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CHAPTER 32

Cross-disciplinary team science initiatives: research, training, and translation[1]

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Over the past two decades, the US government has devoted significant financial resources to the creation of large-scale team research projects, many of which involve hundreds of scientists working together from a wide range of different fields. In the health arena, some initiatives such as the Transdisciplinary Tobacco Use Research Centers (TTURCs) have been operational for nearly 10 years and span multiple university-based centers. Such projects pose considerable logistic, infrastructural, and conceptual challenges that must be overcome to ensure their success. The surge of interest and investment in team science (TS) and training initiatives (Nass and Stillman 2003; National Academy of Sciences 2005) has spawned a rapidly emerging field that focuses on understanding and managing the circumstances that facilitate or hinder the effectiveness of large-scale research, training, and translational initiatives[2] (Kessel *et al.* 2008; Klein 2008; Stokols *et al.* 2008).

This chapter provides a broad overview of the *science of team science* (SOTS) in terms of its historical and conceptual foundations, methodological approaches, training, and translational concerns. It draws on the authors' experiences in designing and implementing evaluative studies for assessing the collaborative processes, scientific training, public policy implications, and potential health outcomes associated with cross-disciplinary TS initiatives funded by the National Cancer Institute (NCI) of the National Institutes of Health (NIH).

[1] Portions of this chapter are based on: Stokols, D., Hall, K.L., Taylor, B.K., and 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. The authors thank the editors for their valuable comments on an earlier version of the manuscript.

[2] Throughout this chapter, the term *translational* refers to the use of scientific knowledge to create evidence-based health promotion policies, community interventions, and clinical practices.

We summarize recent developments in the evaluation of TS initiatives, using the NCI large-center initiatives as exemplars, and propose future directions for this burgeoning field.

The development of large-scale, institutionally based (and, sometimes, multi-institutional) TS initiatives exemplifies one possible arrangement for promoting cross-disciplinary collaboration in health science, training, practice, and policy. Other approaches include scientists working independently to bridge the disciplinary perspectives of multiple fields, and relatively small cross-disciplinary networks and teams whose members are dispersed across locations and who meet regularly through electronic means (e.g. via telephone and video conferencing, e-mail, and intranet) and occasional face-to-face meetings. The SOTS, utilizing evaluation methodologies, network techniques, and organizational and management theories and frameworks, represents a subarea within the field of science studies (Hess 1997) concerned with understanding and enhancing the processes and outcomes associated with team-based initiatives that are undertaken to promote cross-disciplinary research, training, and translations of science into improved practices and policies.

The remainder of this chapter consists of four sections. Sections 32.1 and 32.2 summarize important *conceptual* and *methodological* developments in the SOTS, including the definition of key terms and the development of logic models or program theories to guide the study of TS initiatives; the creation of new methods and metrics for examining the processes and outcomes (including both scientific and translational products) of TS; and the establishment and evaluation of TS training programs. Section 32.3 examines *emerging concerns and research directions* within the SOTS field. These new avenues of research include the development of more rigorous quasi-experimental research designs for assessing the scientific and translational contributions of TS initiatives in comparison with smaller scale, non-team-oriented projects; more comprehensive models of cross-disciplinary training and strategies for evaluating training outcomes; a more nuanced typology of cross-disciplinary TS initiatives and funding models as, well as strategies for evaluating their relative efficacy in achieving the intended goals of TS; and a broader understanding of the contextual factors that determine the 'collaboration readiness' of a particular team and scientific field. Section 32.4 is an epilogue.

32.1 Conceptual developments in the science of team science

The SOTS integrates and builds on many of the efforts highlighted in this book. For instance, Klein (Chapter 2 this volume) offers a rich discussion explicating the complexities of defining disciplines, *per se*, and explores different kinds of disciplinary interactions by developing a taxonomy of interdisciplinarity. Such complexities among key SOTS concepts drive the field forward as well as create challenges for defining the scope of the field and evaluating the work therein. In this section we provide succinct definitions that have served as the basis for our earlier research within the SOTS field. Furthermore, we define our units of analysis with respect to process and outcome goals of TS initiatives and then describe how they can be integrated into theoretical models and conceptual frameworks.

32.1.1 Key terms and conceptual models

We distinguish between TS initiatives themselves and the SOTS field whose principal units of analysis are the large research and training initiatives implemented by public agencies and non-public organizations. TS initiatives are designed to promote collaboration and facilitate cross-disciplinary approaches to conceptualizing and analyzing research questions about particular phenomena. In contrast, the SOTS field is construed more broadly as a branch of *science studies* concerned especially with understanding and managing circumstances that facilitate or hinder the effectiveness of TS initiatives (Stokols *et al.* 2008a).

32.1.2 Characteristics of scientific initiatives and teams

Research teams may comprise investigators drawn from either the same or different academic fields (i.e. unidisciplinary versus cross-disciplinary teams). These teams vary not only by their disciplinary composition, but also by their size, organizational complexity, and geographic scope, ranging from a few participants working at the same site to many investigators dispersed across different geographic and organizational venues. Furthermore, the goals of TS initiatives are diverse (e.g. spanning scientific discovery, training, clinical translational, public health, and policy-related goals), and both the quality and level of intellectual integration between disciplines that is intended and achieved varies from one program to the next, for example along a continuum ranging from unidisciplinary to multidisciplinary, interdisciplinary, and transdisciplinary integration.

Because TS initiatives differ along so many dimensions, it is important to differentiate between various types of research and training initiatives (Klein, Chapter 2 this volume). Team-based projects can include a handful of scientists working together at a single site, all the way to larger and more complex initiatives comprising many (e.g. 50–200) investigators who work collaboratively on multiple research projects and are dispersed across different departments, institutions, and geographic sites. Expenditure is another dimension; Trochim *et al.* (2008), for example, define large research initiatives as grant-funded projects solicited through specific requests for applications (RFAs) with an average annual expenditure of at least $5 million. The usual duration of these initiatives, e.g. National Institutes of Health (NIH) P50 and U54 centers, National Cancer Institute (NCI) specialized programs of research excellence (SPOREs), is 5 years and may be renewed, in some cases, extending over one or more decades. Some broad-gauged initiatives such as the NIH roadmap programs provide an over-arching framework and funding source for scores of interrelated research and training initiatives, all of which are designed to promote cross-disciplinary scientific collaboration (National Institutes of Health 2003). Often, large research initiatives incorporate career development and training components as well as clinical translation, health promotion, and policy-related functions.

