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Cognitive Sciences

Overview of the Science of Team Science

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Overview of the Science of Team Science

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- **Part 1. Why Team Science?**
  - 1.1. Setting the Stage
  - 1.2. Defining Disciplinary Approaches
  - 1.3. Interaction Across Disciplines
- **Part 2. The Scholarly Study of Science**
  - 2.1. Foundational Approaches
  - 1.2. Developing the Field of SciTS

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Why Team Science?

1.1. *Setting the Stage*

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ISSUE - ***Dealing with Aristotle's Legacy***

- Disciplines are distinguished partly for historical reasons and reasons of administrative convenience (such as the organization of teaching and of appointments)... But all this classification and distinction is a comparatively unimportant and superficial affair. **We are not students of some subject matter but students of problems. And problems may cut across the borders of any subject matter or discipline** (Popper, 1963).
- What is critical to realize is that "the way in which our universities have divided up the sciences does not reflect the way in which nature has divided up its problems" (Salzinger, 2003, p. 3)

CHALLENGE – ***Collaboration across the sciences***

- Must now bring together people from **differing disciplines** (and sometimes professions) so as to address the **multi-faceted nature** of complex problems

Why Team Science?
1.1. *Setting the Stage*

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ISSUE - ***Prevalence of Interdisciplinary Research***

- Collaborations influencing the **practice of science**
- Interdisciplinary collaboration influencing **production of knowledge**

CHALLENGE 1 – ***Make use of what we know now***

- Need to better **translate extant knowledge** on collaboration and on interdisciplinarity to the practice of science

CHALLENGE 2 - ***Much remains unknown with regard to interdisciplinary research***

- Difficulty in **defining** what is meant by interdisciplinarity
- Problem in understanding **how to do** interdisciplinary research

Why Team Science?
1.1. *Setting the Stage*

- Consider what was published on this topic in the journal *Science*:
  - "The interdisciplinary approach is becoming one of the prominent characteristics of [science] and represents a synthesizing trend which focuses the specialized research techniques on problems common to a number of separate disciplines. Such cooperative research has to overcome serious obstacles when operating within the existing departmentalized framework of the universities. It appears that real progress in this direction will be made in institutions which are organized on a permanent and frankly cooperative basis. Psychologically, interdisciplinary research requires not only abstract, theoretical intelligence…, but also 'social intelligence.' Cooperative work is a social art and has to be practiced with patience."

Why Team Science?
1.1. *Setting the Stage*

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<u>What is informative here?</u>

- Increasing influence/importance of interdisciplinarity as method of inquiry
- Challenge of interdisciplinarity distinguished in 2 ways
  - 1) The problem of **<u>infrastructure</u>** - tangible and tacit
    - Inherent challenge associated with structure of the modern university - <u>the discipline bound department</u> - and the tacit norms which prevent or stifle interaction amongst them
  - 2) The problem of **<u>interaction</u>**
    - Difficulty inherent in communicating and collaborating across disciplines and how patience and a <u>particular form of social intelligence</u> are necessary precursors to effective collaboration in such environments

Why Team Science?
1.1. *Setting the Stage*

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- Anyone familiar with some manner of cross-disciplinary collaborative effort will likely have experienced some or all of these factors
  - ***So one might wonder why this quote is particularly informative***
- What is informative is not **what** was said, it is **when** it was said
  - ***Written well over a half century ago in one of first articles specifically addressing interdisciplinary research (Brozek & Keys, 1944).***

- **Science still struggles so why should we think anything will change?**
  - ***Should we be so bold as to think that we have a better chance at overcoming these challenges than those from generations before us?***

Why Team Science?
1.1. *Setting the Stage*

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- **YES - for THREE main reasons:**
  1. Increased **emphasis on collaborative research** projects that create a team of scientists to address some complex phenomenon
  2. **Policy, Academia, and Industry** communities all making more of a concerted effort to examine scientific collaborations
  3. Tremendous **growth in the study and understanding of groups and teams**
     - ***It is the scientific study of teamwork that could be the true catalyst for change***
       - Matured into its own area of inquiry producing a rich base of knowledge
       - Helped us to better understand the complex coordinative processes engaged by teams
     - **To understand why "teamwork" matters, we need to understand what is interdisciplinary research**

