National Science Foundation Workshop Report: Interdisciplinary Collaboration in Innovative Science and Engineering Fields

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Introduction: Goals of the Workshop

Innovation is vital to a healthy national economy. Cross-functional and multidisciplinary teams help create some of our most popular products, from the iPod (software, hardware, user-researchers) to new medical devices. In addition, innovation across multiple disciplines is essential for solving some of the country's most pressing problems, from fixing a ruptured oil well on the ocean floor to providing clean energy sources. Science and engineering teams are, as a result, increasingly multi- and/or interdisciplinary. Funding agencies have recognized that solving complex problems often requires teams from multiple disciplines, and universities are continuing to develop cross-disciplinary programs (Derry & Schunn, 2005). Interdisciplinarity is more apparent in research that is problem-based or translational (Jacobs & Frickel 2009). For cognitive, interpersonal, team, cultural, and institutional reasons (and interactions between all these), multidisciplinarity is extremely difficult to arrange in a way that consistently results in innovative solutions. Furthermore, the study of inter- and multidisciplinarity itself has been conducted in a rather balkanized fashion, ironically, within disciplinary domains. When so many studies are conducted in idiosyncratic, discipline-focused styles, they may be valuable taken alone but are hard to compare. Even more importantly, it may be difficult to integrate the literature on this topic into a coherent, practical (useful) whole.

The main goals of this workshop were to: (1) share constructs across the different fields that study multidisciplinary collaboration and related issues, (2) elaborate on specific similarities and differences in theory, data, and methods, (3) classify gaps and important future directions in the state of the art of the study of multidisciplinary collaboration, and (4) identify specific infrastructure changes and needs that would enable both the study and practice of multi- and interdisciplinary collaboration (e.g., data sharing, shared public database).

Overview

The workshop took place November 4 through 5th, 2010, at Boston University. The format included many brief (10-15 minute) presentations by the participants, three plenary presentations by interdisciplinary science practitioners (20-45 minutes long), five small group roundtable discussion sessions, and four main full group discussion sessions (see Appendix A, Agenda).

Participants. Including the two organizers, two NSF representatives, and four graduate student scribes, there were 37 individuals at the workshop. The attendees came from a broad range of disciplines: economics, cognitive and social psychology, learning sciences, sociology, micro and macro organizational behavior, political science and public policy, anthropology,

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history, philosophy, gender studies, other sciences (biology, physics), and science and technology studies (see Appendix B, Participants). The participants shared expertise and interest in interdisciplinarity in science and engineering. Although a majority of the attendees were full professors from academic institutions across the United States, assistant professors and researchers at institutes were also in attendance. Overall, the workshop participants represented a diverse group of scholars in their training, career age, gender, and racial and national background.

Presentations. The plenary speaker Robert Hull presented a personal story about interdisciplinary experiences and lessons learned for supporting and improving multidisciplinary research in material science, such as postdoctoral fellowships in different fields, large, interdisciplinary facilities, and capitalizing on discovery. Stephanie Pfirman, an arctic studies professor, presented research on gender, disciplinary training, and other characteristics of interdisciplinary scholars at the second plenary. Her presentation included suggestions for how to collaborate strategically and properly cite interdisciplinary work, as well as institutional changes that could support interdisciplinary research at universities. The last plenary speaker, Sara Kiesler, added to her initial talk on interdisciplinary and interinstitutional research collaborations a discussion of the problems involved in submitting interdisciplinary work to conferences and journals.

Twenty-one participants gave 10-12 minute presentations based on their research. These presentations highlighted the variety of social science perspectives on innovation in inter- and multi-disciplinary teams of scientists and/or engineers (see Appendix A for a list of the titles of these talks). The presentation of data spanned a variety of levels of analysis, including individual characteristics, small group dynamics, laboratory teams, departments, organizations, and entire fields. Topics ranged widely, including methods of measuring innovation success in interdisciplinary groups (e.g., going beyond citations); social networks and innovation; gender in both collaboration and interdisciplinary science; small group dynamics, cognition, and creativity in diverse teams; and career trajectories of those who wish to be interdisciplinary in science. In addition, the question was raised in more than one talk as to whether interdisciplinary teams really do generate more innovation, particularly given the substantial logistic, psychological, and organizational obstacles to conducting such work. These presentations served to inform the participants of each others' work and perspectives. These introductions had both long- and short-term purposes: both to spread knowledge across some of the more eminent scholars in the different disciplines, sharing constructs across different fields (as noted in goal #1 above), and to support cross-disciplinary discussions during the workshop.

Roundtable and Full Group Discussion Themes

The other three goals of the workshop (to identify connections, gaps and ways to facilitate research) were addressed via roundtable (small group) and full group discussions (see Appendix C for roundtable questions and Appendix D for roundtable summaries). The intent of raising these questions for discussion was to build knowledge on increasing innovation and success in interdisciplinary collaborations in science and engineering, and increasing success in interdisciplinary collaborations in the study *of* interdisciplinary collaboration.

Current state-of-the-art: Infrastructure, concepts, and data. If research centers and associations represent key types of academic infrastructure, only a few centers and associations

currently exist that have cross-disciplinary collaboration as their main research focus: AIS (Association for Integrative Studies); Philosophy of Interdisciplinarity Network (PIN), a consortium of three universities; Transdisciplinary network (TD net)— sponsored by the Swiss Acadmies of Arts and Sciences (http://www.transdisciplinarity.ch/e/About/), and The Center for the Study of Interdisciplinarity at University of North Texas (CSID). AIS is an American professional association which has met since 1979: Annual meetings have about 250 individuals. CSID was created in 2008 and is the only center in the United States devoted to the study of interdisciplinarity. PIN, created in 2009, is a consortium of Georgia Tech, the University of Darmstadt, and CSID. There are also additional cross-institutional networks and associations, such as the Interdisciplinary Network for Group Research (INGroup, http://www.ingroup.info/ of which Laurie Weingart at Carnegie Mellon University is the president) and the NIH and NCI "Science of Team Science" communities, one of which involves a listserve run by Holly Falk-Krzesinski at Northwestern University. INGroup is an interdisciplinary association of individuals who research teams and groups. Its annual conferences (since 2006) attract 100 to over 200 participants from over a dozen distinct disciplines. In addition to the attendees, many of whom were from institutions supportive of interdisciplinary work, other pockets of researchers were identified, such as the National Bureau for Economic Research (NBER), Stanford University SCANCOR group in higher education, and the Cornell University study of Medline. Recent technology has facilitated bringing together distributed researchers from around the world: Email, wikis, listserves, and video chat can all help researchers work together. However, it was noted by some participants that physical co-location is extremely important to successful collaboration of any type.

Definition of concepts and constructs was also a heated topic of discussion. In the study of interdisciplinarity and multidisciplinarity, starting with those terms themselves (and related ones, e.g., cross-disciplinary), there are multiple definitions of the same terms, particularly across such diverse fields as were represented at the workshop. Interdisciplinarity could involve diversity in individual cognition, individual disciplines, or even organizational disciplines. "Collaboration" is also a term that has been used to describe a range of activities, and it has been operationalized in different ways in different studies (e.g., some count face-to-face working groups, others count co-authors who may have never met but share a dataset). The range of related constructs studied by the participants was vast: Psychologists (e.g., conflict, trust, cohesion, social identity, emotion, creativity, team processes), sociologists and Science and Technology Studies scholars (e.g., trading zones, networks, interactional expertise, boundaries, gender, innovation, cultural capital, career progression), and economists (e.g., value, incentives, predictive markets) all take constructs from their own fields and apply them to the study of interdisciplinary collaboration and/or teamwork.

The data, methods, and measures used by the researchers matched their disciplinary variety. While bibliometrics and citation counts are popular among some disciplines, other researchers focused on historical case studies, archival data, and/or ethnographies. Still others conducted experiments, collected survey data, and/or quantified naturalistic data. Observation (naturalistic, audio-videotaped, and/or participant-observation), interviews, surveys, and experiments were all used. Studies could be longitudinal, cross-sectional, and/or theory-driven.

Current obstacles to an interdisciplinary study of interdisciplinary collaboration for innovation. Many participants in the roundtable discussions brought up obstacles that currently make a cross-disciplinary study of interdisciplinary and multidisciplinary collaboration difficult.

First, it is not clear that interdisciplinary collaboration is inherently positive (even if problems with it are overcome). Second, the variety of constructs, methods, and language use noted in the prior section makes cross-disciplinary work on interdisciplinarity a daunting task, including during this workshop (see Reflexivity section below). Communication can be difficult, even with engaged, motivated individuals. Terms like "knowledge diversity" and "expertise" can mean different things even within the context of a single discipline. Similarly, individuals from different disciplines do not necessarily agree with the usage of all methodological practices. Practically and logistically, it can be difficult for individual researchers to gain both the depth of knowledge necessary to do innovative work while still remaining broad enough in knowledge and methodological skills to communicate across disciplines or subdisciplines.

Even more importantly, there are very real structural, organizational, and institutional barriers to both working on interdisciplinary science problems and studying the social science of interdisciplinary collaboration. These barriers involve the reward systems in academia: lack of respected (non-marginalized, interdisciplinary) journals for publication and conferences; lack of respect, interest, and/or understanding of what constitutes quality interdisciplinary work by gate-keepers (e.g., those who make hiring and tenure decisions); a general lack of appreciation for collaboration paired with a focus on individual "stars" in academia; differential benefits accrued from interdisciplinary work (e.g., such work benefits tenured, already-respected individuals more so than junior faculty, women); and data mining and searching the literature in other fields varies in difficulty and accessibility from discipline to discipline. In interdisciplinary teams, status differences and conflicts may arise, particularly when someone already in power attempts to keep control of valuable data, machine, reagant, etc., effectively disempowering colleagues. The differences between disciplines also make graduate training of interdisciplinary researchers difficult. Similarly, the study of interdisciplinarity is currently decentralized across a wide range of disciplines. However, many participants noted that centralizing the study of interdisciplinarity would not be effective unless these structural barriers could be overcome in a realistic fashion.

Current gaps: Theory and data. A great deal of important research could still be done to study interdisciplinary collaboration. First, understanding the causal mechanisms that predict successful interdisciplinary collaboration would be useful. Leadership, team composition, group dynamics, organizational structures, and institutional legitimacy may all play a role in promoting innovation in interdisciplinary teams. Second, better data on the 'dollar yield' and productivity gains of interdisciplinary collaboration would be useful, not only in directly tying specific behaviors and activities to success, but to justifying research and funding in this area. Such research could directly link interdisciplinary collaboration to the 'broader impacts' that funding agencies find extremely important.

In terms of data, it can be difficult to convince researchers to become research subjects themselves, but that would be necessary to move the study of research forward. There was enthusiasm to increase the prominence and respect given to non-bibliometric methods. Bibliometrics (the study of collaboration via coauthorship in published literature) were perceived as dominating the more respected literature but as having a number of conceptual and methodological weaknesses. The missing elements of bibliometric data—communication, group dynamics, and other processes—are potentially interesting research topics. The history of disciplines would also be interesting: Some fields start as interdisciplinary endeavors and become progressively narrower, whereas other topics of study emerge from disparate specialized disciplines. Many participants noted that funding agencies have access to detailed information

about research projects (both proposed and funded research) and the eventual success of funded research. Other participants noted that some funding agencies simply did not collect data in a manner that makes research on collaboration and success trends possible. While confidentiality (and practicality and collection) issues would make mining such data difficult, finding some way to use such a wealth of information to study interdisciplinarity and success would be a worthy goal for informing science policy as well as building social science knowledge. Professional societies were also noted as a possible, separate source of data.

