This chapter addresses the core question of this book: “What constitutes interdisciplinary communication in teams?” After situating the topic in current contexts and definitions, it investigates the inter-relationship of communication and collaboration (C²) within interdisciplinary research (IDR) from two sets of perspectives. The first set brings together insights from the specialties of philosophy, language studies, communication studies, and management. The second set situates those findings in the literature on interdisciplinarity through discourse analysis of the intersecting thematics of integration and learning. The underlying premise is that IDR is a form of boundary work that bridges cognitive and social dynamics of knowledge production in integrative research cultures. Expert praxis does not lie in generic formulas. It emerges from communicative actions in an iterative process that requires collaborative readiness, robust platforms, negotiation of differences, management of conflict, collective communication competence (CCC), mutual learning, interactions in trading zones of language communities, and construction of common ground. The chapter concludes with take-home lessons in the form of questions for teams to ask throughout the research process, encapsulating the wisdom of theory and practice for interdisciplinary C².
Introduction

The 2010 conference that gave rise to this book—Enhancing Communication in Cross-Disciplinary Research (ECCDR)—is one of many events that document growing interest in IDR. It is fitting that this conference emanated from a project funded by the U.S. National Science Foundation (NSF), since the earliest substantive literature on IDR emanated from conferences cosponsored by NSF in the late 1970s and 1980s (Klein, 1990a). In 2010, Lance Haworth of NSF’s Office of Integrative Activities framed the ECCDR meeting within the context of the agency’s new internal and disciplinary cross-cutting programs and activities. And, in late 2011, NSF’s Directorate for Social, Behavioral, and Economic Sciences took a step further in a new report on the future of research that places increased priority on interdisciplinary training, integration, and synthesis.

Other organizations have also heightened the profile of interdisciplinarity. At the National Institutes of Health (NIH), interest accelerated after the 2003 launch of a new Roadmap for Medical Research that included a targeted focus on “Research Teams of the Future.” Interest deepened with a multiyear initiative in transdisciplinary research (TDR) aimed at building new paradigms in health and wellness. By 2006, the NIH Tenure Review Committee had revised its internal criteria to include credit for team science. The Clinical and Translational Science Awards Consortium was also established to promote interdisciplinary collaboration, the NIH Guide for Intramural Research was revised to include a fuller description of teams, and the Science of Team Science network partnered with NIH in the study of collaborative research. Outside the United States, the European-based Network for Transdisciplinary Research, known as td-net, is a major forum for TDR, involving stakeholders in society in real-world problem solving (Bennett, Gadlin, & Levine-Finley, 2010, p. 2; http://www.scienceofteamscience.org/, http://www.transdisciplinarity.ch/d/index.php).

Not all forms of collaborative research are interdisciplinary, so preliminary definitions are in order. Interdisciplinary teams, Mitchell McCooe (1982) explains, operate in a more complex environment than do other teams. They are open, not closed, systems that have a heterogeneous though interconnected membership. In tackling the core question of this chapter—“What constitutes interdisciplinary communication in teams?”—Britt Holbrook (2012) cautions that the answer is not straightforward, because views of interdisciplinary communication have a normative relationship with views of interdisciplinarity. Nevertheless, a recognized baseline vocabulary provides a framework for thinking about $C^2$ in IDR and TDR (Klein, 2010b; Scholz, 2011, pp. 373–378).

Multidisciplinarity juxtaposes two or more disciplines or bodies of knowledge focused on a common problem, question, topic, or theme. From the standpoint of $C^2$, communication occurs typically at the level of coordinating information, not collaborating.
Interdisciplinarity integrates information, data, methods, tools, concepts, or theories from two or more disciplines or bodies of knowledge to address a complex question, problem, topic, or theme. Work may occur individually or in teams, though in the latter case, communication is essential to successful collaboration.

Transdisciplinarity transcends disciplinary worldviews through (1) more comprehensive frameworks and/or (2) problem-oriented research that crosses boundaries of academic disciplines and the public and private spheres. Major examples of the first connotation—new synthetic frameworks—include general systems theory, feminist theory, sustainability, new paradigms for health and wellness, and new principles of unity informed by the worldview of complexity in science. In the second connotation, mutual learning, joint work, and knowledge integration are key to solving “real-world” problems.

The first step in investigating the role of $C^2$ across types of cross-disciplinarity (i.e., multi-, inter-, and trans-) is to inform understanding with the baseline vocabulary of major forms and insights from the specialties of philosophy, language studies, communication studies, and management.