Team science initiatives also vary with respect to the collaborative orientations and disciplinary perspectives of team members. This chapter focuses primarily on initiatives intended to promote *cross-disciplinary* (CD) rather than *unidisciplinary* (UD) collaboration. CD teams strive for leverage and, in some cases, integrate concepts, methods, and theories drawn from two or more fields. Three different approaches to CD collaboration, which have become relatively standard in this nascent field, have been described by Rosenfield (1992). *Multidisciplinarity* (MD) is a process in which scholars from disparate fields work independently or sequentially, periodically coming together to share their individual perspectives to achieve broader-gauged analyses of common research problems. Participants in MD teams remain firmly anchored in the concepts and methods of their respective fields. *Interdisciplinarity* (ID) is a more robust approach to scientific integration in the sense that team members not only combine or juxtapose concepts and methods drawn from their different fields, but also work more intensively to integrate their divergent perspectives, while remaining anchored in their own respective fields. *Transdisciplinarity* (TD) is a process whereby team members representing different fields work together over extended periods to develop shared conceptual and methodological frameworks that not only integrate but also transcend their respective disciplinary perspectives. Our definition for TD is distinct from others such as Huutoniemi (Chapter 21, this volume), who suggest that TD is different from ID based on the inclusion of contributors from outside academia rather than the distinction being the degree of synergy or integration as Rosenfield (1992) proposes. Considering both Rosenfield's and Huutoniemi's definitions, TD collaborations perhaps have the greatest potential to produce highly novel and generative scientific outcomes, but they are more difficult to achieve and sustain (compared with UD, MD, and ID projects) due to their greater complexity and loftier aspirations for achieving transcendent, supradisciplinary integrations.

The ensuing discussion focuses on ID and TD (rather than UD and MD) science initiatives in which an explicit goal of collaboration is to integrate theories, methods, and training strategies drawn from two or more fields. Examples of large-scale ID and TD team initiatives are the NCI TTURCs, the Centers for Excellence in Cancer Communications Research (CECCR), the Centers for Population Health and Health Disparities (CPHHD), and the Transdisciplinary Research on Energetics and Cancer (TREC) Centers; and the National Center for Research Resources (NCRR) Clinical and Translational Science Centers (CTSC).

The distinctions between UD, MD, ID, and TD forms of scientific collaboration are directly relevant to the development of criteria for gauging the success of TS initiatives. In particular, measures of scientific collaboration and its outcomes should be appropriately matched to the research, training, and translational goals of a particular initiative (Huutoniemi, Chapter 21 this volume). A major goal of ID and TD initiatives, for example, is to bridge the perspectives of different fields through collaborative development of integrative conceptualizations, methodological approaches, and training strategies. Thus, an important criterion for gauging the success of these initiatives is the extent to which cross-disciplinary integrations are actually achieved by research teams.

32.1.3 Units of analysis, theoretical models, and conceptual frameworks

It is important to define the major units of analysis and core subject matter of the SOTS field. A major challenge in this regard is to specify the dimensions of *program effectiveness* or *success* as they pertain to TS initiatives. For example, the quality of scientific work may be defined differently in the context of ID and TD team initiatives as compared to UD projects. Traditional criteria of scientific quality include conceptual originality, methodological rigor (e.g. validity and reliability of empirical findings), and the amount of research output produced, such as peer-reviewed publications. In the context of TS initiatives, however, the *quality and scope of ID and TD integration* (e.g. development of integrative conceptualizations, methodological approaches, training programs bridging two or more fields, and/or the emergence of new hybrid fields of inquiry, organizational structures, and management strategies for supporting TS) are important facets of TS initiatives that must be considered in view of their explicit mission to promote scientific integration (Stokols *et al.* 2003). Finally, it is important to identify the defining features of successful *ID and TD training* (e.g. multi-mentor training models, trainees' subsequent career trajectories, and the intellectual contributions of current and former trainees).

To date, a number of conceptual models have been proposed by SOTS scholars to identify key *antecedent conditions, intervening processes, and outcomes* (including near-term, mid-term, and long-term outcomes) associated with TS initiatives and to explain the interrelationships among them (e.g. the presence of institutional supports or constraints at the beginning of an initiative and their impact on subsequent collaborative processes and outcomes). For instance, Trochim *et al.* (2008) used concept mapping techniques to derive an empirically based logic model, which guided the NCI TTURC Initiative-wide Evaluation Study. The TTURC logic model, shown in Fig. 32.1, posits a series of temporal links between early processes of intellectual collaboration and TD integration and subsequent outcomes, including scholarly publications, TD training programs, community health interventions, and public policy initiatives. Using the TTURC logic model, both the constructs of interest for evaluation (e.g. the degree of collaboration achieved; the emergence of integrative conceptual frameworks) as well as the temporal sequence in which one would expect to see changes are clearly delineated.

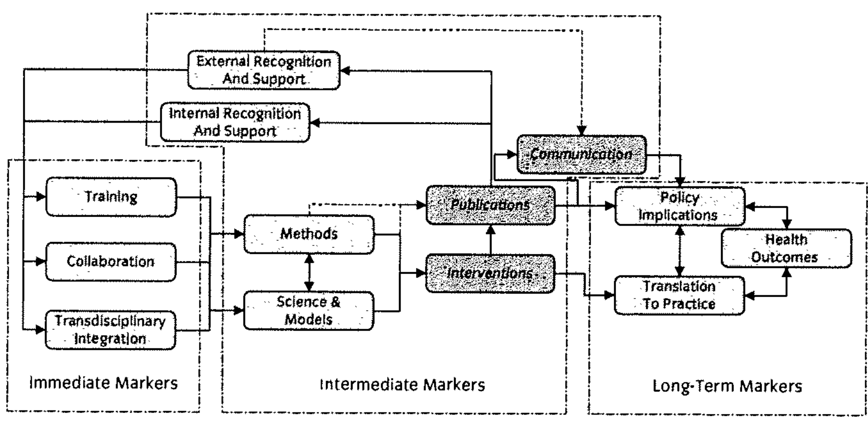

Figure 32.1 Logic model for the Transdisciplinary Tobacco Use Research Center(TTURC) initiative-wide evaluation study. Reprinted from Trochim *et al.* (2008).

In their work, Stokols and colleagues have proposed a different antecedent–process–outcome model of TD science in which several interpersonal, environmental, and organizational antecedents of collaboration are considered, such as the leadership styles of center directors, scientists' commitment to team research, the availability of shared research and meeting space, electronic connectivity among team members, and the extent to which they share a history of working together on prior projects (Stokols *et al.* 2003). Intervening processes examined in this model include intellectual, interpersonal, and affective experiences as well as observed and/or self-reported collaborative behaviors. Examples of these processes are: brainstorming strategies to create and integrate new ideas; cross-disciplinary biases and tensions that often arise in collaborative situations; and strategies for negotiating and resolving conflicts. The antecedent and process variables specified in the model, in turn, influence several near-term, mid-term, and long-term outcomes of scientific collaboration including the development of new conceptual frameworks, research publications, training programs, and translational innovations over the course of the initiative (see Fig. 32.2). Empirical support for the hypothesized links among antecedent, process, and outcome variables was derived from a longitudinal (5-year) comparative study of the TTURC centers.