In addition to gaps between current and ideal states, researchers remarked on real methodological, communication, and construct gaps between disciplines. For example, how does one conceptualize and measure 'effective collaboration', let alone 'interdisciplinarity'? How different do fields need to be for researchers doing work between them to be considered interdisciplinary, cross-disciplinary, and/or multidisciplinary? Given the obstacles noted above, the participants raised two different (and potentially conflicting) strategies for solving the gaps in constructs: (1) centralizing and agreeing to standards of words and constructs, and/or (2) allowing the proliferation of constructs but defining them clearly, particularly when writing for broad audiences.

Other questions posed by participants considered how values and ethics entered the discussion and analysis of interdisciplinary research, both on the part of those doing interdisciplinary science and those studying it. In addition, interdisciplinary work has often neglected global problems and research coming out of other countries, in part because scientific knowledge, articles, and practice are usually based in English and in countries with a higher investment in research infrastructure and funding. The tendency of underrepresented groups (e.g., women, minorities) to conduct interdisciplinary work was also discussed as an important topic of study in its implications for innovation and career equity.

Future capabilities, infrastructure, and suggestions. While some participants contended that physical co-location is key to supporting interdisciplinary collaboration in the sciences and engineering, many of the attendees felt it would not be useful to develop research centers on interdisciplinarity without overcoming other institutional obstacles. Specifically, there was a concern that 'disciplinizing' the study of interdisciplinarity could simply serve to marginalize the field further and/or de-legitimize different kinds of research. This contention did not rule out other ways of collaborating to study interdisciplinarity in ways that involved co-location (e.g., visiting researchers, project-focused collaborations). Most participants (but not all) viewed it important to continue examining interdisciplinarity using a range of methods and theoretical approaches—which did not mean that each study of interdisciplinarity must *be* interdisciplinary. It is not always appropriate to attempt to merge disparate disciplinary epistemologies. One participant noted that integration and latent synergy among approaches to interdisciplinarity simply would not occur unless there were clever strategies for creating them. In general, having clear goals and keeping projects specific and concrete was seen as a useful approach, both in the cross-disciplinary study of interdisciplinarity and in interdisciplinary science projects themselves.

The workshop participants proposed several ideas for improving future capabilities: (1) creating a loosely connected group that could easily share and exchange ideas (as with the Society for Social Studies of Science, 4S); (2) forming a dispersed set of centers that would meet periodically (as with NSF's Centers for Ocean Science Education Excellence program) or other kinds of synthesis centers; (3) keeping the study of interdisciplinarity specific and problem-

based; (4) promoting interdisciplinary skills, interests, and career progression via funding postdoctoral and senior fellowships, visits, and cross-training across institutions; (5) funding an open source journal for publishing on interdisciplinary collaboration; (6) promoting online journals that support peer review via large expert crowds rather than the typical 2-4 reviewers; (7) establishing technical infrastructure that supports searching for articles across different disciplines, taking into account disciplinary language differences; (8) establishing infrastructure for sharing data across disciplines about scientists and science projects; (9) encouraging institutional incentives for interdisciplinary research that sidestep traditional academic reward and hiring systems, such as reforming traditional criteria for tenure and promotion; and (10) setting up a virtual clearing house for finding experts who are helpful (e.g., an academic Facebook). After the workshop was over, we requested that these ideas be ranked by the participants. These ideas and others they suggested are in Appendix E.

Many participants were enthusiastic about improving collaboration efforts, both for our own research and for scientists working in interdisciplinary teams. Ideas included encouraging the involvement of different publics and groups, and addressing the dynamics by which traditionally disadvantaged groups are rejected and/or accepted both by peers and by academic authorities. In addition to leveraging known methods for facilitating collaboration within and across groups, it would be useful to understand what it is that excites people about interdisciplinary collaboration, specifically. In addition, in some situations, creating cross-cutting constructs that could enable the study of interdisciplinarity.

Many specific suggestions regarding data and measurement were raised. Some comments came in direct response to questions about gaps in research and are listed in that section above (e.g., more historical and longitudinal studies, more studies of team processes and communication, particularly over time, and measuring success in multiple ways). Other comments focused more on the larger picture of building knowledge on interdisciplinary collaboration. For example, comparative research on both successful and 'failed' interdisciplinary teams would help shed light into correlates of success, as would measuring levels of interaction (e.g., strength of ties). Projects led by small groups of researchers from different disciplines could be set up to collect a wide variety of longitudinal data (bibliographic, observational, survey, etc.) on many research groups before it is known whether they will be successful or not. These sorts of projects could overcome existing conceptual gaps between current studies. For example, a project could involve network research that includes psychological variables of individual scientists. In addition to potentially obtaining data from funding agencies (e.g., data on funded centers like IGERTs), patents were noted as a possible outcome measure of innovation. Research collection that occurs before and after governmental interventions could help shed light on the outcomes of funded interdisciplinary collaboration in the form of patents, publications, citations, individual career trajectories, creativity, and group dynamics.

Reflexivity: How to Study Ourselves

Many of the issues raised above in terms of the difficulty in conducting cross-disciplinary collaboration occurred during the workshop itself. For example, participants had to be specific and explicit in defining their terms (e.g., "interdisciplinarity") because otherwise, miscommunications could and did occur. Indeed, there were some tensions around the predictable social science faultlines of quantitative-qualitative and experimental-observational methods. In general, workshop participants were extremely collegial, with dissension resulting in

discussants speaking around each other rather than growing frustrated and angry (although the latter did occur in some instances). As one researcher commented after the workshop was over, "the units of analysis are sufficiently different that it is hard to make good linkages in the research. Also, the [different perspectives and data] lead to vastly different questions." On the one hand, this difference in perspectives led to a few disagreements when different participants felt that their own disciplines were, could, or should be dominant in the study of interdisciplinary collaboration. On the other hand, most dissent was, upon reading the transcripts and notes (see Appendix D), simply healthy epistemological, methodological, and conceptual diversity: When not brainstorming together (building on each others' ideas), most participants were likely to discuss around or past each others' ideas, leading to complimentary opinions, rather than raise points that outright conflicted with each other.

Several participants expressed appreciation for the diversity of the workshop group, particularly the inclusion of members of underrepresented groups (in terms of race/ethnicity, age, gender, and discipline) and felt that a diverse community of scholars studying interdisciplinarity should continue into the future. Representation of groups came up a few times. One researcher suggested making sure that non-academic settings were both studied and represented, and another stressed the need for integrating international scholars (e.g., from India, China, Brazil, Mexico, etc.), given that discovery and innovation were international activities. A comment during one of the large group discussions suggested that although psychologists were present, none were personality psychologists who would study individual difference characteristics in being attracted to and succeeding in interdisciplinary groups. The relative isolation of philosophy, methodologically and epistemologically, from the social science studies of interdisciplinarity, was noted at several points by both philosophers and others who were present.

One idea that was sparked by a discussion at the workshop was to conduct a literature review of the various ways in which interdisciplinary, multidisciplinary, etc. and collaboration had been conceptualized and measured across different disciplines. Although there currently exist books and articles on interdisciplinarity (see Appendix F), with few exceptions, they are usually written from within specific disciplines and do not represent the breadth of communities represented at the workshop. The new literature review would be written with a broader audience in mind and could serve as a basic grounding across a range of disciplines.

To continue cross-disciplinary communication on the topic of interdisciplinary collaboration, it was suggested that conferences (like INGRoup's) host symposia on select research from the different disciplinary perspectives. Another idea involved sharing relevant citations, of which Appendix F is a beginning (Appendix G is the original list of citations from the workshop proposal). The citations and most presentation slides will be posted at the website for the Center for the Study of Interdisciplinarity at the University of North Texas.

Conclusion

In general, the researchers present felt that interdisciplinary research and discussion is difficult but an extremely worthy area of study. Even given the difficulties in communication across different methods and epistemologies and the conflicting opinions, the majority of the participants were enthusiastic about continuing a dialogue across disciplines in order to gain a deeper and broader understanding of interdisciplinarity. It was not considered necessary to merge all disciplines into one coherent approach to interdisciplinarity, but there was widely shared curiosity about the research questions, methods, findings, and approaches from different fields.

Appendix A: Workshop Agenda

NSF Workshop on Interdisciplinary Collaboration in Innovative Science & Engineering Fields

November 4-5, 2010
Location: Boston University,
1 Silber Way, 9th floor, Trustee's Ballroom
Boston, MA 02215

AGENDA

Thursday, November 4th
8:30 am -- Coffee and light refreshments available

9:00 -- Welcome to Boston University: Andrei Ruckenstein, Associate Provost and Vice President of Research

9:05 -- Workshop Overview (Susannah Paletz and Laurel Smith-Doerr)

9:20 -- Introductions

9:45 -- Practitioner plenary: Robert Hull, Rensselaer Polytechnic Institute: "Materials, Science, and Nanotechnology"

10:15 -- Robert Hull Q&A, full group discussion

10:30 -- Break

10:45 -- *Organizational, Economic, and Policy Issues*

- Jason Owen-Smith, University of Michigan: "The Network Ecology of Collaboration"
- Kaye Husbands Fealing, University of Minnesota: "Boundary Conditions"
- Stephen Zehr, University of Southern Indiana: "Science Policy Gaps in the Promotion of Interdisciplinary Research"

11:30 -- Roundtable discussion

12:00 pm -- Lunch and plenary presentation by Stephanie Pfirman, Barnard College: "Environmental Science, Arctic Studies, and Interdisciplinarity" (including Q&A)

1:00 -- *Multidisciplinary Cognition*

- Christian Schunn, University of Pittsburgh: “Vacuous and Ill-conceived: The Problem of Evaluation Norms in Interdisciplinary Interaction”
- Rogers Hall, Vanderbilt University: "Distributing Cognition in Talk Across Disciplines"
- Anita Williams Woolley, Carnegie Mellon University: “Group Brain?”

2:00 -- Roundtable discussion

2:30 – *Science/Technology Studies*

- Karin Knorr Cetina, University of Chicago: “Can Intercultural and Interdisciplinary Collaborations be Made to Work? Some Insights from Physics”
- Wesley Shrum, Louisiana State University: “Myths of Collaboration and the Public Conscience of Scholars”
- Ray Fouché, University of Illinois at Urbana-Champaign: “The More the Merrier: What is Gained through Interdisciplinary Collaboration?”