Why Team Science?
1.1. *Setting the Stage*

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CROSS-disciplinary Research

- Offer this as a <u>general term to describe:</u>
  - Research meant to utilize, in some way, varied concepts, methods, and theories from differing fields
  - Where science team members contribute their disciplinary expertise and collectively contribute to the production of new knowledge
  - ***Multi-, Inter-, and Trans-disciplinary Research***

Hall, K.L., Vogel, A. L., Stipelman, B.A., Stokols, D., Morgan, G., & Gehlert, S. (2012). A four-phase model of transdisciplinary team-based research: Goals, team processes, and strategies. *Translational Behavioral Medicine, 2(4)*, 415-430.

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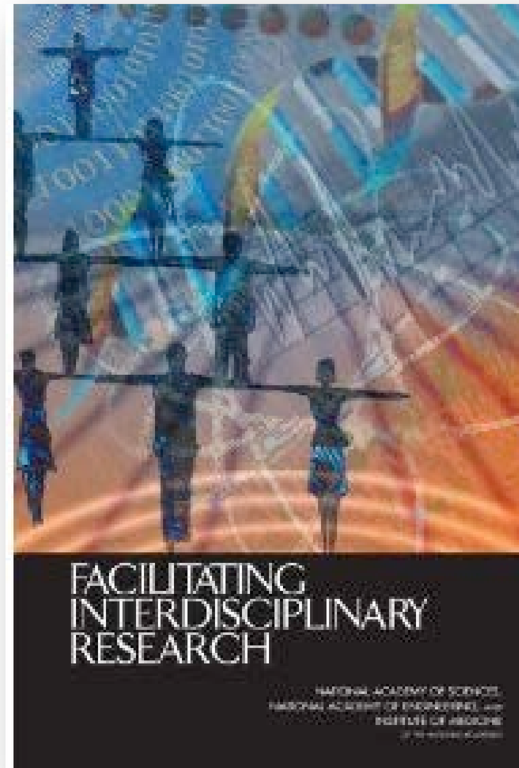
Why Team Science?
1.1. *Setting the Stage*

MULTI-disciplinary Research

- <u>**Collaborative effort**</u> of several disciplines to achieve a common goal
  - *Purpose is to achieve **broader analyses** of common research problems*
- Work independently or sequentially
  - *Periodically come together to **share perspectives***
- Contributions drawn from different disciplines are <u>**complementary**</u>
  - *In service of objective, adopts but not necessarily integrate methods, concepts, theories*



- ***Scientists in multidisciplinary teams remain firmly anchored in the concepts and methods of their respective disciplines.***

Why Team Science?

1.1. *Setting the Stage*

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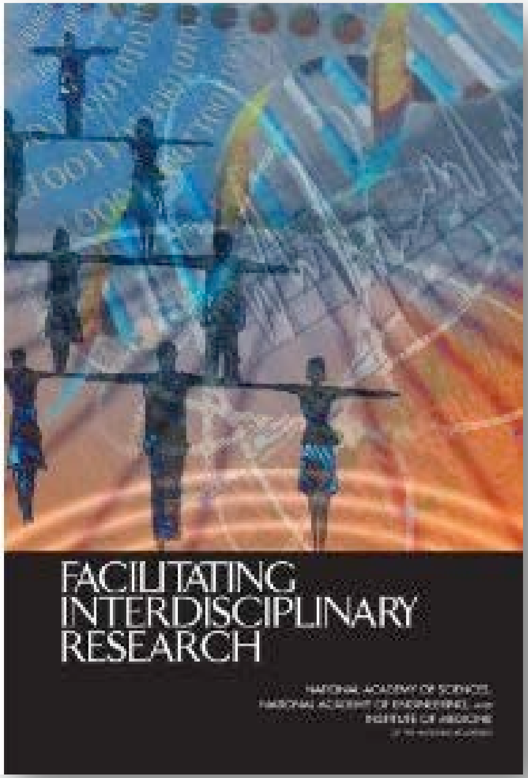
INTER-disciplinary Research

