.g., psychology, anthropology) (Misra et al., 2009).

TD Training at the Doctoral Level: The School of Social Ecology at UC Irvine

UCI's School of Social Ecology and its predecessor, the Program in Social Ecology, was established in 1970 with the mission to train students to research and analyze

policy questions from a broad ecological perspective that integrates multiple disciplines and links basic theory and research to community problem-solving. The social ecological approach is concerned broadly with the study of relationships between people and their socio-physical, cultural, and political environments and adopts the following tenets: (1) CD, multi-level analyses of social phenomena; (2) employing systems theory principles (e.g., negative feedback loops, interdependence of system elements, anticipating the unintended side-effects of interventions) in the analysis of social problems; (3) an emphasis on contextual influences on people-environment relationships; and (4) the translation of theory and research findings into community interventions and public policies.

The School currently offers doctoral degrees in three MD fields–Planning, Policy, and Design; Psychology and Social Behavior; and Criminology, Law, and Society – as well as Ph.D. degrees in Social Ecology and in Social Ecology with an emphasis on Environmental Analysis and Design. The various Ph.D. programs offered include a required core seminar that introduces doctoral students to the social ecological framework for CD research and community problem-solving (see https://eee.uci.edu/08f/51000/). The course readings and lectures guide students through the history of the ecological paradigm, the conceptual and methodological principles of social ecology and systems theory, and the challenges raised by efforts to translate scientific knowledge into evidence-based community interventions and public policies. Also, examples of social ecological theories, research projects, and community interventions are examined from the perspectives of Social Ecology's diverse academic departments and research centers.

Another core curriculum component in the Ph.D. training program is a seminar course on Strategies of Theory Development in which students are trained to develop their own theoretical ideas. Specifically, Ph.D. students: (1) create social ecological models relevant to their particular research interests that highlight the interplay between psychological, socio-cultural, and environmental factors; (2) learn about the challenges that arise when attempting to develop theories that bridge multiple disciplines and levels of analysis; and (3) learn to consider alternative scientific worldviews and contrasting metatheoretical perspectives on the nature and uses of theory.

TD Training at the Post-doctoral Level

Whereas TD training at the undergraduate or early graduate levels emphasize a didactic approach, mentoring and apprenticeship are more crucial at the advanced graduate and post-doctoral educational levels (Nash, 2008). According to Nash (2008), two TD training models are employed at the post-doctoral level: *the single mentor apprenticeship model* and *the multi-mentor apprenticeship model.*

The single mentor apprenticeship model: In this approach, the trainee receives mentorship, guidance, and training in TD methods and concepts from a single TD researcher. The single mentor apprenticeship approach, however, is not common because very few researchers have sufficient knowledge and experience in TD concepts and methods to be able to provide comprehensive CD training (Chang,

Hursting, Perkins, Dores, & Weed, 2005; Nash, 2008). As the culture of research changes and more researchers are trained and become proficient in TD research, a single mentorship approach may become a more viable or common approach, especially at smaller institutions where multi-mentorship models may be difficult to implement due to the intensity of personal resources required. Ultimately, although TD trainees may begin their research under the guidance of a single mentor based on compatible scientific interests and working styles, they often require the guidance and expertise of investigators in other fields and institutions to further their own research interests as they progress through the training program.

The multi-mentor apprenticeship model: In this approach, a team of mentors representing diverse academic disciplines or departmental and institutional affiliations guide the TD trainee on a particular research topic by combining their individual disciplinary perspectives. Through such mentorship and guidance, the trainee learns to develop a broad-gauged TD approach to his or her own research topic.

The NCI's Cancer Prevention Fellowship Program provides an example of the multi-mentor apprenticeship approach (Chang et al., 2005; National Cancer Institute, 2008). The goal of the fellowship program is to provide post-doctoral trainees a thorough grounding in the field of cancer prevention. This program includes didactic components such as a formal 1-year training program in the ID field of Public Health, followed by 2 years of mentored research in one or more substantive areas (e.g., laboratory-based cancer prevention research, epidemiologic research, behavioral science research, prevention-related policy research, qualitative and quantitative research methodologies). The post-doctoral fellows also participate in structured professional development training activities aimed at fostering leadership skills and TD scientific perspectives.