3:15 -- Coffee break and light refreshments

3:30 -- *Multidisciplinary and Diverse Teams*

- Margaret Neale, Stanford University: "Faultlines and Congruence in Diverse Teams"
- Joann Keyton, North Carolina State University: “Team Science Communication: Language, Meaning, and Process”
- Laurie Weingart, Carnegie Mellon University: “Interdisciplinary Collaboration and Team Cognition: The Role of Representational Gaps”
- Lucy Gilson, University of Connecticut: “An Interdisciplinary Approach to the Study of Team Creativity”

4:30 -- Roundtable discussion

5:00 -- Full group discussion

5:30 -- Adjourn for the day

Friday, November 5th

8:00 am -- Coffee and light refreshments available

8:30 -- *Networks and Diversity*

- Laurel Smith-Doerr, Boston University: “Whose Interdisciplinarity? Gendered Organizations in Science and Questions about Interdisciplinary Collaboration”
- Brian Uzzi, Northwestern University: “Multidisciplinarity and Scientific Impact”
- Erin Leahey, University of Arizona: "The Impact of Interdisciplinarity on Scientists' Careers: Variation by Gender & Career Stage"

9:15 -- Roundtable discussion

9:45 -- *Education and Public Participation*

- David Hess, Rensselaer Polytechnic Institute: “Interdisciplinary Research, Publics, and Civil Society”
- Eleonore Pauwels, Woodrow Wilson International Center for Scholars: "Engaging with Synthetic Biology Practices and Doing STS: Experiences and Prospects"
- Ed Hackett, Arizona State University: "Lessons from IGERT for What Might Follow"

10:30 -- Coffee break

10:45 -- Roundtable discussion (*ended up becoming and merging with the full group discussion*)

11:15 -- Full group discussion

12:00 pm -- Lunch and plenary presentation by Sara Kiesler, Carnegie Mellon University: “Human-Computer Interaction and Organization Science of Science” (including Q&A)

1:00 -- *Research on Policies for Funding Interdisciplinary Projects*

- Jonathon Cummings, Duke University: "Research Team Integration: What It Is and Why It Matters For Policy"
- Robert Frodeman and Britt Holbrook, University of North Texas, "The Future of Interdisciplinarity"

1:30 -- Roundtable discussion

2:00 -- Full group meeting/overview and wrap-up (Susannah Paletz)

3:00 -- Adjourn

Appendix B: Participants

Name	Institution	Affiliation
Ruha Benjamin	Boston University	Sociology & African American Studies
Jonathon Cummings	Duke University	School of Business (Management & Organizations)
Zophia Edwards	Boston University	Sociology
Colin Fisher	Boston University	School of Management (Organizational Behavior)
Debra Fitzpatrick	University of Minnesota	Center on Women and Public Policy
Rayvon Fouché	University of Illinois at Urbana-Champaign	History
Robert Frodeman	University of North Texas	Philosophy and Religion Studies; Director, Center for the Study of Interdisciplinarity
Lucy Gilson	University of Connecticut	Management Department
Michael Gorman	National Science Foundation	Science, Technology & Society
Edward Hackett	Arizona State University	School of Human Evolution and Social Change
Rogers Hall	Vanderbilt University	Department of Teaching & Learning
David Hess	Rensselaer Polytechnic Institute	Science and Technology Studies
Britt Holbrook	University of North Texas	Philosophy and Religion Studies; Center for the Study of Interdisciplinarity
Robert Hull	Rensselaer Polytechnic Ins.	Materials Science & Engineering
Kaye Husbands-Fealing	University of Minnesota	Center for Science, Technology & Public Policy
Joann Keyton	North Carolina State University	Communication
Sara Kiesler	Carnegie Mellon University	Human-Computer Interaction Institute
Karin Knorr Cetina	University of Chicago	Sociology
Julia Lane	National Science Foundation	Science of Science & Innovation Policy Program
Manfred Laubichler	Arizona State University	School of Life Sciences
Erin Leahey	University of Arizona	Sociology
Adrienne Lemon	Boston University	Sociology
Jim McQuaid	Boston University	Sociology
Fiona Murray	MIT	School of Management
Margaret Neale	Stanford University	Graduate School of Business (Organizational Behavior)
Jason Owen-Smith	University of Michigan	Sociology & Organizational

Name	Institution	Affiliation
		Studies
Susannah Paletz	University of Pittsburgh	Learning Research & Development Center (Social Psychology)
Eleonore Pauwels	Woodrow Wilson International Center for Scholars	Project on Emerging Nanotechnologies
Stephanie Pfirman	Barnard College	Environmental Science
Christian Schunn	University of Pittsburgh	Psychology, Learning Sciences
Wesley Shrum	Louisiana State University	Sociology
Laurel Smith-Doerr	Boston University	Sociology
Brian Uzzi	Northwestern University	Kellogg School of Management (Management & Organizations) Sociology McCormick School of Engineering
Itai Vardi	Boston University	Sociology
Laurie Weingart	Carnegie Mellon University	School of Business (Organizational Behavior)
Anita Williams Woolley	Carnegie Mellon University	School of Business (Organizational Behavior)
Stephen Zehr	University of Southern Indiana	Sociology

Appendix C: Roundtable Questions

Thursday, November 4th: Roundtable Discussion Questions for 11:30 am
CURRENT STATE OF THE ART: INFRASTRUCTURE

1. What is the current state-of-the-art in your field for studying multi- and interdisciplinarity? Meaning:
- What kinds of data are collected?
- Are there centers and existing teams (cross-disciplinary or not) that study these areas?
- How established are they?
- What journals do people publish in when studying multi- and interdisciplinarity (disciplinary journals, etc.?)

2. Where can researchers who study multidisciplinarity in all its forms and who wish to work in multidisciplinary settings go for lessons learned, advice, tools, and methods, and then contribute such information in return?

Thursday, November 4th: Roundtable Discussion Questions for 2 pm
CURRENT STATE OF THE ART: CONCEPTS AND DATA

1. What are the standard concepts used in researching multi- and interdisciplinarity in each of your fields?

2. How do you measure and conceptualize multi- or interdisciplinarity itself?

3. What kinds of data are currently collected?

Thursday, November 4th: Roundtable Discussion Questions for 4:30 pm
CURRENT GAPS

1. What are the main gaps in the state of the art, from the perspective of theory, data, and methods?

2. What types of data are best suited for a *cross-disciplinary* study of multidisciplinarity, and thus would need to be collected?

Friday, November 5th: Roundtable Discussion Questions for 9:15 am
EXTENDING YESTERDAY'S DISCUSSION

1. After thinking over yesterday's discussion of the current state of the art and gaps, what are things we've missed in our discussions yesterday?
- concepts important to cover
- data important to obtain
- existing groups
- ideal datasets or potential cross-disciplinary collaborations ABOUT multidisciplinarity
- additional gaps in the state of the research?

2. So far we have discussed the study of interdisciplinary collaboration in innovative science & engineering fields—would and how would the study of interdisciplinary collaboration be different in non-innovative and/or non-science/engineering fields?

Friday, November 5th: Roundtable Discussion Questions for 10:45 am
FUTURE REFLEXIVITY

1. How can we be reflexive (employing different forms of evaluative measurement, and considering data collection, curation, dissemination) in the study of cross-disciplinary collaborations?

2. How can we measure ourselves—the work we are doing, our own success (short- and long-term)?

Friday, November 5th: Roundtable Discussion Questions for 1:30 pm
FUTURE INFRASTRUCTURE

1. What kind of infrastructure would be necessary to create and sustain a community of researchers of interdisciplinary collaboration?

- Are additional capabilities necessary for collaborating on this research issue, or do current ways of conducting research on multidisciplinarity suffice?

- Would a Center of some kind be needed to push the frontiers of understanding? What kind of center—virtual, physical?

- What would be *feasible* in terms of developing research and building infrastructure?

Appendix D: De-Identified Roundtable Summaries and Quotes

[*Abbreviations*: ID=Interdisciplinary, IDR=Interdisciplinary Research, MD=Multidisciplinary, NSF = National Science Foundation]

Group 1 Roundtable Summary

Thursday, November 4th: Roundtable #1, 11:30 am

1) What is the current state-of-the-art in your field for studying multi- and interdisciplinarity? 1A. What kinds of data are collected?

- ID research varies based on different disciplines. There is not much communication between disciplines and subdisciplines that study ID (e.g., medical sociologists and others). On the other hand, there is some collaboration between biologists and social scientists.
- 'Science and publics' researchers and environmental scientists will use case studies.
- Depending on the research questions, some groups use Medline, US patent office data, 'clickstream data', historical work.
- Also, there is a gulf between those doing methodological work and the theoretical work that would help make sense of the methodological work.
- Even within teams research, the type of data varies. Some do qualitative work while others are more quantitative (ex. cognitive diversity variables, data on individual characteristics, etc).
- Others study teams via surveys of individuals and teams that are then matched with objective data at the organizational level (e.g., performance metrics).
- Economists use 'predictive markets', in which people try to predict the directions of science.

1B. Are there centers and existing teams (cross-disciplinary or not) that study these areas?

- Brian Uzzi and his team at Northwestern
- Katy Borner and team at Indiana and Notre Dame
- National Bureau of Economic Research
- Dan McFarland and Woody Powell at the Stanford Project (focuses on the entire history of collaboration at Stanford)
- Cornell study of Medline
- Earth Institute at Columbia University
- In the United Kingdom, research is grant based, so innovation centers are pushing ID with foreign scholars and across disciplines and locations.
- Certain groups at the NSF encourage and fund ID.

Related issues raised during this discussion:

- ID researchers can either use massive amounts of subpar data or use a much smaller amount of 'deep' data (very accurate, but narrow and resource intensive to create).
- Looking at the same phenomena using a variety of methods would be useful, but "it is difficult to get people speaking the same language across disciplines."
- Inclusion of outside scholars on dissertation committees can lead to interdisciplinary work, although there may not be a mechanism to encourage that.

- There's a problem of how to define disciplines. Can define by department, but there are problems. Some ID researchers use the term "inter-departmental" instead of interdisciplinary.
    - Some researchers use citation data to see how open/closed disciplines and journals are in order to see boundaries between them. One of the attendees criticizes this measure and points out that size of the unit would bias findings. The participant who initially raised this measure agreed, noted that it's a question of where you set your limits [between disciplines]. 'My Dissertation Abstracts' is a potential data source.
    - Another participant pointed out that the boundaries among scholars are often not departmental, but methodological.

1C. How established are these centers, groups?

- This group did not address this issue directly, but talked at length about an important, related issue—that being the hierarchy of journals. Scholars have set models or lists of what we consider the 'A', or best, journals. Schools and students need to push the idea that alternative journals are ok to publish in. However, more journals may just create more hierarchies and reinforce disciplines.

- The group asked each other: Can information technology break down the hierarchies created by journals? In the past, only those people who got published in the higher status journals actually got read. Even if your work was great, nobody might see it because other scholars didn't physically have the journal where your work appeared. With scholars increasingly using google and other search tools, this is less of an issue. The prestige associated with publication in certain journals remains, but work does not necessarily become invisible if it is published in a lower status journal.
    - One participant pointed out that the size of a field affects this process.
    - Another noted that journals don't often sell themselves as ID, so ID researchers often publish in books, which google scholar doesn't handle well.
    - ID is seen as a success for some disciplines/institutions but as something to be avoided for others. For example, researchers at MIT avoid ID.
    - There is a push [of unclear size in some disciplines] for mainstream journals to include a description of themselves in ID terms and to publish ID work.
    - Some scholars in some disciplines list publications in terms of 'journal equivalents,' which leads to intense debates [during hiring, tenure?] about the value of a particular paper. These debates lead to questions about how much time they want to spend discussing one person's work.
    - In theory, scholars should be focused on the creation and transmission of knowledge. Journals were (and still are) the forums, but scholars have become well-known through things like blogs, some of which have become influential within their disciplines.
        - However, it is unlikely at this time that people will get hired because they have influential blogs. Blogs may have an impact outside of the discipline, but not necessarily within.
        - Some speculation as to whether this will change.
    - Some speculation as to whether some journals will be replaced by internet communication.

- Peer review can be maintained even if journals are replaced by different internet communication, but mechanisms would need to be developed.
- One individual strategy is to have a 'diversified portfolio' of work and modes of disseminating that work. The best way is (half-jokingly) "to do everything well."

2. Where can researchers who study multidisciplinarity in all its forms and who wish to work in multidisciplinary settings go for lessons learned, advice, tools, and methods, and then contribute such information in return?