- Demands **more than just complementarity**
  - Team members **combine or juxtapose** concepts and methods from different disciplines
  - Overarching goal is systematic **integration**
    - **Integrates** information, data, techniques, tools, perspectives, concepts, and/or theories from **two or more disciplines** or bodies of specialized knowledge



- ***Goal is to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or field of research practice.***

Why Team Science?
1.1. *Setting the Stage*

TRANS-disciplinary Research

- Integrates and **builds from** discipline-specific theories, concepts, and methods
  - Pursues collaboration **across levels of analysis**
  - Develops **comprehensive understanding** of problem
  - **May** also include:
    - A focus on **societal problems** and development of **practical knowledge**
    - **Translational partners** from differing sectors (NGO, Community, Industry)

- ***Transcends disciplinary perspectives and enables development and application of new methodologic or conceptual frameworks***

1. Why Team Science?
1.3. *Interaction Across Disciplines*

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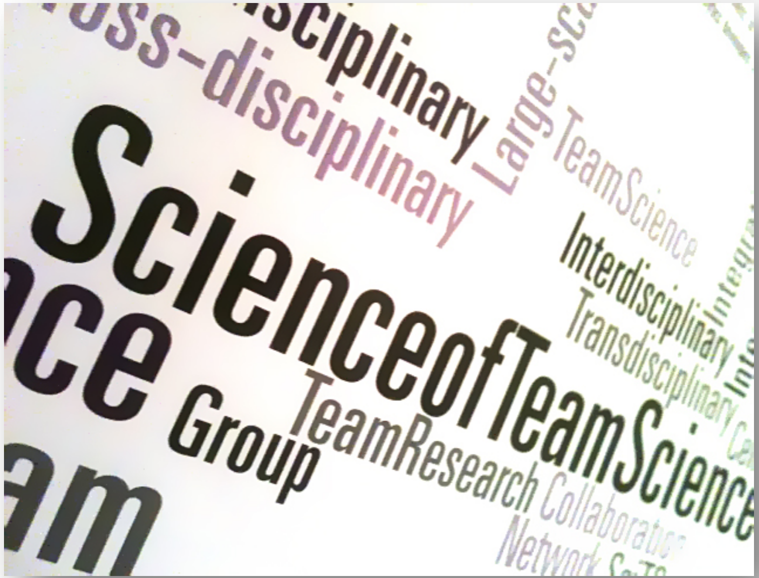
- Interdisciplinary and transdisciplinary research require action -- **act of connecting or <u>inter</u>acting among disciplines**
- But not just any activity, a ***team activity*** -- a process engaged by members of a **<u>coordinated scientific team</u>**
  - Teams are "two or more individuals who must <u>interact</u> and <u>adapt</u> to achieve <u>specified, shared, and valued objectives</u>" (p. 4, Salas, Dickinson, Converse, & Tannenbaum, 1992).
- <u>Characteristics of Teams</u>
  - **Multiple <u>information sources</u> and intensive <u>communication</u>**
  - **<u>Task-relevant knowledge</u> with meaningful task <u>interdependencies</u>**
  - **<u>Coordination</u> among members with <u>specialized roles/responsibilities</u>**
- Teamwork <u>inside and outside of science</u>
  - ***Both bring people together to achieve objective(s) that an individual could not achieve and do so while maintaining partially overlapping knowledge***

1. Why Team Science?
1.3. *Interaction Across Disciplines*

- Reframe interdisciplinary science as a process of teamwork to be mastered
  - ***By understanding the teamwork activities necessary for success we can make the achievement of interdisciplinary science more tractable***

Science of Team Science

- Understand and improve how scientists interact and integrate across disciplinary, professional, and institutional boundaries (e.g., Börner et al., 2010; Falk-Krzesinski et al., 2010; Fiore, 2008; Hall et al., 2008; Stokols et al., 2008).