Philosophers would contend that their discipline is the logical starting point for this investigation. It is, after all, the oldest discipline and has long been concerned with communication. The subdiscipline of epistemology studies how we know what we know, and the subdiscipline of philosophy of language examines the nature, origins, and use of language. Philosophy is also an appropriate starting point because the NSF-funded Toolbox Project that gave rise to the ECCDR conference and this volume is a philosophically informed framework for understanding and improving cross-disciplinary communication (Chap. 11 this volume; see also http://www.cals.uidaho.edu/toolbox/). The project is based on the premise that differences in disciplinary worldviews must be identified and clarified to develop effective communication and minimize interference with collaboration.

In an in-depth exploration of the core question of what constitutes interdisciplinary communication, Holbrook argues that three alternative answers appear in philosophy of science and social/political philosophy. The answers are framed by Donald Davidson’s (1974) contention that different disciplines constitute different conceptual schemes and, hence, different ways of organizing or being tested by facts. Each discipline has its own language, but Davidson believed they ought to be translatable. It is useful to think of these three alternatives as differing views about the possibility and nature of translating between disciplinary languages. The three views correspond, very roughly, to the claims that (1) translation is possible (Habermas–Klein);
(2) translation is impossible—communication requires adopting the other’s language (Kuhn–MacIntyre); and (3) translation is impossible—communication requires creating a new language.

Dominant view of translatability: The Habermas–Klein thesis. The first thesis is prominent in the work of philosopher and critical theorist Jürgen Habermas (1976/1998) and interdisciplinary scholar Julie Thompson Klein (1990b, 1996, 2005, 2010b, 2012). The dominant view in the literature, this thesis asserts that integrating two or more disciplinary languages can generate a new common understanding through reciprocal comprehension and consensus. From the standpoint of C², consensus is a social–psychological construct requiring individual commitments to bring about intersubjective mutuality. The keys are common vocabulary, shared knowledge, reciprocal comprehension, mutual trust, and social accord.

Rival view: The Kuhn–MacIntyre thesis. Based on philosopher Thomas Kuhn’s ideas about knowledge paradigms and philosopher Alasdair MacIntyre’s (1988, 1990) ideas about traditions of moral enquiry, the second thesis holds that disciplinary languages are in principle and often in fact incommensurable. Communication can occur only by learning the language of another discipline. Although Davidson treated this act as one of translation, Kuhn (2000) preferred to use the notion of interpretation. According to MacIntyre, two notions are relevant: a weak notion of translatability and a strong notion of linguistic competence that comes from a process akin to learning a second first language, a form of linguistic competence that entails the capacity to improvise and innovate. For MacIntyre, it is the second of these processes that is central to interdisciplinary communication. By highlighting incommensurability, the Kuhn–MacIntyre thesis opposes the idea of interdisciplinarity as integration and consensus between disciplines. It does, though, focus on their interactions.

Rival view: The Bataille–Lyotard thesis. Based on the work of French writer Georges Bataille (1988, 1992, 1993) and philosopher Jean-François Lyotard (1988), the third thesis holds that incommensurability reveals itself when attempts at communication fail. At that point, further communication is possible only by inventing a new language. Bataille opposed the notion of a strong and powerful sense of communication to a weak or feeble sense. Communication within particular disciplines is usually of the weak variety, with disputes settled under the banner of litigation more than under Lyotard’s concept of differend. By litigation, Lyotard means the kind of disagreement that can be resolved by appeal to rules acceptable to all parties in the disagreement. In contrast, the concept of differend highlights a type of communication breakdown, signaled by a feeling of not being able to find words, that occurs within disciplines but, Holbrook emphasizes, is more likely to occur between disciplines, propelling a “first moment of strong interdisciplinary
communication.” The second moment emerges from invention of a new genre of discourse. More than a simple integration of previously existing genres, it is a novel cocreation that entails risk and relinquishing disciplinary identities. The important question, Holbrook adds, is not whether different disciplines are integrated but whether participants can move forward as though they understand each other (Bataille’s notion of weak communication) or not (Lyotard’s notion of differend).

Taken as a composite framework on the core question (What constitutes interdisciplinary communication?), the three theses raise related questions that now need to be considered through the comparative lenses of other specialties. What role does language play in interdisciplinary communication? And how can differences in worldviews be overcome? Language studies are central to answering both questions.