This roundtable group got to this question towards the end, so didn't spend much time on it. The consensus seemed to be that it was an important question, but no one really knew the answer.

Thursday, November 4th: Roundtable #2, 2 pm

1. What are the standard concepts used in researching multi- and interdisciplinarity in each of your fields?

- The group as a whole has trouble initially answering this question, but after a few moments, ideas came.
- Network theorists have standard measures that are recognized across disciplines but within the methods (nodes, cohesion, etc). One participant pointed out that network theory is unique in that it developed around the method rather than within a discipline.
- Another participant offered measures, such as co-authorship of papers and proposals, grad school affiliation, location of advisor, co-citation networks, and originality.
- Gender, race, interests, and power are all important to study in ID.
- The group discussed use of citations, proposals, and the like as measures. The group agreed such measures are problematic. What *are* citations? Does a citation represent that the cited article is an important piece of scholarship or that the author feels pressure to cite the article out of deference to the author, discipline, or journal?
    - Several participants discussed recent attempts on the part of journals to drive up their impact factors by explicitly including demands to cite more articles from their journal in article reviews.
- Journals also sometimes measure impact by tracking article downloads. The group discussed how measures of impact (in any field, academic or otherwise) are only useful for a short time because people learn how to 'game the system.'

Other, related issues that came up during this session:

- ID scholars may be well-known outside of their own disciplines but largely unknown within.
- Status and gender are an issue. Sometimes it's the women who "pull it all together—they get stuck with the relational and logistical work that ends up in the background." If/when/because marginalized groups do all the work of ID, this adds to the marginalization of ID. Who handles the 'socio-institutional' and the 'socio-emotional' aspects of ID? Who does the work that gets credited in publications, and who handles the 'infrastructure' (arranging meetings, etc.). A participant compared this marginalization to the 'science' versus 'social science' divide.
- It is important that ID team members to trust one another. For example, group members need to be able to trust that others actually have the knowledge they say they do.

- There is a brief discussion of researchers with very specific, narrow skill sets that allow them to move easily between groups (almost as interchangeable parts).

2. How do you measure and conceptualize multi- or interdisciplinarity?

- Bibliometric/citation data: One participant asked the group how they reacted to 'Porter's work,' which was discussed in a talk. The group expressed skepticism, stating that they would want to know more about the measure.
    - One participant noted that a problem with 'bibliometric' data is that there is no behavioral model behind it, and thus nothing to drive the explanation.
    - Another participant suggested qualitative data as a fix.
    - Another participant offered citations as a way to quantify the discipline and see how disparate the fields are [note: this seems to be the use of citations at the discipline level, rather than as discussed above, at the individual level].
    - The group questioned the measure of publications and how to truly judge them. For example, giving researchers credit for half of an article when they publish with an advisor.
- ID researchers tend to be more 'shrub like' (using terminology from one of the talks). They tend to go off in lots of different directions, and that can be death for junior faculty.
- The group discussed three different types of ID. These are all very macro conceptualizations, but if examined as changing scientific practices in a lab, could be micro alternatives.
    1) The disciplinarity of the inputs to the research. For example, all team members could be from the same discipline, but they draw heavily on work outside of their discipline.
    2) The interdisciplinarity of the people doing the work.
    3) the interdisciplinarity of the downstream use of the work (ex. a biology paper that becomes well cited outside of biology).
- However, there is difficulty in classifying disciplines and ID. Classifying one's own work is difficult, so classifying the work of others would be 'dicey.'
- One participant used an analogy from economics: The need to classify firms presents similar difficulties. In the past, economists relied on standardize measures of how firms produced but have since switched to classifying on the basis of what firms produce.
- Since there are no standardized 'buckets' for science or types of research, there is an attempt to use 'topic models' to pull out 'bags of words' associated with topics in order to clarify different areas. Such methods change from a focus on inputs to outputs.
    - A participant pointed out (and this was a theme throughout the roundtables) that such methods ignore process.
    - Also, the NSF doesn't have the structure to mine its own data (more on this later).

3. What kinds of data are currently collected?
This question was noted in the context of the above discussion.

Thursday, November 4th: Roundtable #3, 4:30 pm
1. What are the main gaps in the state of the art, from the perspective of theory, data, and methods?

- In the United Kingdom, researchers have to be able to address policy issues.

- Some curiosity about whether the study of MD can become a MD field itself.
    - It is important to diversify, but too much diversity can lead to a situation in which people can't talk to one another.
    - The role of leaders: Leaders can facilitate or crush ID.
    - The group also discussed the 'dark side' of MD: Why do we *want* to cross fertilize? We need/want an interpretive, critical examination of why we want collaboration. MD researchers should be paying attention to the question of whether the people in groups *should* be working together. One participant said that normative issues need to be recognized or people like this participant would leave the community and critique it from the outside.
    - What are the conference participants privileging?
    - Different scholars' work examine different levels of reality (e.g., psychological to the social). One researcher pointed out that work on networks treats scientists as empty nodes. Scholars in different disciplines see themselves within their own frameworks. He then asks the question of whether we can connect the psych to the social or connect, for example, differences in creativity (referring back to a talk on creativity earlier) to social differences.
- A participant noted that ethics and values components are missing from the overall discussion and roundtable questions.
    - At the least, different disciplines assign different values to outcomes and what are recognized as generative ideas (e.g., differences between Science and Technology Studies, STS, vs. Science of Science Innovation Policy, SciSIP, at NSF). STS questions can be ethical, philosophical, etc., while SciSIP can take work from STS to inform the 'SciSIP agenda,' which is more applied. SciSIP is not concerned with answering innovative science questions, but about understanding a class of policy question. The work allows for informed policy decisions. STS attempts to build a broad understanding of the scientific enterprise, while SciSIP explores how STS work can be used. Studying ID from STS and SciSIP perspectives can be complementary.

2. What types of data are best suited for a cross-disciplinary study of multidisciplinarity, and thus would need to be collected?

- Without a modestly general theory, "we default to the 'we need to collect everything' mindset." There are enormous changes in distance/size/scale by multiplying by ten (see the 'Powers of 10' video).
    - Different disciplines examine different levels of analyses and reality.
- ID researchers need longitudinal data.
- When possible, we should also gather 'objective' data. For example, measures of interaction (# emails, calendars, etc) are both objective and can be collected electronically.
    - That said, what is defined as 'objective' tends to privilege some kinds of data and can be problematic.
- Data on thinking styles may be useful.
- There is a need for qualitative data as well, but qualitative data is often cut (or dismissed) by journals.
- One suggests the goal should be solve specific problems. The group suggests these as problems: environment, economy, organizational survival, harnessing our human capacity,

etc. Can ID help solve these? NSF spends six billion dollars of taxpayer money a year trying to solve problems that can only be handled using ID.
    - Academics don't often think in terms of problems, but may need to.
    - The division between applied and basic science may prevent researchers from solving problems.
    - There is some concern that certain fields may lose scientific autonomy.

Friday, November 5th: Roundtable #4, 9:15 am

1. After thinking over yesterday's discussion of the current state of the art and gaps, what are things we've missed in our discussions yesterday?

- Participants reiterated the importance of bringing work of different levels together.
- Also repeated the need for longitudinal data: what influences success over the long term? Linking processes to outcomes would be useful.
- What brings people together to do collaborations, in addition to expensive machines that are limited resources?
- Issues with graduate students and graduate training:
    - Graduate students in ID teams may see ID as the principle investigator's problem, rather than their problem.
    - Is ID a good way to start a career? It is possible that any benefits of ID research may constitute a short term bump, but the long term effects may be detrimental. Also, the benefits/consequences of ID are likely filtered through gender, status of degree, etc. Career problems may arise when grant agencies dump money in ID research for a few years and then disappear.
    - People do what they are taught: If they are taught ID, they will do it.
- Could be useful to draw on data gathered by granting agencies, including about graduate students.
- Gender is a point of study. Women, who have more familial and teaching responsibilities, may be drawn to ID research because more mainstream work moves too quickly. They can't move fast enough to keep up, but ID work offers a way to make contribution without the same pressure to move quickly. There's an opportunity to make a real contribution given their constraints.
- How does ID actually happen? Is it very top down, such as when a group of high status researchers come together, form a team, and then stand at the top of a large group of researchers? Or, do we see ID when 'fringe' scholars come together on their own to work on an issue?
- What skills do ID work foster? Does ID work help researchers develop skills that can help them in the future? Do they learn deeply (telephone pole metaphor)? Deep and then broad (tree metaphor)? ID may make researchers more flexible and help them in the long run…or not. A PI might be ID, but the people underneath may only work in a very specialized area and not be ID at all. As such, they won't develop any new skills.
    - It can better to have people who are very specialized and can move around, as a "division of innovative labor."
    - People in ID teams should share the same understandings of what they are working on, and should possess "transactive memory." People need to know what it is they are coming in for.

    - Very specialized people who move around can act as bridges across groups.
- It can be difficult to share data. One participant contends that there are no centers to facilitate sharing data across fields.
- One research focus could be early stage ID work. The beginning of the process of working across disciplines sets the stage for whether or not those groups are successful.
- The group discussed "rent seeking" among ID researchers. Some scholars have a monopoly on something (data, a machine, a reagent, etc) and use that monopoly to benefit themselves. Usually it's the women and low-status people who end up "screwed." Example: two researchers spent years building a dataset, but were then essentially held hostage by a third researcher, in a powerful position, who came on later. This third researcher demanded to be a co-author on all publications connected to the data.
    - Rent-seeking is very difficult to measure. James Evans did some work comparing author lists to paper acknowledgements to get a sense of who contributes what, but such work is very time intensive.
    - Authors can report their roles both on papers and in CVs.
- Additional issues with citations:
    - Rent seeking creates problems when using citations as a measure. It's impossible to know (unless scholars start reporting this data) who contributed what to any given project. For example, in a long list of names on a biology paper, you can't know who contributed to the project and who got listed because he or she happened to have a particular reagent sitting in his or her lab's fridge.
    - Researchers who use citations operate with a lay theory of co-authorship, but there is limited real understanding of what it means to be a co-author. We need a typology of co-authors. One could remove first author names to see how that affects citation networks.
    - One participant asserted that research using citations needs to either use lots of data or dive really deeply into smaller data set (fine grained, qualitative). Studies in the middle don't work. There's too much data to really dive into in any sustained way, and there's not enough data to 'wash out' biases and other problems.
- Could study "shocks" to fields, such as the introduction of new funding sources or other changes in incentive structures, to see the effects on fields.
- Possible data source: membership information from professional societies.
    - For example, tiered memberships (lower prices for students, low income, etc.).
    - ID researchers could look at who is proposing special sessions, presenting in lower status sessions (e.g., roundtables versus regular sessions), publishing in proceedings versus journals, and other "nascent divisions."
    - ID researchers may be able to connect conference presentation to publications.
    - Several discussants suggested such divisions are likely connected to gender.
    - Another possible data source: examining connections between patents and papers. While a paper may list many authors, the inventor list on a patent will list fewer. Time delay between paper publication and patent approval can provide insights into author contributions.

Friday, November 5th: Roundtable #6. 1:30 pm
What kind of infrastructure would be necessary to create and sustain a community of researchers of interdisciplinary collaboration?

The majority of the discussion focused on the efforts of NSF to create a system that would allow for researchers within NSF to make use of the data that the NSF gathers.