Other examples of the multi-mentor training model are found within the TTURC initiative at the Brown University Medical School and at UCI (Fuqua et al., 2004; Nash et al., 2003; Stokols et al., 2003; Stokols, Harvey, Gress, Fuqua, & Phillips, 2005). Post-doctoral fellows funded by the TTURC program at Brown University conduct research on tobacco-related cancer prevention and control. In order for fellows to be competent in TD theory and research techniques, research ethics, and grant and manuscript writing related to tobacco research, an individualized training program was developed including didactic elements (e.g., workshops on research methods, behavioral medicine, ethics, and transdisciplinarity), mentorship (e.g., from scholars representing disciplines other than their own who work on tobacco-related topics), and collaborative and independent research opportunities (e.g., writing review papers, conducting small-scale pilot studies, writing and submitting grant proposals). Similarly, at the UCI TTURC, bi-monthly forums were organized to provide post-doctoral fellows and junior faculty opportunities to discuss important papers in the field, share their own recent research, and discuss future scientific directions and disease prevention strategies. The fellows also participated in working groups (e.g., Public Health work group) and a seminar series on the latest tobacco-related research. The forums, workgroups, and seminars were intended to foster fellows' integrative conceptual and methodological skills and also familiarize them with the latest tobacco use research in different fields.

A fundamental assumption underlying the programs and models described above is that TD training will result in superior scientific outcomes and community interventions compared to UD training. However, at the present time, relatively little is known about the effectiveness of large-scale TD training programs and their intellectual and societal value compared to smaller-scale, UD research and training initiatives. Whereas a number of conceptual frameworks have been proposed to evaluate antecedent conditions, intervening processes, and outcomes of TD science initiatives (e.g., Fuqua et al., 2004; Stokols et al., 2003, 2008), very few empirical studies have evaluated the outcomes of TD training programs. The following section discusses the latest developments in the evaluation of TD training programs, including explicit criteria for operationalizing TD training processes and outcomes.

Evaluation of TD Training Programs

Mitrany and Stokols (2005) developed two methodological strategies to evaluate the TD *processes* and *outcomes* of the doctoral training program in Social Ecology at UCI, one of the TD training programs discussed in the previous section. *Process measures* include self-reports of the influence of coursework, research mentorship, and scholarly exchanges as well as self-appraisals of TD values, attitudes, and behaviors. *Product measures* include external, objective assessments of the TD qualities of trainees' published papers, theses, and dissertations. They developed composite scales for assessing the TD scope of doctoral dissertations that can be applied to a wide range of training and research programs. Misra et al. (2009) adapted the Mitrany and Stokols' (2005) measures to develop criteria for evaluating the intellectual processes and products of an undergraduate TD training program (ID-SURE).

In their analyses of the TD training processes and outcomes of the ID-SURE program, Misra et al. (2009) found that the curricular components of the program were effective in training students in TD concepts, methods, and skills. Specifically, the program increased students' TD orientations (e.g., the extent to which they value TD work; are optimistic about the scientific outcomes of such work; are tolerant and open-minded toward research perspectives other than their own; and use multiple research methods from many disciplines) as well as their collaborative behaviors (e.g., reading journals, taking courses, and attending lectures and talks outside of their primary academic major) over the course of the training program. As well, the TD orientation of the students' mentors (e.g., the degree to which they value and engage in TD collaborative work) was found to moderate the influence of the ID-SURE training program on the integrative quality of the students' term projects.