Language Studies

The study of language is not confined to one specialty. It lies at the heart of the ancient discipline of rhetoric, vested in the arts of persuasion, and it is central to the modern discipline of linguistics, which explores the structure, meaning, and contexts of language in subspecialties such as psycholinguistics, sociolinguistics, and discourse analysis. The concept of linguistic relativity is central to understanding interdisciplinary communication. (For a fuller definition, see the work of Benjamin Whorf in Carroll, 1956.) The core premise is that language shapes the ways speakers conceptualize their worldviews, including the ways they think (cognition) and act (behavior). One of the most prominent related topics in studies of collaborative IDR is the meaning of words. In a case study of an urban development project in the Swiss Lowlands, Baccini and Oswald (2008) identified two crucial communication tasks: learning each other’s specialized language and understanding perceptions hidden in words. The project began in 1993 when Baccini and Oswald, a scientist and an architect, realized they had a common interest in sustainable urban development. It expanded when other collaborators joined them. One group (morphologists) was rooted in the academic culture of architecture and urban planning, while the other group (physiologists) was composed of natural scientists, engineers, and an economist. Participants found that even such basic words as landscape, urban, project, and process were understood differently.

In an early study of interdisciplinary communication, Gerhard Frey (1973) reported that interdisciplinary discussions normally take place on a level similar to a “popular scientific presentation.” Discussions become more precise as individuals combine everyday and specialist languages. When another major initiative, the Austrian Landscape Research program, engaged
stakeholders in society in the research process, organizers expected participants to use everyday language. However, everyday language is ambiguous. Teams might adopt formal languages, such as metamathematics or general systems theory, for greater precision. Yet Bergmann and colleagues (2010) advise, formal languages must be adapted to the “concrete occasions” and “constellations of disciplines and stakeholder views” within particular projects. Successful collaboration, they add, requires getting past nonspecialist understandings of common colloquialisms and trying out terms that foster “interdisciplinary connectivity” through bridge words. Recalling the Swiss project, above, 2 years of mutual learning resulted in a shared definition of the underlying concept of “urbanity” and the bridge concept of “net city” (Netzstadt) as an agglomeration of lowlands with connected knots or nodes, rather than a fixed center. In another sustainability project, the bridge word mobility functioned as a boundary object, a focal point enabling individuals to work together on a common interest while retaining separate identities and interpretations. It fostered cooperation and coordination around the common objective of “sustainable renovation” of housing units (Bergmann & Jahn, 2008).

In the second philosophical thesis Holbrook identified, MacIntyre likened interdisciplinary communication to learning a second language. Bilingualism is a popular metaphor of interdisciplinary work. However, mastery of two disciplinary languages rarely occurs. Holbrook likens the invention of a new language described in the third philosophical thesis to two concepts in science studies: pidgin and creole. A pidgin is an interim tongue, providing a trade language between groups with different primary languages. A creole is a first language among members of a new social and cognitive community. These concepts are also familiar to linguists, though in science studies they are associated with anthropology because Peter Galison (1997), who introduced the terms to science studies, borrowed them from anthropology to explain interactions in physics as part of the concept of “trading zones.” The core idea is that dissimilar subcultures can find common ground through exchanges, such as bartering fish for baskets. In physics, exchanges occurred between scientific subcultures of theory and experiment, and across different traditions of making instruments and subcultures of theorizing.

Ultimately, Wilhelm Vosskamp (1994) suggests, the quality of collaborative outcomes cannot be separated from the development and richness of a shared language culture, whether the trading zones are small teams or large-scale programs. Achieving that goal, Myra Strober (2011) advises, requires understanding that styles of communication derive from disciplinary cultures and the habits of mind they instill. Individuals need to become “ethnographers” of their own disciplines (Strober, 2011, pp. 57, 161–162). They also need some understanding of insights developed in the field of communication studies. In a guide to conducting IDR, Catherine Lyall, Ann Bruce, Joyce Tait, and Laura Meagher (2011, p. 59) identify difficulty of communication
as one of the key challenges. The underlying notion of “communication,” though, is ambiguous because the term is used widely across popular, academic, and professional contexts.

**Communication Studies**

Academic studies of communication range across a wide variety of interests, from conversation analysis and the dynamics of small-group communication to social networks, computer-mediated communication, and training for the communication industries. Specialties and schools of thought, Robert Craig (1999) also reports, operate separately in rhetorical, semiotic, phenomenological, cybernetic, sociopsychological, sociocultural, and critical traditions. Few of these studies have focused directly on IDR, although the closest links have been drawn in studies of group communication.