- NSF infrastructure (including both information technology and legal) is not designed to gather and store the data it collects in a way that makes it usable by researchers for mining. Attempts to make a usable dataset are extremely time-consuming, even within groups.
- The group was very interested in the possibility of the NSF creating a system that would allow outside researchers to access and mine the NSF's data. The NSF is working on a system that would make the data useable, but confidentiality and other legal barriers stand in the way of making such data public. Also, the technical hurdles are enormous.
    - The unit of analysis is the award, not the researcher.
    - The data are not searchable. Often just pdfs.
    - NSF has 40 legacy, unlinked systems. The goal would be to have one system, but such a system is being created incrementally.
    - Ideally, there would be a mineable system of longitudinal data on PIs and all those touched by NSF funds. Such a system, if connected to the Web of Science, would be useful. Could also be linked to conference proceedings, dissertations, abstracts, co-panelships, graduate students, etc. It could even include blogs, software, datasets, etc. that the individuals create and maintain. One discussant suggests building in a way to track calls for proposals to see who has applied for them.
- The NSF is interested in accessing such data for its own purposes (trends, conflicts of interest, etc). Also, legislative pressures are in play here: There is currently no mechanism in place to track where the money that the NSF spends actually goes, and Congress is demanding that information.
- Similar / parallel systems:
    - STAR METRICS http://www.nsf.gov/news/news_summ.jsp?cntn_id=117042
    - The Brazilian Lattes System (which is described in a paper published in *Nature* by Julia Lane) serves as a possible model for the NSF system. The Lattes is a Brazilian Science and Technology database that gathers information and automatically populates researchers' CVs. Researchers then validate the system's findings.
    - STAR STATISTICS, which could pull human resources information out of universities. Such a system could automatically gather information about undergraduates and graduate students. One discussant suggests linking the system to SEC reports to firms.
    - Would STAR METRICS and STAR STATISTICS be opt-in or opt-out? Systems would probably be opt-in. Opt out systems and compulsory systems generate bad data. It is possible that the OMB [Office of Management & Budget] will act if NSF does not and will require a compulsory system.
- NSF could attempt to embed evaluation researchers into projects that are at the planning stages to track how those groups actually work together. Such researchers would study the process that teams go through while planning and designing projects. They suggest that, up to this point, there has been little focus on the ways in which teams are built, how planning occurs, etc.

Group 2 Roundtable Summary

Thursday, November 4th: Roundtable #1, 11:30 am

1) What is the current state-of-the-art in your field for studying multi- and interdisciplinarity?

- Team science is trying to bring people together to partake in that type of research, but it is difficult. They are marginally established and existing centers are rare. There's 60 years of research on how groups and teams research, but sciences that study IDR do not reference it.
- It is possible to publish IDR work, though (e.g., Journal of Infometrics). However, there is not one journal.
- Centers include:
    - an IDR center in Bielfeld, Germany
    - University of North Texas
      Association of Integrative Studies
    - Philosophy of ID Network
    - S.C.I.T.E.S.

This group did discuss gaps right away:

- There was some discussion about whether funding agencies do or do not have data about disciplines and outcomes.
    - It would be useful to study progression throughout the research process.
- What counts as one's discipline? What one got a Ph.D. in, one's current affiliation?
- The traditional journal system needs to be advanced to better reward ID. Some disciplines reward based on conferences.
- There needs to be a distinction between studying ID as a form of research and then assessing whether this research is working.
- Coming up with good metrics, including of function and outcomes of research, is difficult.
    - See Weitzman's paper—what is the team's value? What are they contributing?
    - What do researchers of IDR want teams to achieve? One big discovery?
    - We need mechanisms to collect and process data on function and progress.
    - We need some comprehensive literature review articles in IDR.
- Cooperation within disciplines can be as difficult as cooperation between disciplines, but there are deeper communication problems across disciplines.

Thursday, November 4th: Roundtable #2, 2 pm

1. What are the standard concepts used in researching multi- and interdisciplinarity in each of your fields?

- In philosophy, the concept of "integration" is often used in IDR, while in MDR it is "juxtaposition."
- In some research, "transdisciplinary" is when you take the knowledge back to your discipline of origin.
    - "In Europe this also means bringing people from outside of academia."
- Different concepts are used by academics versus administrators.

- Main differences are methodological rather than conceptual, e.g., quantitative vs. qualitative data.
- "Diversities:" In organizational behavior, there's research on "diversities:" People are experts in different fields – the question then becomes how they work together. But in economics, "diversity" refers to gender and/or racial diversity. [Editor note: in psychology, diversity can refer to either demographic and/or cognitive diversity.] Need to distinguish the type of diversity.
- In communication, "communication style" means how information moves within groups.
- Distance and distance formulas are important as measures and concepts in different fields that study ID.
    - Psychological research shows that groups are bad at effective information processing. In particular, people do not share exclusive and new information and are more likely to repeat what's already mentioned/shared. This research occurs via measuring groups by both distance and information flows.

This group also brought up additional gaps and issues:

- Focus in researching ID is usually "how do they do it" because people presume that it is good. But *is* it good? For what? When? It can be very costly.
    - It is also differentially costly. One of the participants noted that "Students tell me horror stories about working in ID collaborations because the PI comes from a 'star culture' and not an ID culture."
- This leads to the question of, can we carry out ID work within existing institutional power structures, such as seniority?
    - In certain research designs, may be possible to have participants not know about the power structure in detail.

Thursday, November 4th: Roundtable #3, 4:30 pm

1. What are the main gaps in the state of the art, from the perspective of theory, data, and methods?

- Translating the expertise gathered about IDR into policy. The current movement is toward 'disciplinizing' the interdisciplinary, and not to translate it into policy.
    - There is a challenge in coming up with generic knowledge, given the diversity of methods, perspectives, and disciplines even studying ID.
    - Some members of this group also saw a lot of similarity among the talks.
    - Regardless, "We have to translate the knowledge for the *practitioners,*" not just for policy.
    - "I think that what we want is a list of factors of how teams work, proper resources, shared identities."
        - Some research on these issues already exists, needs to be translated and shared.
- Huge gaps between those who study ID.
    - Methodological gaps. Different methodologies are used by researchers of ID.
        - "Philosophers do not use methods" (said by a philosopher)
    - Gaps between disciplines

- Gaps in what are considered appropriate outcomes, e.g., "what is effective collaboration?" beyond publication.
- It would be useful to have longitudinal studies of scientists' career progression between disciplinary and interdisciplinary paths.
- Gaps in defining the boundaries of 'disciplines' is itself a highly problematic thing, because today what are considered 'disciplines' are already interdisciplinary,
- Possible measures were suggested:
    - Occupations, PhDs, publications, number of authors, citations and how they are used.
    - Process measures.
    - Causal mechanisms that lead to a successful collaboration.
    - Policy impacts (political science outcome measures)
    - Resolution of problems. For example, one can argue that Hurricane Katrina was actually a failure of science, because despite all the accurate prediction the disaster still occurred.
    - Expertise and how it can be a component of measurement seems important.
    - The boundary system, the technology, or the laboratory, that shapes the epistemic culture in which the collaboration takes place.
- It would be interesting to link the processes to the outcomes that people want to achieve, i.e. what makes a successful collaboration.
- Important to examine institutional legitimacy. How are the institutions involved on the ID perceived by the public and the participants? The question of legitimacy can be tied in this respect to the question of expertise.

Friday, November 5th: Roundtable #4, 9:15 am

1. After thinking over yesterday's discussion of the current state of the art and gaps, what are things we've missed in our discussions yesterday?

- One main policy gap is how to translate IDR into solving real world problems.
    - One way to solve that problem is by looking at patents, for example medical patenting.
- Defining MD and ID can be very difficult. The subdivisions within the disciplines are too big to bridge. This can then make defining goals problematic—the gaps affect the goals.
    - There are real institutional practices that keep these concepts intact but different. For example: how do sociologist view other sociologists? This is not only a matter of looking at labels, but of practices and mechanism. Sociologists meet yearly at the ASA meeting, and this kind of mechanism enhances a sense of disciplinarity.
- What knowledge and expertise do people bring to ID in addition to individual careers—what specific knowledge is brought to the table?
- How do people *read* ID papers? How do they interpret them, use them, etc.?
- Another problem is that disciplines suddenly "discover" things that other disciplines have already discovered, but just use different terms to label them.
- Another problem is the complexity of data sets, in which one author is usually [in some fields] a population researcher. The problem is then on the field level: *emerging conventions* in different areas are important, that is what counts as ID in the different fields. For example, most sociology students today work on existing data sets instead of trying to come up with their own.

- There is often a problem of legitimization, conflicts between experts to define who is an expert.
- How does one distinguish between MDR and IDR in work using citations as an outcome measure?
    - Right now they call it MDR but don't know if it is in fact *integration*. One would have to get into the actual paper to do that and can't do that now with huge datasets. ID has to be a subset of MD.
    - One participant raised that maybe the concepts of ID and MD are the wrong concepts and unit of analysis, and new concepts, cross-specialty concepts are needed that would be based on epistemic approaches and methodology rather than disciplinary boundaries.
- Citations are only one, perhaps limited measure. Other measures include team process data.
- Qualitative analyses can pose different kind of questions in order for the concepts to vary according to the level of analysis.

Friday, November 5th: Roundtable #6. 1:30 pm
What kind of infrastructure would be necessary to create and sustain a community of researchers of interdisciplinary collaboration?

- Many in this group seemed to agree that we don't "need a discipline of ID, because then we risk becoming insular and won't talk to each other." "ID as a phenomenon" is thus a problematic perspective.
- Some discussion of the development of fields over time.
    - Organizational behavior, for example, is an ID discipline that developed over time.
    - Criminology used to be a subfield of sociology but spun off.
- We should be studying more the ID between academia and non-academic publics and bodies. What are the mechanisms and frameworks that operate in these processes, e.g., in medicine.
    - Could NSF provide access to their databases on ID centers?

Useful infrastructure could include:
- Something like 4S, which is not really a discipline but a loosely connected group from different areas that exchange ideas.
- A more organic model could work for infrastructure: once a group shows that it can work together successfully, then we should support it; this is instead of forcing groups to work together artificially.
- Dispersed centers that get together periodically, a consortium of centers. For example, there is CO-SEA – 12 oceanic studies centers. That's a good model, a network of centers.
- Problem is the reward system in academia.
- One infrastructure could be a funded mechanism for training people in IDR.
    - E.g., mid-career people, who are already tenured, and who can now learn how to do IDR. This could be done through an NSF program, for example. A sort of "career re-tooling", maybe integrated into a sabbatical.
        - NSF already has a similar program: visiting fellowships for collaborations.
        - NSF has an OIA, an Office for Integrative Activities.
    - But if you force people to move it might actually inhibit their work. Also, there are people who don't get sabbaticals, what about them?

    - Maybe it can be worked in a two-way fashion: Not only sending people off to learn IDR but using funding to *bring* people that you would like to work with in an ID project.
    - Another mechanism is a postdoc that trains people in IDR.
- Where do the people in this roundtable get their funding for IDR studies, currently? NSF (STS, SciSIP), NIH, private investors, some within-university funding (for management).
- The Omni research grant on network centers recently awarded $32 million to studying networks. They forced to work in teams, to be part of centers and work between centers. So they took existing infrastructure and conditioned that the researchers must work together. I think that such a thing can work at the NSF.
- There should be a data management plan and a way to measure the broader impacts. Congress is very interested in broader impacts.
- One idea is to have a cross-disciplinary literature review of standard concepts in the field (e.g., ID, MD), how they are defined, how they are operationalized.

Group 3 Roundtable Summary

Thursday, November 4th: Roundtable #1, 11:30 am

1) What is the current state-of-the-art in your field for studying multi- and interdisciplinarity?