More recently, Hall, Stokols *et al.* (2008), Holmes *et al.* (2008), and Warnecke *et al.* (2008) developed multistage conceptual frameworks that have guided TD research, training, and community intervention efforts within the NCI TREC and CPHHD initiatives, respectively. From its inception, the CPHHD initiative has placed greater emphasis on community-based participatory research strategies (as compared with the TTURC and TREC initiatives) for the purposes of translating scientific knowledge about the causes of health disparities in the United States into university–community partnerships and collaborative interventions to mitigate these disparities. Thus, the CPHHD evaluation model incorporates a 'community stakeholder–investigator incubator' component (see Fig. 32.3) not

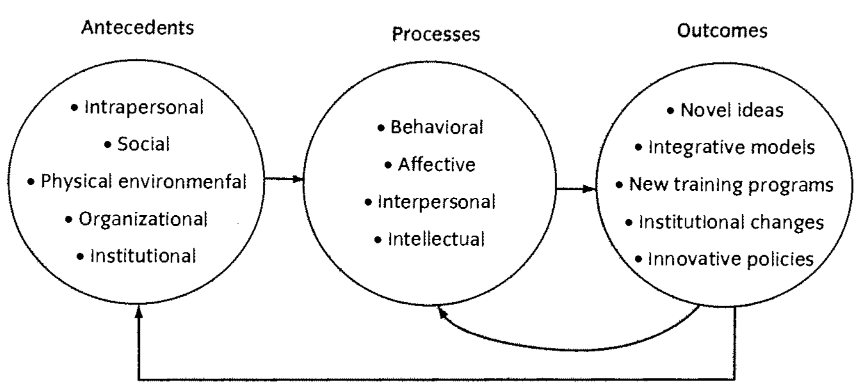

Figure 32.2 Antecedents, processes, and outcomes of cross-disciplinary scientific collaboration. Reprinted from Stokols *et al.* (2005).

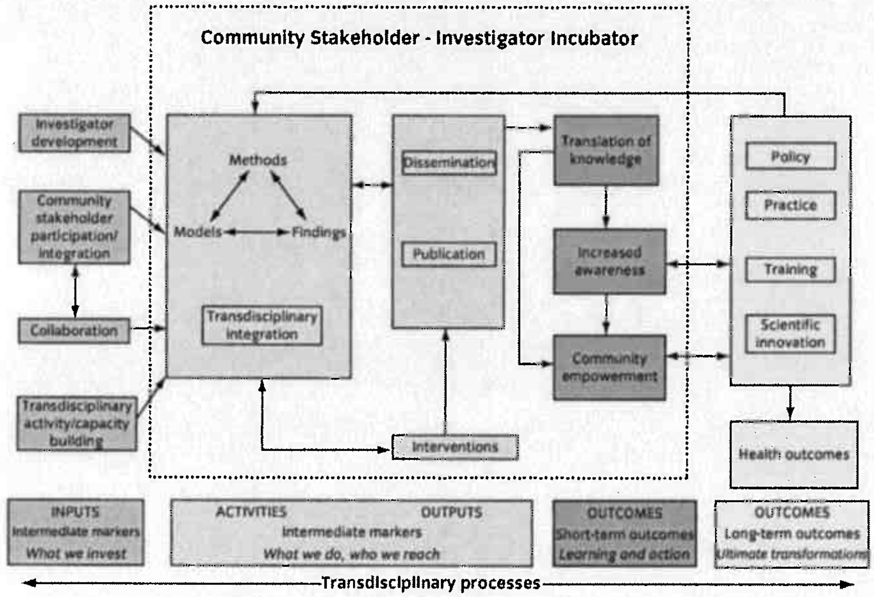

Figure 32.3 Centers for Population Health and Health Disparities (CPHHD) evaluation logic model. Reprinted from Holmes *et al.* (2008).

found in the previously described TTURC logic model (Fig. 32.1) or in the TREC evaluation logic model (see Fig. 32.4) outlined by Hall and colleagues.

Existing models of ID and TD collaboration raise several questions for future research. For example, antecedent conditions present at the outset of a TS initiative can be conceptualized as *collaboration readiness* (CR) factors that jointly influence a team's prospects for success over the course of an initiative (Hall *et al.* 2008a). However, the relative contributions of individual CR factors (e.g. leadership skills of center directors, availability of shared office and laboratory space, team members' experiences of working together on earlier projects) to specific dimensions of collaborative effectiveness (e.g. number of team publications produced as well as their integrative quality and scope; development of sustainable partnerships with community organizations) are not well understood and warrant further study.

Also, earlier conceptual models and the field studies on which they are based suggest that the scientific outcomes of TS initiatives are strongly influenced by social and interpersonal processes, including team members' collaborative styles and behaviors, interpersonal skills, and negotiation strategies. Yet the precise ways in which these social processes—such as team members' disagreements about scientific issues, interpersonal trust, 'group-think' among scientists who have worked together over extended periods—influence scientific productivity and TD integration are not known. The empirical links between interpersonal and intellectual dimensions of scientific collaboration remain unclear.

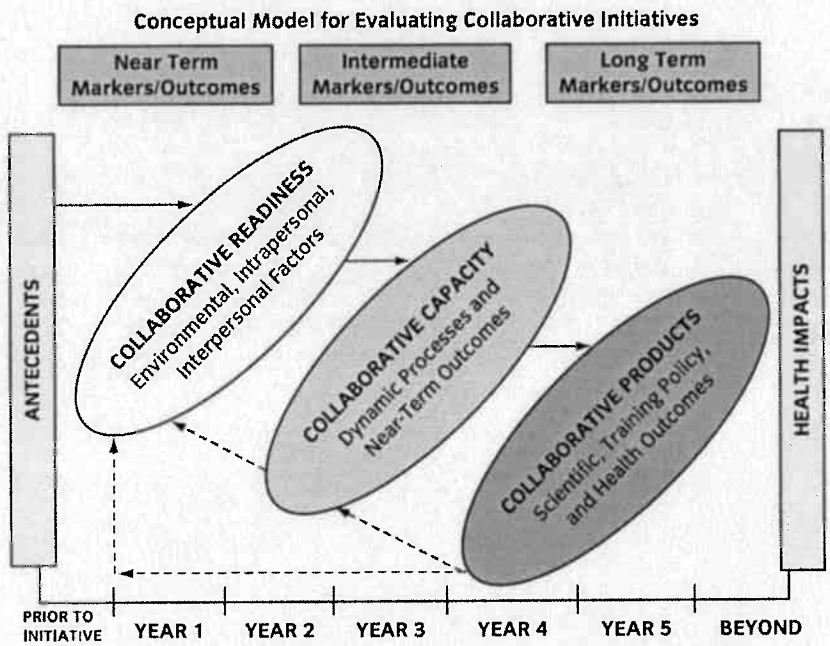

Figure 32.4 Transdisciplinary Research on Energetics and Cancer (TREC) evaluation logic model. Reprinted from Hall *et al.* (2008a).