In defining the underlying concept of “communication,” Burtis and Turman (2006) highlight two processes: “transfer of information from one source to another” and “making and sharing meaning” (pp. 10, 53–54). All group communication, they add, engages in “boundary spanning,” necessitating “boundary negotiations” in both internal and external communication. Transferring information, sharing meaning, boundary spanning, and boundary negotiation take on greater importance in collaborative IDR. It is a joint effort, Defila, Di Giulio, and Scheuermann (2006) emphasize. Awareness of the diversity of disciplinary languages is prerequisite to achieving a common language and theoretical basis for research (Defila et al., 2006, pp. 128, 131, 133). Communication studies scholar Jessica Leigh Thompson (2009) takes a further step in placing the concept of CCC at the heart of IDR collaboration. CCC is based on the premise that there are interrelationships among communicators, goals, participants’ abilities to integrate knowledge and expertise from different sources, and a range of interpersonal, relational, organizational, and pedagogical contexts. Many communication scholars, Thompson adds, use systems theory to explain the complexity of small-group interactions in dynamically changing environments.

Thompson’s ethnographic study of an academic team as a participant-observer looked closely at processes that facilitated and hindered communication. The team was focused on human behaviors related to the production of greenhouse gas emissions in urban areas. Her findings led Thompson to make four suggestions for team members and managers: (1) build in trust-building time, (2) host explicit discussions about language differences, (3) schedule social time, and (4) confront communication challenges early. She also recommends using a facilitator to reflect on and navigate challenges that require team members to continually negotiate their standards for CCC. The key points of connection between the literature on IDR collaboration and Thompson’s synthesis of communication studies include openness, willingness to learn from each other, and early negotiation of language differences.
Her concepts of “presence” in the form of engagement and “deep listening” are also crucial, requiring self-consciousness and awareness of the impact of individual behavior and assertions of personal status on group dynamics. Reflexive communication, Thompson adds, helps members reinforce mutual trust and gain confidence about sharing individual perspectives and insights.

Combined insights from philosophy, language studies, and communication studies indicate that collaborative IDR is a form of boundary work that bridges cognitive and social dynamics of knowledge production in integrative research cultures. Expert praxis in the form of authoritative knowledge and actions does not lie in generic formulas. It emerges from actions that also require management, the fourth source of pertinent insights into interdisciplinary C².

Management

Studies of IDR in the management literature tend to focus on organizing teams and facilitating interactions. The formal study of teams, James Davis (1995) recalled in his book on interdisciplinary team teaching, started in employment settings. Early studies of group behavior, Davis added, evolved into more specialized studies of human communication and the social psychology of groups. Interdisciplinary task force management has also been a feature of military operations, civilian affairs, engineering projects, feasibility studies, and industrial research and development. World War II was a watershed in collaborative IDR, highlighted by major interdisciplinary initiatives, including the Manhattan Project, and problem-focused operations research. Communication researchers also cite the World War II era as a heyday for small group communications, preceded by studies in the 1920s that adapted John Dewey’s work on democratic group decision making. By the 1970s and 1980s, international competition in science-based industries heightened the demand for collaborative IDR, especially in manufacturing, computer sciences, biomedicine and pharmaceuticals, and high technology. This development, in turn, prompted new studies of large-scale complex projects, including the Human Genome Initiative (Klein, 1996, pp. 173–208; 2010a, pp. 16–21).

The early literature tended to apply management and organizational theories of the day to studies of IDR collaboration, with emphasis on organizational structures, leadership strategies, and types of teams. Over time, the focus expanded from managing teams and organizational units to creating institutional research cultures and the behavioral dynamics of collaboration. In a study of leadership in TDR, Barbara Gray (2008) identified three general categories of tasks for enhancing collaboration: cognitive, structural, and processual. The success of C² depends in no small part on management of structural components that require coordinating tasks, internal linkages, and information flows. The organizational chart and task distribution must
allow time for interaction, joint activities, coordinated use of common research facilities and instruments, consensus building, shared decision making, and networking across subprojects. Thompson (2009) came to a similar conclusion in urging regular attention to CCC, and Hindenlang, Heeb, and Roux (2008) highlight the role of platforms for handling structural tasks. Operating as loosely structured social networks, platforms create a space for communication, fostering mutual understanding, shared goals, concrete ideas and measures, and common assessment.