Mitrany and Stokols (2005) also found in their analyses of the outcomes of doctoral training in Social Ecology at UCI that the TD quality of students' dissertations was strongly influenced by the students' advisors and departmental affiliations. Dissertations written under the supervision of advisors from smaller, more MD, and less traditional departments had higher ratings on the dimensions of TD scope (e.g., degree of TD integration, number of fields brought together,

number of analytic levels bridged, diversity of research methods used, and contextual breadth of students' conceptual approach to the topic). They posit that these results may have occurred because collaborative research based on shared interests rather than affiliation to a certain academic discipline is more readily achieved in smaller departments where there is a more supportive climate for cooperation among scholars representing diverse fields.

Mitrany and Stokols also found that the doctoral training program at UCI has been moderately successful in instilling a CD research orientation in its graduates. Whereas few dissertations demonstrated TD qualities such as the development of novel conceptual frameworks that integrate and transcend disciplinary boundaries (see Rosenfield's (1992) criterion for the most robust form of TD science), a sizable proportion of the dissertations analyzed by independent reviewers revealed strong ID qualities (e.g., linkages between concepts and methods of two or more fields and broad contextual scope of the conceptualization of the topic). While Mitrany and Stokols' research provides evidence for some of the short-term outcomes of TD training programs, the longer-term effects of TD training such as the extent of the TD orientation of trainees' future goals and career trajectories as well as their achievements as TD scholars (Misra et al., 2009) warrant explicit investigation in future studies.

To this point in the chapter, we have examined certain components of TD training, some of its potential short-term benefits, and strategies for evaluating the processes and outcomes of CD education and mentorship. TD training programs, especially at the advanced graduate and post-graduate levels, equip scientists with the skills to work in collaborative settings and to develop broad-gauged approaches to complex topics such as cancer epidemiology and prevention. TD training programs present students with collaborative opportunities that hone their ability to coordinate with colleagues from different fields and cooperate with them as participants in TD teams. Moreover, TD-trained scholars may be more likely to compete successfully for job positions in ID fields that have experienced tremendous growth in recent years (Chang et al., 2005; von Ruschkowski, 2003). Whereas TD training is associated with several potential opportunities, earlier studies have identified certain barriers associated with CD approaches to education. The next section discusses some of the challenges and constraints faced by TD trainees as well as certain factors that can facilitate positive training outcomes.

Challenges Associated with TD Training Programs

Achieving and sustaining transdisciplinarity is a difficult task. Personal interests, values, attitudes, and intellectual orientations play an influential role in determining whether scholars are able to navigate disciplinary boundaries, make integrative theoretical leaps, and become successful collaborators or leaders in team science endeavors (Mitrany and Stokols, 2005; Nash et al., 2003). TD learning can be constrained by exclusionary ways of thinking, methodological rigidity, pessimism about the value of TD work, closed-mindedness, and lack of respect toward divergent

discipline-based epistemologies (Bradbeer, 1999; Stokols, 1998). It may be counterproductive to thrust individuals into TD training programs and teams without regard to their personal and intellectual dispositions. Inconsistency between such dispositions and a given academic or research program may lead to confusion, conflict, and eventual retreat into the familiar domains of their academic disciplines. There is a need to develop targeted recruiting strategies that effectively channel intellectual interests and inclinations of promising undergraduate, graduate, and post-doctoral TD scholars into CD training programs for which they are well suited.

Even among trainees who are inclined toward CD education, learning to accommodate, assimilate, and integrate knowledge from disparate fields can be very challenging and requires sufficient time. For example, a post-doctoral scholar who is proficient in biology may find it very difficult to grasp abstract psychological or sociocultural concepts in his/her efforts to bridge levels of analysis. Further, the TD trainee must not only learn to understand and converse in the specialized languages of different disciplines (Kahn & Prager, 1994; Kessel, Rosenfield, & Anderson, 2008; Morgan et al., 2003; Rhoten & Parker, 2004; von Ruschkowski, 2003), but must also develop an innovative hybrid language, conceptual frameworks, and methodological approaches that bridge two or more fields (Nash, 2008). These tasks require the TD trainee to work within ambiguous and unstructured spaces between disciplines where constructs, theories, methods, and training objectives are yet to be defined. Mentors (even in the multi-mentor training model) are often only familiar with the theories and methods of their specific discipline and as such can only provide limited guidance to trainees in their efforts to traverse and negotiate the unchartered territories between disciplines and analytical levels (Kahn & Prager, 1994; Nash, 2008).