32.2 Methodological developments in the science of team science

A variety of *qualitative* and *quantitative* methods and metrics are available to assess the antecedents, processes, and outcomes of TS initiatives. Examples of these multiple methods and measurement strategies include:

- The use of unstructured and semi-structured interviews with team members to assess key goals and concerns surrounding their collaborative activities.
- Content analyses of interviews with team members to reveal important themes in narrative accounts of collaborative experiences (e.g. perceptions of progress toward cross-disciplinary scientific integration).
- Administration of standardized survey scales to assess participants' collaborative readiness, research orientations and values, and collaborative experiences.
- Protocols to evaluate cross-disciplinary qualities of near-term written products (e.g. co-authored manuscripts and developmental project proposals).
- Social network analyses of cross-disciplinary collaboration.
- Bibliometric and peer-review assessments of scientific impact and productivity.

These methodological approaches and measurement strategies for evaluating TS initiatives are discussed below.

32.2.1 Qualitative methodologies

32.2.1.1 Appreciative inquiry to identify team goals and aspirations

Team-wide discussions among all relevant stakeholders (e.g. participating scientists and trainees, representatives of funding organizations, other partners) can establish a valuable foundation for a smooth and comprehensive evaluation. Appreciative inquiry techniques (Cooperrider and Witney 2005) can be used to identify team members' goals and collaborative aspirations, as well as their major strengths and assets for achieving team goals. These early planning activities offer opportunities, in a supportive environment, to identify and address challenges of particular relevance to ID and TD collaborations (e.g. issues stemming from divergent disciplinary cultures including language barriers, product development priorities related to tenure, scientific discovery) and may enhance 'buy-in' from all relevant stakeholders to the evaluation process.

32.2.1.2 Investigator interviews

Unstructured and semi-structured interviews with individuals or groups of team members can yield valuable insights into the divergent as well as shared perspectives of participating scientists, trainees, research staff, and community partners. Such interviews can be valuable for generating anecdotal evidence and narrative accounts of collaborative 'success stories'. Additionally, interviews can identify areas that need improvement, which can be shared with various stakeholder groups for the purposes of providing feedback about collaborative processes, and offer suggestions for enhancing team projects and outcomes over the course of an initiative.

32.2.1.3 Self-directed qualitative discussions

Alternatively, individuals within a TS initiative can be encouraged to lead self-directed or investigator-led discussions in an attempt to gather qualitative information about the collaborative processes and outcomes of an initiative. Such discussions may be conducted in meetings among investigators, trainees, and/or research staff within a single project, working group, or entire center. Another option is to organize a large scientific retreat that is self-directed and involves the participation of all members within a particular research project, center, or entire TS initiative. Scientific retreats have been found to be highly effective strategies for encouraging informal social communication as well as scientific dialogue and sparking ideas for integration among the members of TS centers (Stokols *et al.* 2003; Fuqua *et al.* 2004).

32.2.1.4 Document review of narrative accounts of team experiences

A valuable qualitative methodology for revealing major themes and patterns reflected in team members' collaborative experiences is to conduct content analyses of transcripts of the proceedings from scientific retreats and brain-storming meetings. Similarly, content analyses of team progress reports and other written products can provide valuable information about the processes and outcomes of TS initiatives. The data from content analyses can be supplemented by quantitative sources of evaluative information as described below.

32.2.1.5 External peer reviews

Analogous to the peer-review process for grants applications and publications, external peer reviews can be conducted to evaluate TS initiatives. The external panel can examine written products of initiative members (e.g. scientific progress reports, pilot research project proposals, peer-reviewed manuscripts, reports of trainees' research accomplishments and career development), and through periodic site visits assess the day-to-day operations and relative progress being made at particular centers over the course of an initiative.

32.2.2 Quantitative methodologies

In addition to the qualitative methods summarized above, several quantitative strategies can be incorporated into evaluations of TS initiatives, as summarized below.

32.2.2.1 Standardized surveys

Structured self-report surveys are used to assess facets of cross-disciplinary collaboration (e.g. focusing on constructs gleaned from the logic model guiding an evaluation), taking into account the temporal course of the initiative. For the TTURC initiative, scales and indices were created to measure each of the 13 constructs delineated in its logic model (see also Fig. 32.1). The results from the year-three TTURC survey revealed greater progress toward achieving proximal outcomes (e.g. transdisciplinary integration) as compared to more distal ones (e.g. community interventions and their impacts on health outcomes; cf. Mâsse *et al.* (2008) and Trochim *et al.* (2008)).

32.2.2.2. Ratings of written products

As part of the TREC evaluation study, a written products protocol was developed to evaluate the cross-disciplinary qualities of these types of collaborative scientific products. An example of written products includes the research proposals submitted by TREC investigators (during the first and second years of the initiative) to obtain TREC center developmental project funds. The written products protocol was designed to evaluate the conceptual breadth and integrative scope of the developmental projects, as well as the number and type of scientific disciplines and levels of analysis represented by the project staff. Reviews of the proposals were conducted by trained reviewers in consultation with a moderator and expert consultant to reach consensus on the identification and rating of each construct. The written products protocol is intended to be implemented several times over the course of the initiative to examine hypothesized changes over time (Hall *et al.* 2008a), such as progress toward TD integration.

32.2.2.3 Financial analyses

Because of the large monetary investment in cross-disciplinary scientific initiatives and the corresponding need to ensure that the management of these funds is handled effectively, it is important to assess project-specific and center-wide financial expenditures as the initiative progresses from its initial to later phases. Mandatory annual grant reports were used in the TTURC evaluation to compare actual versus proposed yearly spending and to identify any resulting carry-over funds from one year to the next. In addition, data for any financial carry-over were obtained from budget justifications included in investigators' annual reports. Using pre-existing, mandated budget and expenditure reports as a source of evaluative data reduced the participant burden of the overall evaluation. Results from these analyses can be used to identify centers that are having difficulty allocating their financial resources as planned. Large discrepancies between proposed and actual expenditure levels may indicate, in some instances, that team members are encountering collaborative difficulties in their efforts to implement proposed research projects. Often, these discrepancies are larger at the outset of a complex TS initiative when administrative structures and procedures are still in the early stages of development.

32.2.2.4 Social network analyses

Social network analysis (SNA) is another useful tool for evaluating TS programs. TS, by definition, involves people working collaboratively and a SNA can help reveal how these scientific networks develop over time, the density of the networks (i.e. the number of relationships within any particular network), and who the 'brokers' are (i.e. those who facilitate linking others together) within and between participating centers. SNA techniques also can be used to assess constructs such as the quantity and quality of TD work accomplished by the members of a particular network. The CPHHD and TTURC evaluations (see Stokols *et al.* 2005; National Cancer Institute 2007) utilized this methodology to obtain quantitative and visual evidence of collaborative relationships among scientists over time. Within the TTURC and CPHHD initiatives, for example, SNA data were used to assess network densities and the prevalence of collaboration among participating scientists within and across centers. It is also possible to correlate these networking outcomes with other measures such as publication history and scientific impact using bibliometric data.