Requires we build from and synthesize:
(1) The scholarly study of science
(2) The scholarly study of teams

Overview of the Science of Team Science

- Part 1. Why Team Science?
  - 1.1. Setting the Stage
  - 1.2. Defining Disciplinary Approaches
  - 1.3. Interaction Across Disciplines

- Part 2. The Scholarly Study of Science
  - 2.1. Foundational Approaches
  - 2.2. Developing the Field of SciTS

2. The Scholarly Study of Science
2.1. *Foundational Approaches*

History and Philosophy of Science

- Decades long tradition of scholarly work examining science and medicine through historical lens
- Draws from Philosophy, History, Anthropology, Sociology
  - Examines how humanity's understanding of the natural world has changed over the centuries
  - Studies the cultural, economic, and political impacts of scientific innovation

2. The Scholarly Study of Science
2.1. *Foundational Approaches*

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Science & Technology Studies

- More recent tradition examining the **social dimensions** of **science and technology**
- Examines how scientific and technical knowledge is "**created, evaluated, challenged, spread, and fitted into social relations**"
  - Studies **normative issues** influencing developments of S&T
  - Explores the **role of S&T in society**
  - Explores **ethical implications** arising from S&T

2. The Scholarly Study of Science

2.1. *Foundational Approaches*

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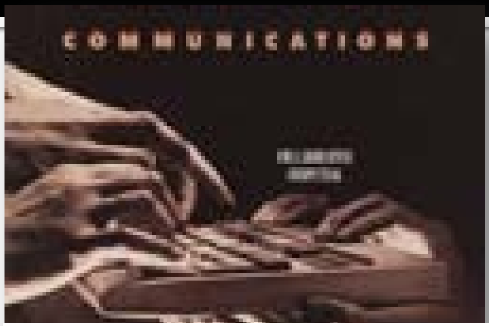

Update On National Science Foundation Funding Of The "Collaboratory"

Laurence C. Rosenberg

NSF-funded collaboratories are experimental and empirical research environments in which domain scientists work with computer, communications, behavioral and social scientists to design systems, participate in collaborative science, and conduct experiments to evaluate and improve the systems. These research projects are concerned with distributed and collaborative research that requires intense reliance on wide-area networks and the Internet, to bring together instruments, laboratories and researchers.

Three NSF programs in the Computer and Information Science and Engineering Directorate support the design of collaboratories and coordination experiments:

1. *Coordination Theory and Collaboration Technology Special Initiative (CT2).* This initiative supports the fundamental research of relevance to the design of collaboratories. The research covers a broad spectrum of coordination problems, from formal theory to software design and collaboratory development. For the past two years, the Information Technology and Organizations (ITO) Program has coordinated this initiative. A total of 17 awards have been made. Funding for existing as well as new CT2 awards is expected to be about $3 million this year. Also starting in FY 1991 the initiative has been institutionalized by making it an integral part of the ITO program, with an enhanced base to its budget.

2. *Research on scientific databases.* A new call seeks proposals for work on problems that are fundamental to the design of scientific databases, written by interdisciplinary groups that include relevant domain scientists. The success of the overall collaboratory design enterprise requires the ability to store and easily access the data and knowledge in extremely large, heterogeneous and distributed databases. The Database and Expert Systems Program coordinates this effort. Funding for proposals under this announcement will total more than $1 million.

3. *The Gigabit Network project.* NSF and DARPA have awarded over $15 million to the Corporation for National Research Initiative (CNRI) to create testbeds to perform research on the design and development of networks that operate with data rates of about one GB per second. The availability of GB networks may enable a major paradigm shift from text-based to image-based communication. Five contracts awarded by CNRI address network architectures and potential applications for GB networks. This testbed research includes distributed computing using multiple supercomputers and workstations, and real-time processing of composite high-speed data streams. The experiments explore the feasibility of group collaboration over the network and the use of GB networks to develop simulated environments. C