Whereas the process of navigating disciplinary boundaries eventually can result in the development of novel theoretical frameworks and methodological approaches that bridge multiple fields, it is important to ease the difficulties that TD trainees face by developing innovative mentoring practices. For example, mentors participating in TD training programs should be trained to be aware of and sensitive to the challenges faced by their advisees and acquire as much direct experience as possible with TD scientific collaborations. Mentors should not only be responsible for guiding trainees through the terrain of their own discipline but also assist them in their efforts to learn about different fields and to transcend boundaries of disciplines. These training processes can be facilitated if the mentor shares a TD orientation with the mentee as well as through frequent face-to-face and electronic communication (Kessel et al., 2008; Misra et al., 2009; Nash, 2008).

To be effective TD scientists, trainees should be able to establish and sustain collaborative relationships that reach across disciplinary and institutional boundaries (Kessel et al., 2008; Nash, 2008). This requires the trainee to engage with dissimilar academic cultures and manage conflict arising from contrasting scientific worldviews, prejudices, and rivalry among departments (Campbell, 1969). TD mentoring practices should include exposure to collaborative leadership styles and communication skills, as well as interpersonal, managerial, and technological skills to foster relationship-building skills. To ensure the success of TD training, Nash

(2008) recommends the development of individualized training plans that (1) allow adequate time for the trainee to establish relationships across departmental lines; learn diverse discipline-based terminology, concepts, and methods; and acquire a TD ethic; (2) focus on a specific research problem with the goal of mastering problem-relevant theories and methods rather than attempting to master several different fields simultaneously; and (3) balance the scope or breadth of the disciplines included in the training program according to the trainee's interests and aptitudes, since broad-gauged TD training that bridges multiple disciplines and analytical levels can be difficult to achieve, especially for a student who is new to TD research and practice.

It is important to be aware that significant impediments to TD training are created by traditional academic organizational and institutional structures (Campbell, 1969; Nash et al., 2003; Nyden, 2003; Rosenfield, 1992). Departments and institutions vary with respect to their academic philosophies and openness to collaborative enterprises. Hierarchical organizational structures, departmental competition for resources, and lack of co-ordination between academic departments can hinder CD teaching and learning and obstruct cross-departmental collaboration. The lack of departmental or institutional funding for CD courses is another disincentive for TD training. University and department policies should be reformed to support the financial and structural needs of TD training programs. This requires the development of comprehensive TD training strategies that support the needs of senior investigators charged with managing large- or small-team science initiatives as well as all other levels of training.

Additional challenges faced by TD scientists are the risks and uncertainties associated with choosing a TD career trajectory. TD scientists often report feeling undervalued and do not identify with any single discipline (Chang et al., 2005; Mitrany & Stokols, 2005; Nash et al., 2003; Rhoten & Parker, 2004; von Ruschkowski, 2003). TD scholars, in some instances, may be less competitive for job positions within traditional academic units and can face difficulties and uncertainties associated with UD academic structures and reward systems. For instance, publishing research or securing grant funding for research that does not lie in the purview of the domain of any one academic discipline can be quite challenging because not all reviewers are familiar with TD scientific approaches (Kessel et al., 2008; Nash, 2008). Junior TD scientists also can encounter obstacles when their work is reviewed by tenure and promotion committees whose members are skeptical of co-authored publications spanning multiple fields and regard those less highly than single authored UD publications. A change in institutional policies for promotion and tenure at multiple levels as well as a more fundamental shift in academic structures, reward systems, and norms are needed if the difficulties and uncertainties faced by TD researchers are to be addressed.