32.2.2.5 Bibliometric analysis

Bibliometric analysis is another method for assessing the impact of scientific initiatives. This technique provides an assessment of the quantitative and qualitative scholarly impact of publications—those produced either by an individual or a group of individuals—and can be conducted with minimal or no participant burden. Within the TTURC initiative, several bibliometric indices were derived, including the number of times a published work is cited in subsequent publications, the impact factor of the journals in which an article is published, and a measure of how multidisciplinary a journal is. For scientific teams that remain intact over several years, bibliometric analyses can be used to identify temporally lagged changes in the scientific productivity of team members.

As the SOTS field matures, however, there is a need to develop more sophisticated methods and research designs for evaluating processes and outcomes of TS—for example, prospective quasi-experimental (and perhaps truly experimental) research designs, as compared to the retrospective case studies that have been predominant in the SOTS

Managing consensus in interdisciplinary teams

Rico Defila and Antonietta Di Giulio

Collaborative problem framing and consensus

One of the most important requirements of interdisciplinary research consists of what we call 'consensus': By means of suitable procedures and methods, the participants have to arrive at a shared view of the problem under investigation. Consensus here does not mean 'agreement' in an everyday sense. Rather, it means the development of models and theories that integrate the various disciplinary viewpoints in such a way that the result, for example the description of the research objective, is shared by all. Problem framing that incorporates diverse perspectives therefore lies at the heart of successful inter- and transdisciplinary work; success being defined as achieving a synthesis (the integrated result) that is more than just the addition of different points of view and individual results.

Problem framing consists of the following elements:

- Defining the problem (what exactly the problem is and for whom, what is the factual background of the problem, which assumptions and which type of knowledge help us to understand the problem, what is the context in which the problem is meaningful?).
- Figuring out possible solutions to the problem (what is causing the problem, how can and should the problem be approached, where could the most promising solutions be found?).
- Identifying the resources needed to solve the problem (in terms of money, time, perspectives and methods, types of knowledge, stakeholders).

Problem framing in interdisciplinary teams is collaborative problem framing. In the case of wildland fire, Brooks *et al.* (2006, p. 3) state that 'Problem framing involves the different ways that stakeholders define the problem and the terminology and concepts related to it [...]. Different frames allow stakeholders to see what they want to see, or what they are guided to see [...]. The existence of many different frames, or definitions of the problem, suggests a need to develop common goals and a common language'.

The importance of common goals, a common language, and a common theoretical basis is confirmed by the results of the survey conducted by the international cooperation DACH. In 1999 researchers from four inter- and transdisciplinary environmental research programs in Switzerland, Austria, and Germany were sent a written questionnaire about their experiences of and recommendations on research management, leadership and personal skills, methods of knowledge integration, and development of theories etc. Out of 649 questionnaires sent out, 294 completed questionnaires were returned, which corresponds to a response rate of 45%. The results quite clearly show significant differences concerning common goals, a common language, and a common theoretical basis between those who had achieved a synthesis and those who had not (see Figs. 1–3).

Of course, research in an interdisciplinary project will not be carried out collectively with the whole team acting all the time as a group. Rather, there is a division of labor. The common goals, the common questions, and the shared description of the research object are the starting points for individual research work and the point to return to after this work has been done (see Fig. 4).

The role of management in achieving consensus

Many projects fail in their efforts at collaborative problem framing, and, consequently, in developing integrated results. This is often due to a deficit concerning theory and methodology

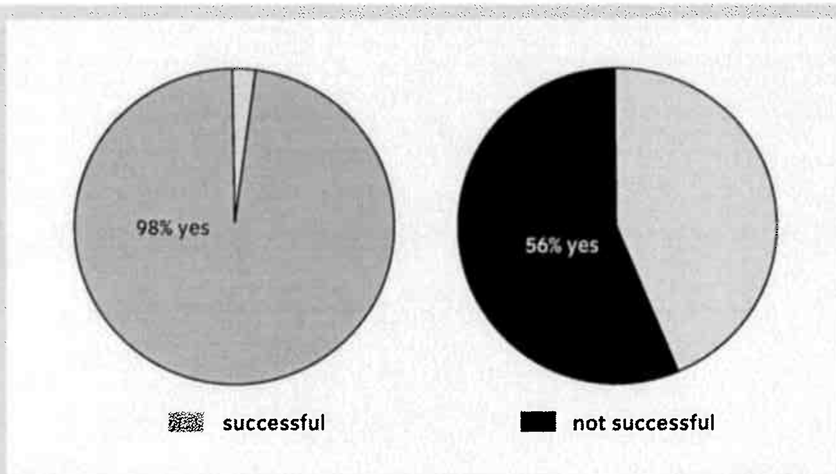

Figure 1 Common goals: of those who achieved a synthesis, 98% said that they had had common goals, whereas only 56% of those who had not achieved a synthesis had common goals (Defila *et al.* 2006, p. 72).

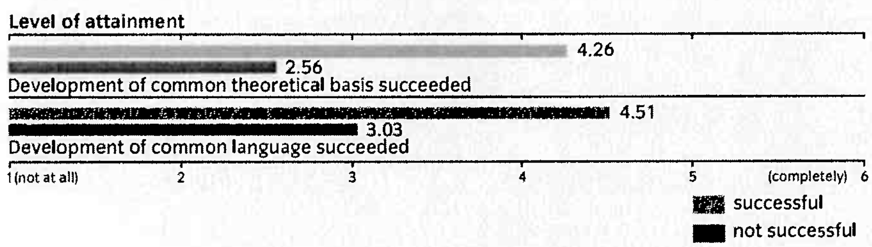

Figure 2 Common language, common theoretical basis: those having achieved a synthesis (the successful ones) were also successful concerning the development of a common language and a common theoretical basis (Defila *et al.* 2006, p. 118).

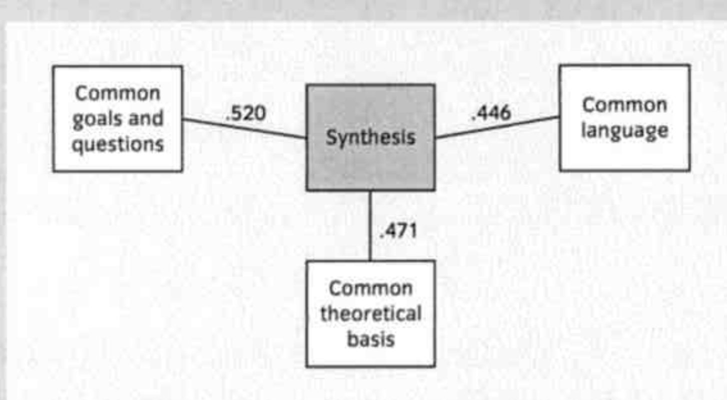

Figure 3 Success factors: the correlation between common goals and achieved synthesis is rather high, as is the correlation between common language and synthesis and between a common theoretical basis and synthesis (Defila *et al.* 2006, p. 49).