- You can study the degree of interdisciplinarity at the paper, person, and institution level. There is a large literature in sociology on boundary-crossing and category-crossing, and the risks, penalties, and benefits from doing IDR, the peer review process (see Michele Lamont "How Professors Think…" who looks at interdisciplinary funding, consensus making about which projects to fund etc), and how to foster IDR (top-down or bottom-up)?
- Interdisciplinary network for groups research (www.ingroup.info) which has an annual conference and brings people in from psychology, sociology, political science etc. Contact person is Laurie Weingart at Carnegie Mellon University.
- Creation of the Philosophy of Interdisciplinarity (PIN) Network at the University of Colorado at Boulder where scholars think about *interdisciplining* the field of Philosophy. They argue that the humanities should have never been conceived of as a discipline. They have developed survey for PhD programs in Philosophy in North America (there are 101 programs) and they had a 40% response rate. The survey covered main themes understanding the degree of interdisciplinarity in philosophy e.g. how much funding goes toward this work, how often you work with people in other disciplines, etc. Thus, surveys are another tool for assessing multidisciplinarity.
- In engineering, graduate students can get training in another discipline through class offerings.
- Arizona State University is trying to implement interdisciplinarity at the group and institutional level. They are finding fast and fluid collaborations across very different fields. However, there are obstacles such as programs that restrict their seminars to their students (because of seat limits or prerequisites).

What are the challenges?

- Searching, finding articles
    - For engineers, this sociology literature is inaccessible. It is difficult for them to find the right articles in the Web of Science or Engineering Village.
    - This may be a deficiency in the search engines! There are linguistic barriers in the Web of Science so when you search using key words from another discipline, you cannot pull up this sociology literature.
    - You can use googlescholar
    - Even with these search tools, as a researcher entering publications in a different field, you do not know what journals/work is rigorous and what is not, which ones to focus on etc.

- The rigidity of data mining tools and data collection methods differ vastly between disciplines. To do interdisciplinary work, you have to re-train yourself. Do places exist to train people in rules of thumb for doing interdisciplinary work or do you have to do it yourself? How do we structure a program so that a student can bridge particular areas A and B? As an academic you will have to do this multiple times, so how do you learn to navigate

multiple disciplines and their different rules-of-thumb.
- Status and legitimization: There are status wars between people, disciplines, methodologies so this poses a risk or barrier to IDR. Therefore, we need to understand what constitutes legitimate data in different disciplines e.g. Interviews, networks.
- Interdisciplinarity should not be at the expense of disciplinarity. This is a big concern for undergraduate degrees and assistant professors seeking tenure. Schools are worried about multi- and interdisciplinary PhD programs since they are developing students who are too broad, raising issues of where would they fit when they leave, in which programs do you place them, etc. This is a double-edged sword for tenure and for writing for particular audiences.
- Cognitive and social dynamics are different depending upon the number of people working on a project. For successful outcomes, you need a symbiotic relationship with mutual benefits for collaborators.
- As an individual, it is difficult to be both broad and deep. At the group level, we want to know how to bring people who have a lot of depth to work together.
- Institutional barriers and policy are driven about questions of accountability, broader impacts, and philosophical assumptions underlying interdisciplinarity.

Thursday, November 4th: Roundtable #2, 2 pm

1. What are the standard concepts used in researching multi- and interdisciplinarity in each of your fields?

- Measure scholars according to a pi rather than a T. A pi is someone who has breadth and depth in two substantive areas vs a T is someone who has breadth in one area and depth in one area.
- Emotions, emotional energy (positive, negative affects)
- Cultural capital (see Randall Collins "Interdisciplinary Collaboration…")
- Peer review as a gatekeeping function.

How do you measure and conceptualize multi- and interdisciplinarity itself?

Concepts
- Trading Zones
- Interactional expertise
- Sociology literature of boundaries, boundary-crossing and brokerage
- Think about what kinds of terms force people to leave their disciplinary home e.g. resistance, democracy, colonialism may force historians to collaborate? Are these broad terms or is it how these terms are framed (e.g., as typically-sized areas) that draw people to interdisciplinarity).

Measurements
- Show evidence of integration after a certain amount of time or lose funding. However, this may lead to shams just to get more funding. Pushing procedures that lead to collaboration probably produce better results e.g. Co-teaching, graduate student courses etc.
- Psychology has measures of knowledge/skills
- Sociology has measures of networks.

- You can look at "emergent state" outcomes, that is, outcomes at different stages of the process e.g., group satisfaction, group cohesion, in addition to co-authorships.
- Measure the time frame in which the process of interdisciplinarity is occurring to gauge how long it takes for collaborators to work things out, e.g., over 10 years versus a few minutes.

What kinds of data are currently collected?
- Observations - groups, network structures, process tracing.
- Experiments - field and lab.
- Archival data and e-records.
- Longitudinal interviews.
- Citations and bibliometrics.

Thursday, November 4th: Roundtable #3, 4:30 pm
1. What are the main gaps in the state of the art, from the perspective of theory, data, and methods?

- Develop a variety of strategically constructed experimental platforms. Datasets are still, and this creates something that is dynamic. We need collaboration among STS people and folks coming from different social science disciplines. STS folks often approach these folks with some knowledge of the science. There is a fundamental difference between quiddity (essence) of the professions - are we aiming to generalize or contextualize particularities?
- Could there be an agreement between NSF and NIH and other funding agencies to put together an instrument or data?
- So how do you get people to buy in to be subjects of research? This is a cultural change to get scientists and humanists to consider themselves part of the research process. There is a lot at stake in an academic environment to get scientists to agree to be studied.
- Generate affinity/obligation to respond positively to your own discipline. There is large literature on the value of being an insider.
- We need to be able to compare across cases, or collate data about ID collaborations in one database and it needs to be multi-layered. We need the ability to access many kinds of data.
- Philosophy is isolated. There is a gap in the theory of the philosophy of interdisciplinarity, i.e., the construction and limits of expertise and knowledge.

Can the publics be brought in?
- There is a literature on citizen science and the place of everyday people in the construction of science (see Dave Guston's work, for example).

What kind of data do we need to do a study of ID?
- Longitudinal - we need to be there from the beginning and we need to study different levels of analysis. Look at the interplay with funding.
- Why do some scientific research agendas die? Might be funding and interest. We need to see different levels of outcomes, e.g., changes in behavior in the public in addition to health outcomes.
- We need to study failed cases as well as successes. Content analysis of why authors think their articles were so popular.
- Data gap on accountability. How much data do we have about health outcomes about funding

of projects, e.g., no change in cancer rates even though tons of money on cancer research.

Friday, November 5th: Roundtable #4, 9:15 am

1. After thinking over yesterday's discussion of the current state of the art and gaps, what are things we've missed in our discussions yesterday?

Important concepts to cover:

- What are the language gaps between the terms multidisciplinarity, interdisciplinarity and transdisciplinarity?
- Klein's work "the Taxonomy of Interdisciplinarity" describes multidisciplinary as the juxtaposition of the different pieces of different fields but not integration; interdisciplinarity is the integration of different fields; and transdisciplinarity is going outside the academy and bringing in stakeholders to co-create knowledge. Klein takes about creating a new space or building bridges between two disciplines. The hard work is in the integrative moment.
- There is value in cataloging the differences but we should not to lose sight of why we catalogue: For what ends? In what contexts are differences meaningful? When deciding whether you want to fund a team, you need as assess whether there is collaboration occurring across fields. There may be a management plan that you want to see because what research using interviews has shown is that some of these multidisciplinary projects where people are not really collaborating and there are other who are truly trying to push a frontier by sitting around a table and pushing out ideas etc.

Measuring interdisciplinarity itself:

- How can you tell from the publication alone whether or not something is interdisciplinary or not? How do you measure whether the research is integrative?
- Can we come up with a measure to distinguish between multi-, inter- and transdisciplinarity? Maybe you need a taxonomy of the types of outcomes that these kinds of research processes try to produce? We probably need to measure the ingredients, process and the product.
- You have to get institutional, organizational, policy, and philosophical parts of the process right in order to do interdisciplinary work. Therefore, how can you measure interdisciplinarity? Can you come up with metrics? Maybe, inherently, it cannot be accurately quantified. We must remember that there is a market element to what we call a "discipline" which affects what we count as disciplines.
- The SPRU institute in the UK, especially Ishmael Ruffels [sic] is trying to come up with measure of interdisciplinarity.
- What do we do with research that crosses all 3 of the boundaries (i.e. between multi-, inter-, and transdisciplinary work).
- What is the distance between fields or subfields for it to classify as interdisciplinary?

Moving forward - how to actually integrate?

- We need to know how the terms multi-, inter- and transdisciplinary play out in everyday practice?
- As a productive internal group that can make any progress at all, members need to agree on the central premise of the project and the language, and where they think there is excitement going forward (about which area of these things they want to push forward with).
- The book, "Implementation and Practice," is a codification of what would constitute a

methodology/heuristics/laws for bringing people together to do interdisciplinary work. However, instead of the "one hat fits all" approach or the "I don't wear hats at all" approach, we need to think about this as a continuum/spectrum of ways to integrate disciplines.
- Sometimes bringing things together brings different epistemologies together and sometimes the epistemologies do not fit.
- There are structures that facilitate integration.
- What kinds of integration need to occur? Epistemological (world view), theories, methods, instruments, and resources.

Friday, November 5th: Roundtable #6. 1:30 pm

What kind of infrastructure would be necessary to create and sustain a community of researchers of interdisciplinary collaboration?

- Call former labs
- Populate metaspace with people who are reflectors and people who do the collaborating
- SciSIP is about accountability, broader impacts, RCR, etc. We need research on how to integrate intellectual research with broader impact.
- We need to fund an open source journal that takes away the gatekeepers.
    - You have a system where you can submit a paper and have other scholars rate it and if it gets enough ratings it is considered published. There is also a system for reviewers and their ratings count more than others. This could be a place where IDR needs to find a home, or a place for research on interdisciplinarity, or a pilot project for the first and then turn it into data for research.
    - One problem is what is the incentive process for the reviewers? Should there be status associated with being a reviewer? If you a reviewer with a certain standing, when you submit a paper you get read first.
- What is meant by "transformative"? Might be split reviews, which indicates that scholars regard it as different from the traditional.
- We need to change the way we think through the shift towards relevance and timeliness vs. methodological rigor.
- A virtual clearing house for finding people who can help you find experts, e.g., an academic facebook.
- There is a real challenge in terms of what is a fundable intervention.
- To improve IDR into interdisciplinarity (metaresearch or research on research)- Maybe scope the problem by collaborating with pairs of disciplines, or one particular topic instead of inviting all interdisciplinary scholars to an event like this because you get too much noise. This could be perceived of as exclusive as well. This could also cause specialization so delimiting the research area might shut down innovation.
- You could study things that have already been funded, e.g., centers, IGERTs, ITRs etc.
- Use RET model for ERC (Engineering Research Centers) in this IDR so grant for people attached to the IDR and then a separate grant for people attached to the project doing research on the IDR.

Group 4 Roundtable Summary

Thursday, November 4th: Roundtable #1, 11:30 am

1) What is the current state-of-the-art in your field for studying multi- and interdisciplinarity?

- Paradox in interdisciplinarity: Tenured faculty often ends up with the credit for taking IDR seriously. However, grad students often fuel this research, and then hand it over to older faculty – they are useful, but tenured faculty are the ones who push it into the arena.