In summary, the following institutional level factors appear to facilitate effective TD training: (1) adequate funding from public and private agencies over extended time frames and regular and effective co-ordination and communication between funders and training directors, so necessary to sustain TD programs, especially in terms of creating the requisite organizational, institutional, and technological

infrastructure needed to implement and evaluate TD curricula, and to sustain adequate levels of funding for trainee and research staff stipends; (2) appointment of effective training program leaders and mentors who are well-respected, trusted, and have exceptional negotiation, conflict resolution, interpersonal communication, and managerial skills; (3) provision of opportunities of TD trainees and faculty from different disciplines to meet and exchange ideas in the context of forums, retreats, and regular meetings, along with spatially proximal office and lab spaces and electronic (e.g., Internet, intranet) networks to foster regular communication among team members; (4) adequate space for TD training and research activities; and (5) implementation of multi-level policies and administrative structures to facilitate cross-departmental collaboration.

Conclusions and Directions for Future Research

This chapter has provided an overview of the current state of knowledge in the area of TD training and education. The distinctive features, goals, and key components of effective CD training were presented. Examples of TD training models at undergraduate, doctoral, post-doctoral levels were described in terms of their curricular components and aims. Further, a brief overview of the methods and metrics available for evaluating the processes and outcomes of TD training initiatives was provided; and the results of recent studies examining the short-term outcomes of TD training at undergraduate and doctoral levels were discussed. Finally, an account of the intrapersonal, interpersonal, and organizational challenges and constraints associated with TD training was provided and promising strategies that have the potential to facilitate successful TD training were identified.

The field of TD training as a subarea in the science of team science (Stokols et al., 2008) is an emerging research area that poses several questions for future investigation. Among the conceptual and methodological issues that warrant future study are: (1) the development of theoretical frameworks to account for the circumstances under which TD training initiatives are more or less effective; (2) the creation of new methods and metrics to assess the relative influence of various curricular components and intervening processes on the short-term and longer-term outcomes of TD training at various levels; (3) the evaluation of TD training outcomes at different stages of scholarly or professional development; (4) direct empirical comparisons of TD training programs with MD, ID, and UD approaches; and, finally, (5) longitudinal studies of TD training programs to gauge their long-term scientific and societal value relative to UD training programs.

Acknowledgments The authors thank the editors for the helpful comments on earlier versions of the chapter.

References

Bammer, G. (2008). The case for a new discipline of integration and implementation sciences (I2S). *Integration Insights*. Retrieved May 6, 2008, from http://www.anu.edu/au/iisn

Bradbeer, J. (1999). Barriers to interdisciplinarity: Disciplinary discourses and student learning. *Journal of Geography in Higher Education, 23*(3), 381–396.

Campbell, D. T. (1969). Ethnocentrism of disciplines and the fish-scale model of omniscience. In M. Sherif & C. W. Sherif (Eds.), *Interdisciplinary relationships in the social sciences*(pp. 328–348). Chicago, IL: Aldine Press.

Chang, S., Hursting, S. D., Perkins, S. N., Dores, G. M., & Weed, D. L. (2005). Adapting postdoctoral training to interdisciplinary science in the 21st century: The cancer prevention fellowship program at the National Cancer Institute. *Academic Medicine, 80*(3), 261–265.

Fuqua, J., Stokols, D., Gress, J., Phillips, K., & Harvey, R. (2004). Transdisciplinary scientific collaboration as a basis for enhancing the science and prevention of substance use and abuse. *Substance Use and Misuse, 39*(10–12), 1457–1514.

ID-SURE. (2004). *UCI interdisciplinary summer undergraduate research experience*. Retrieved June 17, 2008, from http://www.urop.uci.edu/id-sure.html .

Kahn, R. L., & Prager, D. J. (1994). Interdisciplinary collaborations are scientific and social imperative. *The Scientist, 8*, 12.