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Managing consensus in interdisciplinary teams (cont.)

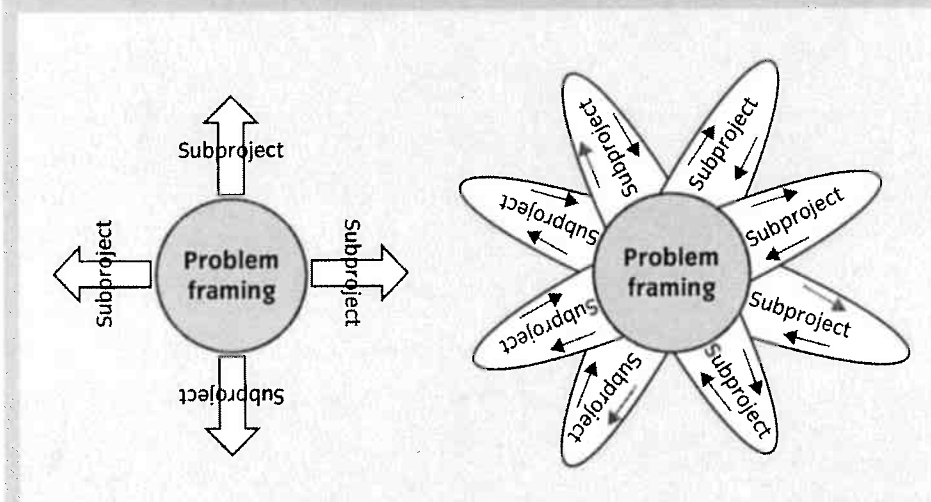

Figure 4 Balancing teamwork and individual work: put metaphorically, the division of labor and the collaborative problem framing together form a flower, the petals standing for the individual research work, respectively the research work in the subprojects.

with regard to interdisciplinary processes. Second, it is due to disciplinary socialization. Interdisciplinarity does not mean the disposal of disciplinarity, ignoring or covering up disciplinary differences. On the contrary, to be successful, the members of a team have to make substantial contributions from their disciplinary ways of thinking and of investigation. To this end they need a strong disciplinary identity and a deep understanding of their disciplinary way of thinking and tackling scientific problems. The specific disciplinary perspectives have to be made productive for interdisciplinary research. This just won't happen if the team members aren't able to relate their disciplinary way of problem framing to the ways of others. If all are convinced that their way of seeing the world is the only possible and right way, that only the questions asked by their discipline are relevant, that their methods of investigation are the only ones possible and the only ones leading to success, collaborative problem framing is out of reach.

So, in interdisciplinary research a strong disciplinary identity is both the *conditio sine qua non* of success and a serious obstacle to success. Collaborative problem framing in interdisciplinary teams therefore has to be balanced with disciplinary problem framing.

Collaborative problem framing in interdisciplinary teams as well as the balancing of teamwork and individual (disciplinary) work will not just happen, even if all team members are strongly committed and willing. Rather, it has to be properly managed. But which processes have to be managed in order to establish successful interdisciplinary work right from the beginning?

Most teams concentrate only on the process of integration. That, as should be clear by now, would be dangerous. Great attention has to be paid to the process of collaborative problem framing, including the process of defining common goals and questions. To ensure integrative problem framing, managers of interdisciplinary research projects have to make sure that this is accompanied by careful reflection on the disciplinary way of structuring the world and on the disciplinary contributions to the solution of the problem by the members of their teams. Then, during the research work, managers of interdisciplinary research have to make sure that the research is actually informed by the common goals and the common questions and always refers to the common description of the research object.

Other tasks in the management of inter- and transdisciplinary projects are (for details see Defila *et al.* 2006):

- to coordinate the research of the members and subprojects, and support joint surveys;
- to ensure the development of common results (synthesis) and ascertain that the research ends up with common products;
- to support team development by discussing the expectations of the team members towards each other as well as concerning the interdisciplinary project, by monitoring the team's working with an eye to possible conflicts due to the disciplinary socialization of the individuals involved;
- to support the participation of practitioners and cooperation between researchers and the stakeholders involved by negotiating the goals and forms of the cooperation, by reaching an agreement concerning the contribution of the stakeholders involved in terms of time and effort as well as products, and by ensuring that the stakeholders really benefit from the cooperation;
- to design and monitor internal and external communications by defining the different disciplinary and non-scientific target audiences to be addressed, by defining the different media and languages needed for addressing the target audiences, and by discussing specific assignments concerning communication within the project team;
- finally, to organize the work within the project group by negotiating rights and duties, by discussing the criteria to be used in the evaluation of the processes and the achieved results, and by tuning the different disciplinary work schedules.

In conclusion, the management of interdisciplinary research can by no means be reduced to simple technical management. Rather, it is a complex task that researchers have to be specially trained for.

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literature to date. A major challenge facing the development of quasi-experimental designs for evaluating TS initiatives is the identification of appropriate comparison or control groups. One effort to address this challenge consists of a novel bibliometric analysis of the TTURC initiative recently begun by our team that incorporates a quasi-experimental interrupted time-series design (Cook and Campbell 1979), supplemented by science visualization maps for examining the 'footsteps' of an initiative in its broader field of research (e.g. tobacco use) over an extended period of time. This new direction of the SOTS field is examined in Section 32.3.

32.3 Emerging concerns and new developments in the science of team science

Four major emerging directions of the SOTS field are considered in this section:

(1) implementing more rigorous quasi-experimental research designs for evaluating the contributions of TS research;
(2) developing and evaluating TD training programs;
(3) creating a more nuanced typology of cross-disciplinary TS initiatives and funding models, and evaluating their relative efficacy in achieving the intended goals of TS; and
(4) achieving a broader understanding of the contextual factors that determine the *collaboration readiness* of particular teams and scientific fields.

32.3.1 Implementing quasi-experimental research designs

An important direction of research in the SOTS field is the implementation of multimethod, quasi-experimental research designs to evaluate the processes and outcomes of cross-disciplinary scientific projects and initiatives. Both quantitative and qualitative methods are now being used to assess the scholarly productivity and impact of scientists working within particular research areas (e.g. tobacco use research). A key component of these evaluation studies is the inclusion of multiple comparison groups—for example, scientists participating directly in a large-scale initiative such as the TTURCs compared with other scientists who are working in the same field of research (e.g. tobacco use and control) individually on single investigator grants.

32.3.2 Development and evaluation of TD training programs

Another important frontier of the SOTS field is the development and evaluation of comprehensive strategies for training the next generation of TD scholars and professionals. The availability of a critical mass of scientists ready for cross-disciplinary inquiry is crucial for the success of TS initiatives. TD training is increasingly being encouraged and required by both public and private funding agencies (e.g. NIH, NSF, RWJF, McArthur Foundation). Although TD training shares many features with more traditional, unidisciplinary training programs at university and other institutional settings, it is unique in that it focuses on fostering a set of attitudes, knowledge, and skills among trainees that will equip them to transcend disciplinary frameworks and methodologies through creative syntheses and to produce significant advances in scientific research. Although still in an early phase of development, evaluative studies of TD training models and programs have been undertaken over the last decade.