- Learning on the part of individuals: are people changing their concept as a result of what they participate in? To understand this data can be collected in a number of ways.

- Non-video and video-ethnographic and interactive analysis work.
    - Video is a tool of collection, but also communication of results.
- Need data on 'failures' – comparison data between successes and failures.
    - Looking at student engineering teams… some fail and some are successful
    - Much experimental work helps us look at the concept of failure.
    - Is failure in a short-term engagement with others the same as failure in the long-term process?
    - How do we discern whether failure is a result of interdisciplinarity or not?
    - Something that needs an interdisciplinary approach may fail/succeed dependent upon the nature of the scientific problem and other internal reasons for failure.

Advances in the tools for interdisciplinarity
- Computer technology
- Mail and other forms of communication
- Conceptual tools

- How do we separate collaboration and interdisciplinarity?
- Experimental Perspective: creating groups and studying them as they attempt to accomplish a task. What's happening within the confines of the team and how does the team view (perceive) expertise?
- Historical cases/case studies. Look at different time scales: historical changes within interdisciplinary projects
    - Historians typically study things on the biographic model – include historians into interdisciplinary models. (Shrum did attempt this.)
    - Defined the study at the level of the collaboration. Did interviews with each person, but also wrote histories of the evolution of the collaboration.
    - Cross-tab analysis looking for relationships and do case studies of those that reflected the patterns in relationships (trust, etc.).
    - Considering 'space'
    - Knowing the history behind the disciplines that come to the table is important, because those histories are brought to the table when people attempt to collaborate.
- Consider uneven playing fields between collaborators and the 'politics of knowledge.'

  - Example: Center for Society and Genetics
  - Keeping the CSS on medical campus made it difficult for collaboration between social sciences and biological sciences because of relative power of the two groups. They moved it to the social sciences side of campus, which helped foster collaboration between the two groups.

- Physical proximity creating relationships, which then creates collaboration. What is the special distribution of work amongst collaboration?
  - If you collaborate with someone who works in the field, as opposed to in an office, what are the benefits/consequences associated with that?
  - What consequences does that have for the ability to publish and produce knowledge?

- The 'gate keeping' process as a barrier/facilitator for interdisciplinarity
  - Publishing expectations
    - Some disciplines publish books, others publish in journals, and others publish at conferences.
    - What are the barriers associated with different publishing expectations?
  - Where does gate-keeping happen? Hiring, tenure
- Do most people who work in interdisciplinary studies work at professional schools? Venues for publication allowed
  - Duke University has a committee to help inter-disciplinary faculty get tenure – they review non-traditional publications and assess them for how rigorous they are.
  - LSU allows faculty to publish wherever they want after they are accepted as faculty.
- Training of graduate students

Why do we study interdisciplinary work and who do we want to inform?
- If there is a purpose to doing interdisciplinary work, shouldn't we find ways to get that information out to people who want to have access to that knowledge?
- Is interdisciplinarity a topic in itself? It's an attribute of collaboration.
- Studying this should guide our feedback into the community that finds this important.
- Why you study interdisciplinarity matters… in terms of where you want to publish – it can inform traditional approaches, as well. Perhaps it's not necessary to have a separate topic: interdisciplinarity.

Where do you go to study multidisciplinarity? What do you currently go to?
- Northwestern – Team Science, they run an annual conference
- Stanford Team Science grants – understanding is much more rudimentary about how to manage teams and people with different perspectives.
- Using combos of bench scientists and practitioners.
- NSF
- Can also go to a successful collaborating scientist and ask them about their work.
  - However, many who are successful haven't actually thought about what makes them successful.
  - Often, those that are successful have very tough beginnings (how do we define success?). The struggle of getting started caused the success – in having trouble

getting money… this is a long term process where it gets knocked down and then eventually gets picked up again and becomes recognized.
    - This marks the need for comparison data, because many collaborations are failures until the point where they succeed/get funding.

Thursday, November 4th: Roundtable #2, 2 pm

1. What are the standard concepts used in researching multi- and interdisciplinarity in each of your fields?

Standard concepts

- Interdisciplinarity vs. Collaboration
- Collaboration is possibly a lower level of analysis.
- Knowledge diversity may be what's most important here.
    - The 'between disciplines' aspect may be secondary to the question: what shapes how individuals with different sets of knowledge work together on something?
- How are the concepts used different within a group?
- Performance variables (dependent)
- Trust (intermediate variable, really)
- Independent variables:
    - Cohesion
    - Trust
    - Shared Social Identity
    - Level of Interdisciplinarity (are we talking about combining methods - Mechanical Engineers with Computer Scientists, or identities – Object oriented learners and Visually oriented learners, or are we talking about combining theories – evolutionary theory and cognitive theory)
    - Conflict
    - Networks
    - Pre-existing (reputational) variables (how do groups recruit new members)?
- History, Intergenerational Structure

Ways of Measuring

- Experimental
- Manipulation of an identity to see outcomes of collaboration
- Level of overlapping of information within collaborating groups
- Networks
- We may understand interdisciplinarity within a department (5 sociologists who come from different backgrounds)
- We may also understand interdisciplinarity between departments (political science, psychology, sociology)
- Evolutionary theory of intellectual ideas
- Historical evaluation of cases of interdisciplinarity (looking specifically at the dependency of interdisciplinarity, on technology and other historical contexts)

Thursday, November 4th: Roundtable #3, 4:30 pm

1. What are the main gaps in the state of the art, from the perspective of theory, data, and methods?

- Difficult to publish using anything but experimental or case-study data [or citation data]
- There are many ways to study, but only a few reach into the main spaces for legitimation (more prestigious journals).
- In some ways, there's an investment to maintain these gaps (gate-keeping doesn't allow all ways of understanding).
- This gets in the way of a number of collaborations: what is legitimate? What is a legitimate form of inquiry?
- Perhaps there doesn't need to be agreement, but an acknowledgement that there are different methods of study and an acceptance of this to come to a position on issues based on varied methods of research.
- Why might this be the case that social scientists don't find as much agreement, or may have a harder time collaborating?
- More of an emphasis on theory – perhaps
- The measurement problem – measurements underline measurement theory.
- What we decide to measure in the social sciences is actually a major part of the problems and disagreements we have.
- Citation analysis has a mature measure, but it has problems in that it doesn't analyze the process behind citations.
- Could we measure the dollar yield of IDR? This has its own problems with accuracy.
- Many of these measurements have been taken out of context – where a measure for scientific purposes is now used to punish or reward people in the real world. They are poorly designed for this endeavor.
    - Example: Using citations as a measure of productivity has led to the institutionalization of this measure as a way to assess faculty.
- What types of data are best suited for a cross-disciplinary study of multidisciplinarity, and thus, would need to be collected?
- We need a sociology of science and technology to study this phenomenon.
- Sociology of science already has a history of what we are talking about, and they've probably already played out quite a bit in this field.
- When people are working together, but the lines are blurred, it's hard to decide if this is even interdisciplinary.
- You need researchers who understand and have knowledge of the different disciplines they are observing.
- It may be most useful to work with one thing that you can measure and find core exemplars within a particular area of study that allows us to understand something specific.
- We need to distinguish between organizational interdisciplinarity and cognitive interdisciplinarity, which is much more fluid and difficult to define.
- Success can merge disciplines
- If an organizationally interdisciplinary endeavor is truly successful, it almost becomes its own thing, separate from the disciplines they come from.
- Looking at collaboration vs. interdisciplinarity
- How do we understand this concept as people begin to adopt cross-disciplinary methodologies?

Friday, November 5th: Roundtable #4, 9:15 am

1. After thinking over yesterday's discussion of the current state of the art and gaps, what are things we've missed in our discussions yesterday?

Outstanding research questions

- We haven't given very much concern to less developed areas of the world.
    - Interdisciplinary and collaborative work has neglected global problems – reference to other countries.
    - Other countries are left out of the existing database.
    - Major databases massively underrepresent China.
    - There may be bias based on the fact that science is currently based on English. Cross-cultural effects and variables are also important to look at.
    - In terms of resourcefulness: when you have fewer resources, it impels more interdisciplinarity and more flexibility in terms of who you work with.
- Specialization is often possible because you have the resources to do so.
- Race as a factor, or ethnicity.
- How do we measure perceived ability to collaborate?
    - We often measure based on productivity, which is defined by publications.
    - They aren't actually interested in producing in journals; they're interested in money.
- How do we scale up some of the findings that we have seen here? How do we scale up some of these observations and represent them in a way that we can generalize them?
- Collaboration with others who use different methods: Surveys happen a lot for some present, but not a lot of ethnographic work. This means there is always data missing that makes findings more difficult to generalize.

- How do we learn to do research that is at the intersection of disciplines? Combine different research questions:
    - What are our theories of learning, and why is it easier for some to adapt to new disciplinary expectations than others?
    - What are the features of the dynamics that allow learning to take place?
    - How do certain scientific outcomes come about (what are the dynamics of interdisciplinarity)?
    - We also need to include the changes in curricula – how do disciplines change over time? (Perhaps this is more about the context of learning).
    - Context is important – what level of analysis are you looking at? Each of these points is important, but we may not be able to include them in the same study.
    - As we begin to put these layers together, we begin to have a much richer picture.
    - How might we test causality
        - Correlational cross-sectional studies, manipulation and experiment, and other methods will help establish causality in different ways.
    - This is where the interdisciplinarity in the study of interdisciplinarity is useful.
- This workshop is an example of the difficulties of collaboration and the difficulties in what we're studying.
- Non-academic collaborators. There aren't many studies on the concept of non-academic collaboration

- Technological innovations
- Spin-offs to start a company, collaborating with advisors and early investors
- Public spaces and rezoning require collaboration and collaborative studies.
- How do social problems and issues affect science and who collaborates with whom?

Friday, November 5th: Roundtable #6. 1:30 pm
What kind of infrastructure would be necessary to create and sustain a community of researchers of interdisciplinary collaboration?

- Limiting the number of institutions and/or disciplines involved
- The combination of crossing disciplines and institutions is the worst.
- John King at University of Michigan, writing a report for NSF on the study of collaboration.
  - Discusses how NSF should fund studies of collaboration.
  - Mini-funding agencies
  - Minimize coordination costs by subcontracting the job to a group of institutions that can decide who gets a certain pot of money.
- Strategic use of information technology
  - Make use of the Internet for collaboration.
  - Make *realistic* use of IT resources without going overboard
- Data curation support.
- Incentives
  - Monetary, or otherwise.
  - Tenure
  - Prizes that help you achieve tenure? Institutionalizing the prestige of ID research.
  - Recognition
  - Supporting existing programs
  - Funding already existing programs help people who do this research
  - STS programs and interdisciplinary programs
  - Synthesis Centers

- How can we integrate the data that are out there instead of encouraging more and more research when data may already be out there? This would help us to narrow what research further needs to be done.
- The universes in which research occurs are difficult to bring together because of boundaries, but we would get insight into doing just that.
- Budgetary concerns to consider.
- Should we change the question of interdisciplinarity to success in innovation? Then, we can understand interdisciplinarity as one aspect of what makes research processes successful.
  - What is the ideal 'innovation incubator'?
  - What are examples of very successful centers and institutions for innovation?
  - Collaboration can go bad, at a certain point.
  - The study of innovation needs to pay attention to these curvilinear relationships.
- Economics: Many universities don't have experts in your topic in every department, so you have to go outside. Do you develop and grow your own, or do you work with others at other institutions? There may be university-specific differences in the process of interdisciplinarity. There may be differences between regional centers for academia and being at universities

that don't have spatial access to other universities and academics.