Even with strong platforms in place, conflicts arise. Status conflicts are especially tenacious. They arise for many reasons, including disciplinary and professional pecking orders as well as differences between quantitative versus qualitative approaches, academic rank, and gender, race, and cultural background. The theory of “status concordance” holds that success is linked to matched and equal factors. Rarely, though, do perfect matches occur (Klein, 1990b, pp. 127–128). Members of IDR teams also exhibit many of the same fighting and thwarting behaviors as other groups, echoing Bruce Tuckman’s (1965) model of group development in stages of forming, storming, norming, performing, and (a fifth stage added later) advocating or transforming (see also Tuckman & Jensen, 1977). Conflict is associated with both technical issues (definition of a problem, methodologies, and scheduling) and interpersonal issues (leadership style and disciplinary ethnocentrism). Interdisciplinary teams must also overcome “boundaries of reticence” that disciplinary socialization creates, to avoid defaulting to disciplinary worldviews. Individuals must also grant power to others and surrender some degree of control (Caudill & Roberts, 1951; Stone, 1969).

Difference, though, can be an asset. The consent/dissent (.Alteritaet) structure necessary for all communication, Vosskamp (1994) advises, shapes the possibility of interdisciplinary dialogue. Misunderstandings, animosities, and competitions must be taken seriously, not mitigated or glossed over. Moreover, even if differences are negotiated and mediated, they do not go away. They recur as participants work through their differences and attempt to resolve them in the interest of a common goal. In her pioneering study of working relationships among specialists in mental-health projects, Margaret Barron Luszki (1958) reported that members of interdisciplinary teams paid a price for congeniality in the short run. By not dealing with conflicts in definitions of core terms, such as aggression, they reduced the number of creative problem-solving conflicts that would have promoted high-level shared concepts in the long run. Certain ideal characteristics of interdisciplinary individuals have been identified, including flexibility, patience, willingness to learn, sensitivity toward and tolerance of others, reliability, and openness to diversity, new roles, and risk. These are ideals, however (Klein, 1990b, p. 183; Strober, 2011, p. 121). Participants are usually unwilling to abstain from approaching a topic from their own worldviews. Yet, Bruce Thiessen (1998, pp. 49–50) admonishes, adaptive behavior is required to achieve common ground in both language and goal directedness.
The Collaboration and Team Science field guide from the Office of the Ombudsman at NIH (Bennett & Gadlin, Chap. 17 this volume) emphasizes the importance of managing tensions. One of the recommendations for communicating about science is to establish ground rules for how participants will be expected to communicate in meetings. The distinction between dialogue and debate lies at the heart of the ground rules. Dialogue is a collaborative act of working together toward common understanding, rather than being oppositional. Common ground is the goal, not being close-minded, winning individual points, or defending one’s position as the “best.” An open-minded attitude and openness to being wrong and to change are needed. Listening to others provides a basis for agreement or consensus, along with seeing strengths in others’ positions rather than flaws and weaknesses (Bennett et al., 2010, pp. 29–30).

The insights gained from findings in pertinent literatures come together in the overriding thematics of integration and learning in interdisciplinary C².

### Integration

Integration is often regarded as the leading candidate for a distinguishing characteristic of collaborative IDR and its baseline vocabulary (see Holbrook, 2012; Repko, 2010). However, there is no universal theory or model of integration because the scope, degree of coordination of perspectives, nature of interactions, and goals of projects and programs vary too widely to allow a single coherent theoretical perspective. For example, teams operate in many institutional contexts: academic, industrial, governmental, and community organizations and nongovernmental organizations. Yet Pohl, van Kerkhoff, Hirsch, and Bammer (2008) identified four primary classes of “tools” for integration: (1) mutual understanding through communication, (2) theoretical concepts, (3) models, and (4) methods. This last category includes some well-known methods that have been widely applied, including systems theory and modeling, Delphi and scenario building, simulation, concept mapping, computer synthesis of data and information flow, and integrated environmental assessment and risk management. Other methods target communication processes, including facilitating common understanding, mental mapping of stakeholder views, consensus conferences, and collaborative learning.

Yet, integration in collaborative IDR is a social process that requires coconstruction of common ground, even when using well-known approaches. Optimal integration, Davis (1995) exhorts, requires high levels of collaboration: “The greater the level of integration desired, the higher the level of collaboration required” (p. 20). Joint definition of a project is required, along with the core research problem, questions, and goals. Role clarification and negotiation help members assess what they need and expect from each other while clarifying differences in disciplinary language and approaches. And ongoing communication and interaction foster mutual
learning and interdependence, expanding individual identities into group identity. Young teams, Stone (1969) found, exhibit secondary-group relations. Members are self-protective, thinking in terms of “I.” Primary-group relations are characterized by dedication to a common task, thinking in terms of “we.” When the singularity of individual disciplinary identity is called into question, Holbrook suggests, Bataille’s notion of strong interdisciplinary communication is operative.