A number of different TD training models have been examined in earlier studies. Nash (2008) summarized some of these approaches to TD training, one of which includes university-based programs offering structured TD curricula. In this approach, students receive their formal undergraduate and/or graduate training within an interdisciplinary academic unit (e.g. the University of California Irvine's School of Social Ecology; Cornell University's College of Human Ecology, Ithaca, NY). Another TD training model incorporates multi-mentor apprenticeship whereby a trainee is assigned, through mutual agreement, to more than one faculty advisor and is designated as an apprentice of two or more established mentors in their domains (e.g. as occurs within the TTURC at Brown University, Providence, RI). In yet a third TD training prototype, sometimes referred to as 'residential scholars', junior investigators are encouraged to expand their training experiences by conducting research projects at a center other than their own over a specified period (e.g. 2 to 3 months). In this model, which is being pursued by the TREC centers, trainees have the opportunity to collaborate with colleagues in other institutions by working on a joint project with them and overcoming geographic barriers to TD collaboration. With the growing interest and investment in cross-disciplinary TS, TD training models are likely to continue to evolve and expand in future years.

32.3.2.1 Challenges in TD training

There are several challenges inherent in developing and refining TD training models to respond to the rapidly changing landscape of TS. In addition to the need to overcome language and cultural barriers associated with exposure to multiple disciplines, first-generation TD trainees face many uncertainties in their career development owing to traditional academic reward systems that encourage first or sole authorships on scholarly publications, principal investigator status on grant-funded projects, and the publication of peer-reviewed articles in prestigious unidisciplinary journals (see Graybill and Shandas, chapter 28 this volume).

Moreover, prior TD training models have been dominated by programs designed for advanced graduate and postdoctoral training. A more comprehensive training model is needed for senior investigators who are charged with greater management responsibilities within large research initiatives. Broader models of TD training that encompass the needs of all stakeholders including senior investigators, junior investigators, postdoctoral scholars, graduate students, and research support staff, should be incorporated into the overall infrastructure of collaborative TS. Also, future TD training programs should offer innovative mentoring practices, and expose trainees to collaborative leadership styles and communication strategies, interpersonal and managerial skills, and technological expertise (Gray 2008).

32.3.2.2 Evaluation of TD training processes and outcomes

In earlier evaluations of TD training programs and outcomes, a variety of metrics have been used to assess the quality, novelty, and scope of disciplinary integration reflected in the work completed by trainees. Further refinement and validation of these metrics are sorely needed in the SOTS field. Quantitative and qualitative measures of trainees' career trajectories as they evolve within various TS initiatives can provide a deeper understanding of the near-term, mid-term, and long-term outcomes of these programs, and the ways in which TD trainees gain entry to various academic, government, and private sector jobs; as well as whether their collaborative (e.g. multi-mentor) training leads to sustained TD research efforts as they move forward in their careers. For example, the assessment of changes in trainees' research orientations over time may be used to model and subsequently predict the long-term career outcomes of these individuals. Systematically tracking the career development of TD trainees over time and examining the influence of collaborative training programs on their subsequent productivity will ultimately help to gauge the returns on TS investments at both individual and societal levels.

32.3.3 A typology of team science initiatives and funding models

A substantial increase in funding initiatives for ID and TD science and training has occurred in recent years. Critics of TS, in addition to being concerned about the volume of funds directed towards cross-disciplinary TS initiatives and away from unidisciplinary research, contend that once TD-specific funding is withdrawn from a research group, center, or institution, the collaborative efforts will cease (Weissmann 2005; Marks 2006). To date, this contention has not been tested directly by evaluating whether TD teams remain productive and cohesive once their original sources of funding are gone. These critiques of TS initiatives raise important concerns about the continuity of and strategies for funding collaborative research.

Currently, a variety of different funding model is used to support and sustain TD science and training initiatives. Funding for TD research varies along several dimensions that may affect the continuity of funding and the sustainability of TD science. For instance, an initiative may have several sources of funds, including private foundations and federal agencies as well as combinations thereof (e.g. an initiative funded by both a foundation and a federal agency). Funding mechanisms also vary with regard to the scope of the science addressed: medical research (broadly) versus tobacco use (specifically); the breadth of disciplines spanned (molecular to policy versus social science to policy); the amount of funding (e.g. thousands versus millions of dollars per project/center); and whether or not a strategic plan is developed at the outset to guide the research agenda over the course of the project.

Future evaluations of TS initiatives, therefore, should address the following kinds of questions. To what extent will the collaborative research supported by various funding models produce integrative conceptual models, methodological approaches, and empirical advances spanning multiple fields and extended periods? What happens when the funding for a TS initiative is withdrawn—will the TD science stagnate? Will the lack of long-term funding commitment lead researchers to revert to more traditional small, incremental scientific development processes? What situational factors facilitate the sustainability of cross-disciplinary inquiry communities? Can substantial gains in cross-disciplinary integration and translations to health practice be achieved through small-scale TD science teams? Is small-scale TD science more sustainable with respect to funding streams, or do we ultimately need large-scale TD science to create a critical mass of researchers and infrastructure for the sustainability of TD science? What are the necessary conditions to ensure the continuity of funding for TD science projects of different scopes and sizes? Are large initiative-based TD science centers (as compared with smaller-scale projects) required to foster sufficient levels of cross-disciplinary expertise in order to propel collaborations as well as theoretical and methodological advances in resolving the most urgent societal health problems?

32.3.4 Understanding multiple determinants of collaboration readiness

'Collaboration readiness' (CR) in cross-disciplinary TS can be conceptualized and measured in a variety of ways—for instance, in terms of individual and group research orientations; organizational and technological resources that enhance capacity for collaboration; and the scientific readiness of different fields for collaborative integration. Stokols, Misra *et al.* (2008) offered a social ecological framework for identifying multiple factors that enhance collaboration readiness, including the availability of specific communication tools and cyberinfrastructural resources, shifts in individuals' research orientations and their attitudes toward collaboration, and funding agencies' willingness to invest in center-based, multiple-PI (Principal Investigator) grants. A diagrammatic representation of the typology of contextual influences on the effectiveness of TD team science initiatives is shown in Fig. 32.5. Key categories of contextual influences on CR are organized according to intrapersonal, interpersonal, organizational, institutional, physical environmental, technological, and political and societal levels of analysis.