- Rethinking 'team' collaboration. Is there a space/time element? Teams may vary based on much more elusive variables like space and time, vs. 'universities' or this more concrete ideas.
- And outcomes may be something akin to the idea of 'innovative energy' or 'creative energy,' etc.
- The 'bending' of trajectory (innovative trajectories) – individuals with different sets of information may 'bend' the innovative process.
- Synthesis Centers: One participant mentioned 'bobcows' in Santa Barbara. Idea of synthesis centers is to bring together disparate data and thrash through ways to fit findings together to understand problems.
- INGROUP – A working group meeting that might be able to attract attention. 7 or 8 major disciplines that are there – they do group team research.

Infrastructure Ideas

- Open source journal
- Reviews and reviewers get rated
- Process is open, and may get rid of some narrowing of disciplines.
- Clearing houses
- Academic version of facebook??
- Being able to get funding to work in a different department for a time (in a different discipline).
- How do you break mindsets?
- We may need to develop a model of collaboration
- Find ways to create a big panel of person-level career data. You could see which groups get access to grants and compare ones that get funded to those that don't get funded.
- Build off of the notion of career to let you see interesting aspects.
- Incentives to participate are huge
- A career can be personal, or the career of the project.

Combined Groups 1-4 Full Group Discussion, Replaced Roundtable #5

Friday, November 5th: Full Group Discussion, Replaced Roundtable #5, 10:45 am
(Combined notes)
1. How can we be reflexive (employing different forms of evaluative measurement, and considering data collection, curation, and dissemination) in the study of cross-disciplinary collaborations?

2. How can we measure ourselves – the work we are doing, our own success (short- and long-term)?

- One discussant brings up the issue of rent seeking. Certain people control valuable resources and this affects our measures of ID (ex. I have a machine, so I let you use it in exchange for co-authorship). Rent seeking is likely connected to race and gender.

- Changing the measure of citations:
    - A discussant suggests improving work using citations see how removing PIs from the analysis affects the outcome. A question is raised concerning how to know who is a PI. Also, it would be difficult to accomplish this for a large dataset – it would be very labor intensive.
    - Someone suggests using 'surrogate variables' (like they do in epidemiology) to tease gender, race, etc from data. Another suggests building institutional affiliation into the analysis.

- NSF data:
    - There is a discussion lamenting NSF's inability and unwillingness to release the data it gathers to the public. NSF wrestles with questions like this, but questions of confidentiality often trump the research public's desire to utilize the data.
    - A discussant suggests that the NSF gather the data and than analyze it in-house. Evidently NSF does, but that people should push their advisory committees to do this.

- Additional data sources and variables to examine:
    - Critical assessment of interdisciplinarity (Frickel and Jacobs, *Annual Review of Sociology* piece)
    - Another participant notes using data from professional societies to learn about members. For example, who is submitting papers, participating in meetings, etc? Where and how are people participating?
    - Serving on dissertation committees, patenting as other measures of ID.
    - Levels of analysis ID researchers can use to study themselves: One discussant suggests ID researchers uses methods historians use to study the movements of fields, while another suggests using more interactional methods favored by those who study small groups. Is there a practical way to for ID researchers to study ID researchers?
    - One discussant suggests looking at the number of research centers in relation to departments over time. For example, Stanford received funding to study 2 or 3 ID

centers at many different levels of analysis. Looking at the impact of these centers on ID collaboration.
    - There is a lot of work out there that looks at membership categories, but what about encouraging more psychologists to study personality types and their effects on ID research? What sort of personality characteristics lend themselves to ID? Are there ID 'virtues'? If so, how do we approach studying them?
    - The value of creativity theory, examining teams and leaders. You can't just put people together on a team and assume things will work out. Different kinds of people and leaders will lead to different outcomes.
        - For example, do leaders allow minority voices to be heard?
        - Also, people don't necessarily speak the same language. People also bring their institutions with them (rules, habits, funding requirements, publication expectations, etc), so we cannot think of people in teams as individuals. "Individuals always come with the baggage of their institutions."
        - Teams of teams: interdisciplinary work does not just merge personalities but also existing databases, preferred software, protocols for graduate students, etc.
    - Toward the end of the discussion, the conversation moved back to questions of creativity and cognitive styles. What mix of cognitive styles work together most effectively in the ID field? ID teams need different types of people in different roles.
        - One participant points out that there are no representatives from personality psychology.

- How can we define reflexivity? Do we ask normative questions (why this way and not another?) or others? What are the criteria for reflexivity? A definition wouldn't solve the problem, but would open the pathway for debate. It would be difficult to [translate?] criteria.
    - A discussant splits the question into two parts:
        - 1. How do we know what we're doing?
        - 2. How do we know we're doing it well?
    - Participant argues that question 2 is premature. It cannot be answered until we have a survey of the field.

- ID carries with it the problem of integrating different types of knowledge and including different publics (i.e. scientists, policy makers, the general public(s), etc, all of whom have different skill levels, capacity to understand the work, and interests).

- Gender, race, marginal groups:
    - A discussant points out that the discussions have ignored the developing world. It may be that researchers in the developing world collaborate more out of necessity (lack of resources, etc).
    - One discussant suggests that women may use ID research as a strategy to define their own research agenda. Women, who often face time and resource constraints, may struggle with the mainstreams of their fields, so they may turn to ID as a way to define their own areas and make valuable contributions.
    - How are the processes of ID research racialized and gendered? How do 'strangers' (women and minorities) experience ID work when they move into groups/teams

dominated by white men? How are they experienced by those white men? How does the introduction of 'strangers' reshape relationships?

- Value of ID:
  - Is ID is good for everyone?
  - Does losing depth in disciplines hurt them?
  - Who is best suited to collaborate across disciplines?
  - How do we take ID research and turn it into practice?
  - Disciplines themselves die when they "run out of variables." ID research can bring concepts and ideas from one area to another where they still have something to add.
  - Stakeholders outside of the academy care about the dependent variables ('problems' to the outside world) researchers study. "Publics and policy-makers are interested in dependent variables, i.e., what you are trying to explain."

- What about incentives? What drives scholars to ID research? Funding? Skill Building? What about disincentives?
  - The NSF and other government agencies provide short-term incentives, but the long-term consequences of ID research for careers are unclear.
  - What does ID research do to chances for tenure and promotion?
  - What about external vs. internal (within department) validation
  - Do people avoid ID research early in their careers because of disincentives or a lack of incentives?
  - Departments tend to assess candidates (for tenure, promotion, etc) on the basis of external acceptance. Researching ID research would provide a basis for ID researchers and departments to assess ID researchers' outside contributions and acceptance.
  - The conversation returns to a discussion of hiring committees and junior faculty. Someone asks if departments will be willing to hire, for example, 'half an economist.' Why would departments hire a person who spends half his or her time working in different fields when there are plenty of candidates who work exclusively to advance knowledge within the discipline? Do ID scholars become "pets" in Kanter's conceptualization (friendly, kind of fun, they get grants, but don't have a seat at the table) or are they treated as "peers?"

- Development of disciplines:
  - What about the implications for the relationship between science and society? In the past, science was divided into departments where scientists were disconnected from society. Those scientists created knowledge that those outside of science (on the other side of the wall) could use for their own purposes, but this divide is (or may be) breaking down. Now, departments are being replaced by problems as science's organizing forces, and the implications for society are more important to the research than in the past. One discussant mentions 'transdisciplinarity,' which somehow is connected to society's demands on science.
  - To stay on the cutting edge of one's discipline, then, one must look at other disciplines, who offer new dependent variables. Also, this process forces disciplines to look at their problems in deeper ways. New fields begin as MD, but become

increasingly narrow over time. They then become disciplines, eventually run out of variables, and become MD again. The process occurs again and again.
    - Over time, methodologies within disciplines become increasingly complex. One discussant compared this process to a rubber band being stretched: as methods become more complex, each generation only has to learn to understand a small portion of that complexity, technology - in the form of statistical packages, etc – take over for the users of the new methods.
    - What about the structural and economic forces that shape fields? What 'forces the hand of a field'? Markets do this (such as google driving a need for certain types of knowledge).

- What about the capacities of departments to seek funding? Some departments may be very well equipped to seek outside funding, while others aren't. A financial analysis of different types of institutions would be useful here. Some institutions, for instance, seek out a large numbers of grants/money to build buildings.

- One discussant offers "reality check" for the science end of it: Can we recognize a breakthrough in a science where there was knowledge in one place that gets moved to another? What is the new phenomenon in ID—"is it new knowledge, new tools, or a reorganization of institutional practices?"
    - Another discussant offers network theory as an example of a breakthrough. Network theory began as a relatively unimportant area, but has since developed techniques (that are heavily computational) that have spread to, and influenced, many fields.
    - Calculus is offered as another example.
    - In terms of creativity, one can also consider breakthroughs vs. incremental changes—both can be types of creativity and progress.
    - Is it about new insights, and/or is it about the distribution and education of science?

Appendix E: Infrastructure Improvement Rankings

Idea	Median Rank	Average Rank	Standard Deviation	N (not everyone responded to each)
(I) encouraging institutional incentives for interdisciplinary research that sidestep traditional academic reward and hiring systems	2	2.9	2.5	7
(B) forming a dispersed set of centers that would meet periodically (as with Oceanic Studies) or other kinds of synthesis centers	3	3.6	2.8	7
(A) creating a loosely connected group that could easily share and exchange ideas (as with the Society for Social Studies of Science, 4S)	4	5.1	3.7	7
(C) keeping the study of interdisciplinarity specific and problem-based	5	4.5	3.0	6
(D) promoting interdisciplinary skills, interests, and career progression via funding postdoctoral and senior fellowships, visits, and cross-training across institutions	5	4.3	2.4	6
(H) establishing infrastructure for sharing data across disciplines about scientists and science projects	6	4.9	3.4	7
(G) establishing technical infrastructure that supports searching for articles across different disciplines, taking into account disciplinary language differences	8	7.3	3.4	7
(J) setting up a virtual clearing house for finding experts who are helpful (e.g., an academic Facebook)	8	7.8	3.8	5
(E) funding an open source journal for publishing on interdisciplinary collaboration	8.5	8.3	2.9	6
(K) conducting a cross-disciplinary literature review describing similarities and differences in terms common to the study of interdisciplinary collaboration (e.g., "interdisciplinary," "collaboration," etc.).	9	8.8	2.6	6

Idea	Median Rank	Average Rank	Standard Deviation	N (not everyone responded to each)
(L) Linking existing centers and groups in some manner	10	8.2	3.7	6
(F) promoting online journals that support peer review via large expert crowds rather than the typical 2-4 reviewers	12	11.4	2.1	5
(M1) Other (write-in): Keeping the study of interdisciplinarity separate among disciplines, but engaging all these disciplines and research networks in a shared clearinghouse of references	3	2.7	1.5	3
(M2) Other (write-in): encouraging reform of existing tenure and promotion criteria (note: see also I)	3	3.3	2.5	3

Appendix F: Participant-Suggested Citations

At the end of and after the workshop, participants were asked to send in 2-3 relevant citations regarding the workshop topic from their different disciplines. Here is what they sent.

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Additional Resources

Holly Falk-Krzesinski (h-falk@northwestern.edu) maintains an Endnote database of Science of Team Science citations.

Julie Thompson Klein is a prolific author on interdisciplinarity. Here is a link to her publications: http://csid.unt.edu/about/people/klein/articlesandchapters.html

Appendix G: Original Workshop Proposal Citations

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