In an analogy that will ring true for veterans of collaborative research, Koepp-Baker (1979) likens an interdisciplinary health care team to a polygamous marriage. The team is launched by announcement of intentions, engagement, publicity, a honeymoon, and finally the long haul (Koepp-Baker, 1979, p. 54). The Collaborators Pre-Nup, adapted from NIH, highlights the importance of early discussion of goals, roles, coauthorship, ownership of intellectual property, and obligations of teamwork (Ledford, 2008). From the outset, contextual factors also influence “collaborative readiness.” In their studies of TDR centers, Stokols et al. (2010; Stokols, Misra, Moser, Hall, & Taylor, 2008) concluded, the more contextual factors in place at the outset, the greater the chances of success. Antecedents span interpersonal, environmental, and organizational parameters of research:

- Institutional supports for collaboration
- Breadth of disciplines, departments, and institutions at a center
- Prior experience working as team members on projects
- Spatial proximity or distance of offices and laboratories
- Electronic linkages (Stokols et al., 2008, 2010)

Making it through the “long haul” requires ongoing management of integrative process. Processual tasks, Gray (2008) stipulates, ensure constructive and productive interactions, with subtasks devoted to designing meetings, determining ground rules, identifying tasks that move partners toward common objectives, building trust, and ensuring effective communication. Defila et al.’s (2006) literature review of case studies identified more than 500 tips. McDonald, Bammer, and Deane’s (2009) repertoire of dialogue methods includes hypothesis and model building, integrative assessment procedures, boundary objects and concepts, heuristics, research questions, artifacts and products, mutual learning, and stakeholder participation. Defila et al. (2006) also consider recursive procedure to be a general design principle of TDR. Iterative peer editing is one of the most common methods, fostering coassessment of individual contributions, collective reconciliation of differences, and greater likelihood of moving beyond multidisciplinary juxtaposition to interdisciplinary integration. Ideal models, Maurice DeWachter (1982) counsels, start with the assumption that individuals will suspend their disciplinary/professional worldviews. Yet his experience in bioethical decision making indicates the best chance of success lies in starting by translating a global question into the specific language of each discipline then working back and forth in iterative fashion. By constantly checking the
Learning

Even with the current heightened profile of IDR, educational needs are underserved. The top recommendations for students in the National Academy of Sciences report on *Facilitating Interdisciplinarity Research* include taking a broad range of courses while developing a solid background in one discipline (Committee on Facilitating Interdisciplinary Research, 2004). Undergraduates in particular are urged to seek courses at the interfaces of traditional disciplines that address basic research problems, courses studying social problems, research experiences spanning more than one discipline, and opportunities to work with faculty with expertise in both their disciplines and interdisciplinary process. Graduate students are encouraged to gain knowledge and skills in one or more fields beyond their primary area: by doing theses or dissertations with advisers from different disciplines, participating in conferences outside their primary fields, and, for all students, working with mentors from more than one discipline. The top recommendations for educators are to develop curricula incorporating interdisciplinary concepts, offer more interdisciplinary studies courses, take teacher-development courses on interdisciplinary topics and methods of teaching nonmajors, and provide opportunities that relate foundation courses, data gathering and analysis, and research activities to other fields of study and to society at large. The report also urged more training across the board in interdisciplinary research techniques, team management skills, and summer immersion experiences for learning new disciplinary languages and cultures (Committee on Facilitating Interdisciplinary Research, 2004).

Professional organizations have also called for greater attention to the need for interdisciplinary education. Pellmar and Eisenberg’s (2000) *Bridging Disciplines in the Brain, Behavioral, and Clinical Sciences* presents models for training at all levels, from undergraduate curricula through postdoctoral fellowships, predoctoral and postdoctoral training programs, and career-long opportunities. The targeted areas for improving communication in particular are jargon, intellectual turf, team building, leadership, and interactions within physical spaces. *BIO 2010* (National Research Council, 2003) presents a blueprint for aligning undergraduate education in biology with contemporary research in a curriculum that integrates physical sciences with information technology and mathematics with life sciences. Both reports also expand the locus of learning from traditional academic curricula to open spaces of faculty development programs and training modules *in situ*. Training for IDR and TDR shares many features with traditional programs, but its distinct emphasis, Justin Nash (2008) emphasizes, is developing researchers who can synthesize theoretical and methodological approaches from multiple disciplines. The most common form of training is a multimentor apprenticeship model, with relevance of each answer to a core question, no single answer is privileged. This process clearly entails the second overriding theme—learning.
mentors in separate disciplines in addition to multiple faculty advisors and