Future research in the SOTS field should explicitly consider multiple levels and dimensions of CR for TD team science and undertake in-depth case studies to identify which types of readiness factors (e.g. psychological, interpersonal, organizational, societal, technological, scientific) exert the greatest influence on the effectiveness of TS projects and initiatives. A readiness framework can help generate appropriate multilevel interventions to increase the success of TD team science. For instance, at the interpersonal level, understanding a team's readiness to engage in group processes to create common ground, common language, and shared goals can lead to the development of workshop modules to foster improved communications skills and team cohesiveness (Stokols *et al.* 2008b). To date, evaluations of TD initiatives have not examined the joint influence of these diverse readiness factors on the effectiveness of TS and training. This is a potentially fruitful direction for future research in the SOTS field.

Finally, the demands for cross-disciplinary and cross-national collaborations in health science, engineering, and technology will continue to grow in the coming decades. TD team science at a global scale requires an understanding of and sensitivity to cultural differences and their impact on teamwork to ensure success. Also, as funding streams ebb and flow, the need to coordinate and integrate health research efforts among academic institutions, government agencies, and private corporations and foundations will become increasingly important.

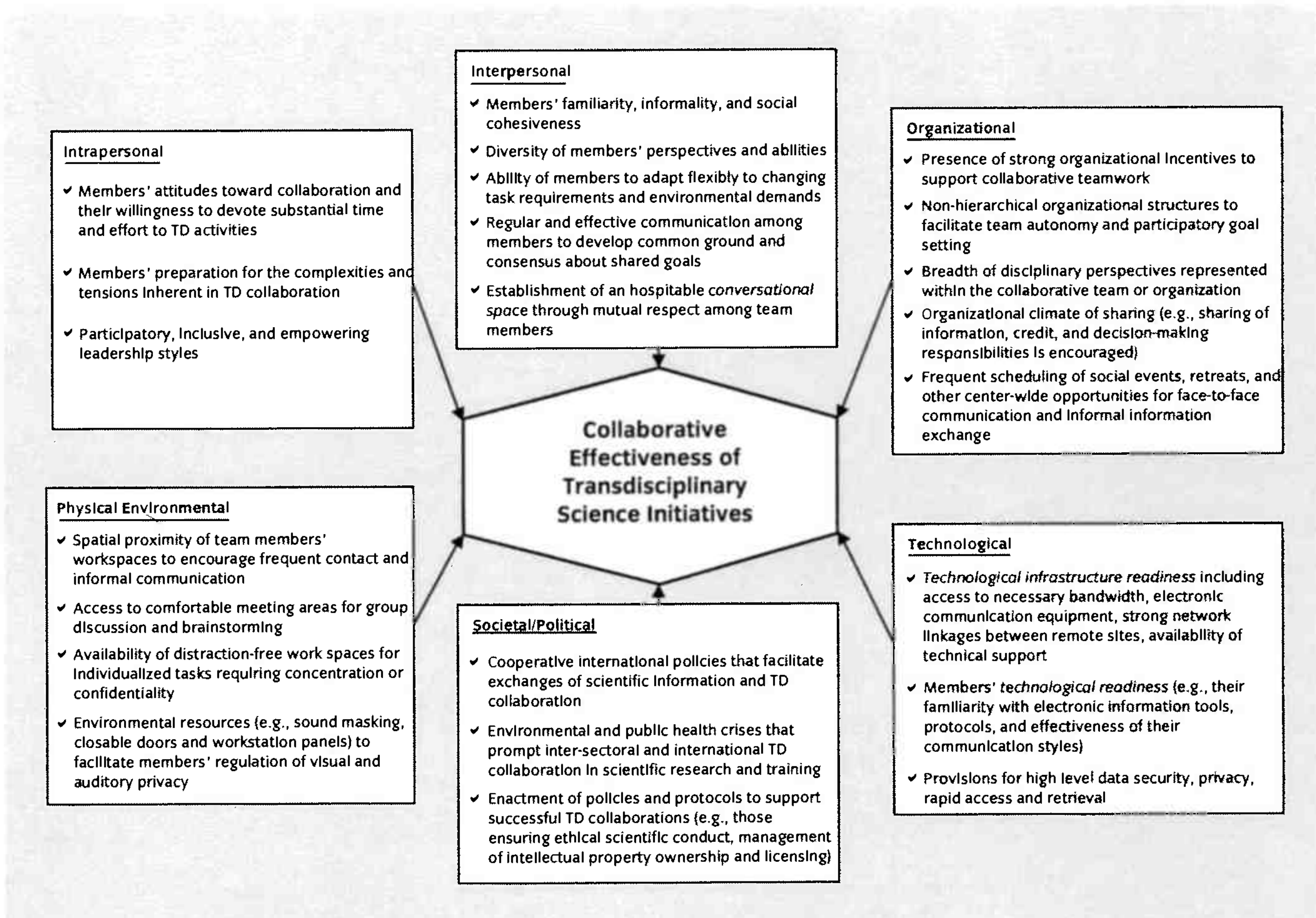

Figure 32.5 Typology of contextual factors that influence the effectiveness of TD scientific collaboration. Reprinted from Stokols et al. (2008b).

32.4 Epilogue

Whereas the SOTS field is at a relatively early stage in its development, it is likely to expand substantially in several new directions owing to the increasing investment in cross-disciplinary TS initiatives by both public and private funding organizations, and the corresponding need to evaluate the scientific, training, and societal outcomes of these programs. Several promising directions for future SOTS research were identified in earlier sections of the chapter, including: the development of more rigorous research designs for evaluating the outcomes of TS initiatives; new and innovative models for funding TS research and training programs as well as systematic evaluations of them; and a broader understanding of the multiple factors that influence the collaboration readiness and capacity of particular teams, institutions, and scientific fields.

In addition to the emerging concerns and research directions of the SOTS field identified above, several other topics are likely to arise as a focus for future evaluations of TS initiatives. Although not explicitly addressed in this chapter, the challenges of creating and sustaining new collaborative partnerships among government research agencies, non-government organizations, and private corporations and foundations for the purposes of promoting and supporting cross-disciplinary science and training programs is likely to become more salient in future SOTS research. How can the disparate and sometimes seemingly incommensurate goals of these diverse (e.g. for profit versus non-profit) entities be aligned in ways that encourage and sustain cross-disciplinary collaboration in science, training, and the translation of research knowledge into effective health promotion policies and interventions? What new theoretical frameworks, metrics, and research designs will be required to evaluate the success of these multi-sectoral partnerships?

Yet another promising direction for SOTS research that has received little attention to date is the set of challenges associated with managing information overload in TD team science initiatives. Whereas many contextual factors contribute to collaborative readiness, the capacity of a TD team to sustain effective collaboration over extended periods depends to a large extent on how well team members are able to manage the enormous amounts of new information they are exposed to as they work with colleagues trained in multiple fields, who are often dispersed across several geographic locations. Future studies on TD science, training, and research initiatives should investigate the impact of information overload on the processes and outcomes of TD work. Further, new organizational, infrastructural, and intra- and interpersonal models and strategies that can better help manage information overload need to be developed to enhance the effectiveness of TD collaboration. These are among the exciting and important questions that are likely to command the attention of participating scholars as SOTS field moves forward.

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