Kessel, F. S., Rosenfield, P. L., & Anderson, N. B. (Eds.). (2008). *Interdisciplinary research: Case studies from health and social science*. New York: Oxford University Press.

Lattuca, L. R. (2001). *Creating interdisciplinarity*. Nashville, TN: Vanderbilt University Press.

Misra, S., Stokols, D., Harvey, R., Pine, K., Fuqua, J., Shokair, S., et al. (2009). Evaluating an interdisciplinary undergraduate training program in health promotion research. *American Journal of Preventive Medicine, 36*(4), 358–365. Retrieved July 31, 2010, from http://dx.doi.org/10.1016/j.amepre.2008.11.014

Mitrany, M., & Stokols, D. (2005). Gauging the transdisciplinary qualities and outcomes of doctoral training programs. *Journal of Planning Education and Research, 24*, 437–449.

Morgan, G., Kobus, K., Gerlach, K. K., Neighbors, C., Lerman, C., Abrams, D. B., et al. (2003). Facilitating transdisciplinary research: The experience of the transdisciplinary tobacco use research centers. *Nicotine and Tobacco Research, 5*(Suppl. 1), S11–S19.

Nash, J. M. (2008). Transdisciplinary training programs: Key components and prerequisites for success. *American Journal of Preventive Medicine, 35*(2S), S133–S140.

Nash, J. M., Collins, B. N., Loughlin, S. E., Solbrig, M., Harvey, R., Krishnan-Sarin, S., et al. (2003). Training the transdisciplinary scientist: A general framework applied to tobacco use behavior. *Nictoine and Tobacco Research, 5*(S-1), S41–S53.

National Academy of Sciences. (2003). *The NAS/keck initiative to transform interdisciplinary research*. Retrieved July 18, 2003, from http://www.keckfutures.org

National Cancer Institute. (2008). *National Cancer Institute cancer prevention fellowship program*. Retrieved December 28, 2008, from http://www3.cancer.gov/prevention/pob /

Nyden, P. (2003). Academic incentives for faculty participation in community-based participatory research. *Journal of General Internal Medicine, 18*, 576–585.

Rhoten, D., & Parker, A. (2004). Risks and rewards of an interdisciplinary research path. *Science, 306*(5704), 2046.

Robert Wood Johnson Foundation. (2008). *Robert Wood Johnson Foundation health and society scholars*. Retrieved December 27, 2008, from http://www.healthandsocietyscholars.org /

Rosenfield, P. L. (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.

Stokols, D. (1998). *The future of interdisciplinarity in the School of Social Ecology*. Retrieved March 25, 2005, from http://www.drugabuse.gov/ttuc/Readings.html

Stokols, D. (2006). Toward a science of transdisciplinary action research. *American Journal of Community Psychology, 38*(1), 63–77.

Stokols, D., Fuqua, J., Gress, J., Harvey, R., Phillips, K., Baezconde-Garbanati, L., et al. (2003). Evaluating transdisciplinary science. *Nicotine and Tobacco Research, 5*(Suppl. 1), S21–S39.

Stokols, D., Hall, K. L., Taylor, B., & 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.

Stokols, D., Harvey, R., Gress, J., Fuqua, J., & Phillips, K. (2005). In vivo studies of transdisciplinary scientific collaboration: Lessons learned and implications for active living research. *American Journal of Preventive Medicine, 28*(2S2), 202–213.

UC Irvine. (2008). *UCI School of Social Ecology*. Retrieved December 28, 2008, from http://socialecology.uci.edu/

von Ruschkowski, E. (2003). Changes in the world of science: The realities of interdisciplinary training. *Science*. Retrieved July 31, 2010, from http://sciencecareers.sciencemag.org/career_development/previous_issues/articles/2170/changes_in_the_world_of_science_the_realities_of_interdisciplinary_training

Younglove-Webb, J., Gray, B., Abdalla, C. W., & Purvis Thurow, A. (1999). The dynamics of multidisciplinary research teams in academia. *The Review of Higher Education, 22*(4), 425–440.