The principle of mutual learning also repeats across levels, from the prag-
matics of daily work to theory and epistemology. “Mutual learning” requires
knowing how to recognize ignorance of a particular area, then soliciting and
gathering new information and knowledge. In defining transdisciplinarity in
domains of environmental literacy, Roland Scholz (2011) stresses processes
of capacity/competence building, consensus building, analytic mediation,
and legitimation of public policy. Generating “socially robust knowledge”
when working with stakeholders in public and private sectors goes beyond
listening to their inputs to actually engaging them in the research process in
a manner that provides feedback to the generation of scientific knowledge
and theory building (Scholz, 2011, pp. 373–374). Knowledge is not simply
exchanged. It is constructed as individuals with differing views and stakes
work together.

In defining the three major forms of collaboration in TDR—common
group learning, deliberation among experts, and integration by a subgroup
or individual—Pohl et al. (2008) capture the principle of mutual learning at
the heart of the first form. “Common group learning,” they admonish,
“means that integration takes place as a learning process of the whole
group” (p. 415). Management is still crucial, however. Leaders need to coach
the process by promoting joint learning activities. Adopting a conscious,
targeted approach to communication, Schmithals and Berhenhage also urge,
is crucial for integrating knowledge and methods when working across cog-
nitive cultures (cited in Bergmann et al., 2010). A project-specific “coopera-
tion and communication culture” must be established, with attention paid to
interfaces: to points where the work of one participant is necessary for the
work of another and to points where participants must coordinate effec-
tively (Schmithals & Berhenhage, cited in Bergmann et al., 2010). For lead-
ers, creating a common culture also entails the third of Gray’s (2008) general
categories of tasks for enhancing collaboration—cognition. The cognitive
task entails managing sense making by creating a mental model, map, or
mind-set of goals and ways of achieving them through visioning and framing

In a case study of an interdisciplinary team focused on STEM education
(science, technology, engineering, and mathematics), DuRussel and Derry
(2011) integrate conceptual understandings of mental models with the con-
cept of situation awareness in organizational literature. Social and cognitive
integration, DuRussel and Derry affirm, are tightly interwoven in situation
awareness. An individual’s prior knowledge helps shape his or her mental
model (i.e., cognitive representation) of a particular situation. Yet models are
dynamic and changing. As situational learning occurs, new models influence
and change the content and structure of permanent schemas. The key insight
is alignment of mental models. Common features correlate positively with
productivity, but, akin to the Toolbox Project, models must be made explicit
if common understanding is to be achieved. Contexts range from goals and
objectives of projects to the variety of tools that mediate between individual work and team objectives. They also include norms and rules that influence communication patterns, as well as distribution of tasks and patterns of interactions, including regular participation in meetings and common criteria of evaluation. Visioning and (re)framing models stimulate ideas about how disciplines might overlap in constructive ways that generate new understandings and encourage collaborative work modes.

In a project that brings together learning theory, epistemology, and sociology of knowledge, Boix Mansilla, Lamont, and Sato (forthcoming-a, forthcoming-b) posit an emerging model of sociocognitive platforms for interdisciplinary collaboration. The team studied experts working in nine established research programs and networks. Their case studies yield an empirically based picture of the social-interactive ways participants construct group membership and collective norms, and the ways norms contribute to or hinder creation of common platforms. They also considered the cognitive-epistemic ways experts define their enterprise and platforms for integration. Preliminary data from five networks affirm the need for early investments of time and effort to define a problem space and approach. The group climate of networks differs, though, influencing problem definition, intellectual agendas, degrees of exchange and integration, and patterns of dominance in particular disciplinary mixes. One network, for instance, had a just-in-time approach. Its “agile” and “opportunistic” work style contrasted with the prescriptive style of another group. Contrasts in emotional intensity also appeared, and products that function as boundary objects varied. Products provide “concrete space” for interaction, coproduction, and disciplinary translation in the form, for example, of graphics, concept maps, and constructs. Platforms also change over time. Gains in communicative and collaborative capacity in particular include greater clarity about disciplinary languages, increased comfort with unknown terrains, and recalibrated beliefs about another discipline. Microsocial networks realign, too, with growing “deliberative competency” at the group level and individual-level sociocognitive gains, such as the ability to provide “honest and constructive feedback” (Boix Mansilla et al., forthcoming-a, forthcoming-b).

Conclusion

A final example bridges the two core concepts engaged in this investigation—communication and collaboration. Vosskamp (1994) and Klein (1996) treat interdisciplinarity as communicative action, and in a major study of an urban planning project, Després and colleagues (2008) extended this idea. Scientific and academic knowledge alone, they argue, cannot deal adequately with the complexity of subjects and problem domains such as revitalization of neighborhoods, including their case study of retrofitting older residential
neighborhoods on the outskirts of Quebec City. Following Habermas’s (1987) *Theory of Communicative Action*, instrumental, ethical, and aesthetic forms of knowledge are all needed. Moreover, rational knowledge comes out of not only “what we know” but “how we communicate” it, generating a form of “communicative rationality.” Stakeholders entering into negotiation confront the four kinds of knowledge in a series of encounters that allow representatives of each type to express their views and proposals. In the process, a fifth type of knowledge progressively emerges. It is a hybrid product, the result of “making sense together.” Fostering “intersubjectivity,” the fifth type of knowledge requires ongoing effort to achieve mutual understanding, aided in this case by a mediator who helped extract individual interests or views. As progressively shared meanings, diagnoses, and objectives emerge, individual interests and views are seen in different perspectives.

The underlying premises of this case study—communicative action, communicative rationality, negotiation, intersubjectivity, and mutual understanding—bring us full circle back to philosophy. Anne Balsamo (2011, p. 163; see also Balsamo & Mitcham, 2010, p. 270) frames that return in ethical principles of collaboration. The first two principles accentuate requirements for individuals:

*Intellectual confidence:* The understanding that one has something important to contribute to the collaborative process. This is the commitment that makes one accountable for the quality of an individual’s contribution to the collaboration. Everyone’s contribution to the collaboration must be reliable. It must be thorough and full of integrity; it must refuse shortcuts and guard against intellectual laziness.

*Intellectual humility:* The understanding that one’s knowledge is always partial and incomplete and can always be extended and revised by insights from others. This is the quality that allows people to admit they don’t know something without suffering loss of confidence or a blow to their self-esteem.

The second two principles move from individuality to group responsibility:

*Intellectual generosity:* The sincere acknowledgment of the work of others. This acknowledgment must be explicitly expressed to collaborators as well as through citation practices. Showing appreciation for other ideas in face-to-face dialogue and throughout the process of collaborative process sows the seeds for intellectual risk taking and courageous acts of creativity.

*Intellectual flexibility:* The ability to change one’s perspective based on new insights that come from other people. This is the capacity both for play and reimagining the rules of reality: to suspend judgment and to imagine other ways of being in the world, and other worlds to be within.
An overriding principle of integrity emerges from the move to group responsibility:

*Intellectual integrity*: The habit of responsible participation that serves as a basis for the development of trust among collaborators. This is a quality that compels colleagues to bring their best work and contribute their best thinking to collaborative efforts.

Skills of research integration, McDonald et al. (2009) assert, have become as essential today as disciplinary skills. These skills are all the more important when disciplines are undergoing changes characterized by greater boundary crossing, openness to interdisciplinary developments, prioritizing of real-world problems, and grappling with the complexities of contingency, contextualization, and diversity. However, much of the wisdom of practice is not captured for future use. Handbooks and networks are vital forums for disseminating wisdom of practice, highlighted recently by a new online suite of team science learning modules on the Team Science website (http://teamsce.net/) and the NIH Team Science Toolkit (http://www.teamscetoolkit.cancer.gov/public/Home.aspx). However, “expert praxis” does not lie simply in formulas, well-honed guidelines, or tested models. It is emergent from communicative actions among the participants. O’Donnell and Derry (2005) liken the challenge that interdisciplinary teams face to Krauss and Fussell’s (1990) concept of the “‘mutual knowledge’ problem.” Experts within a discipline typically share a “common referential base,” aiding communication. Participants in collaborative IDR must develop “a shared knowledge base” that constitutes “group intelligence” (O’Donnell & Derry, 2005, pp. 73, 76–77).

**Take-Home Messages**

A number of lessons emerge from comparative exploration of interdisciplinary C². They can be thought of as aims for teams to be striving toward throughout the research process. Only by keeping these aims steadily in view will the prospect of success increase:

- C² should be understood as an interdisciplinary construct, not viewed through the lens of a single disciplinary framework.
- Explicit moments and actions for reflection on integration and collaboration should be built into the research process, starting with assessment of collaborative readiness.
- CCC should be achieved through mutual learning and the social process of establishing trust, common vocabulary, and shared knowledge.
- Differences should be negotiated through management of conflict.
- Explicit attention should be paid to the boundary work of connectivity and integration while drawing on the accumulated wisdom of practice and theory in pertinent literatures.
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References