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LAURENCE C. ROSENBERG is deputy director of the National Science Foundation's Division of Information, Robotics and Intelligent Systems (IRIS). This division supports fundamental scientific research on the approximation of certain human capabilities in computers and on the accommodation of individuals, groups and organizations to environments that incorporate sophisticated computer and communications technology. He is responsible for NSF's research funding efforts on the development and use of computer and communications technology for scientific collaboration and cooperative work.
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Cooperation, Coordination and Control in Computer-Supported Work

Rob Kling

The Technologies for Computer-Supported Cooperative Work

Researchers disagree about the definition of computer-supported cooperative work [CSCW], but the current definitions focus on the technology. CSCW may be seen as a conjunction of certain kinds of *technologies* (described elsewhere in this issue), certain *kinds of users* (usually small self-directed professional teams), and a *worldview* that emphasizes convivial work relations. These three elements, taken together, differentiate CSCW from other related forms of computerization, such as information systems and office automation. They differ as much in their typical users and the worldview describing the role of technology in work, as on the technology itself. CSCW is the product of a particular computer-based social movement rather than simply a family of technologies [13]. Descriptions of these technologies in the CSCW

- *Computer Science and Development of Collaboration Technologies*
  - Rise of distributed teams and "collaboratories"
  - 1991 issue of *Communications of ACM*
    - **<u>NSF-funded collaboratories are experimental and empirical distributed research environments</u>** in which domain scientists work with computer, communications, behavioral and social scientists to design systems, **<u>participate in collaborative science</u>**, and conduct experiments to evaluate and improve the systems.

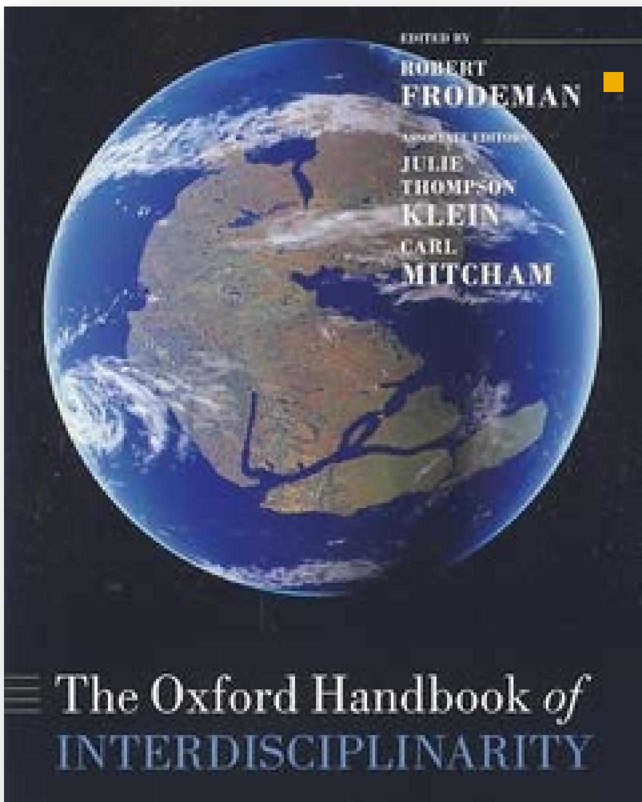
Studies of **<u>distributed scientific collaboration</u>** by Computer Scientists set the stage for studying scientific teamwork

- Pioneering work of Gary and Judith Olson on CSCW in collaboratories
- Foundational work by Jonathan Cummings and Sara Kiesler on effectiveness in distributed science centers

2. The Scholarly Study of Science
2.1. *Foundational Approaches*

Scholarship of Interdisciplinarity

- Works to support arts and sciences on intellectual and organizational issues related to furthering integrative studies.



- *The Oxford Handbook of Interdisciplinarity*
  - Edited by Robert Frodeman, Julie Thompson Klein and Carl Mitcham
  - Summarizes state of interdisciplinary **research, education, administration and management**
  - Crosses disciplines and interdisciplinary fields, and spans space between **academic community and society at large**

2. The Scholarly Study of Science
2.1. *Foundational Approaches*

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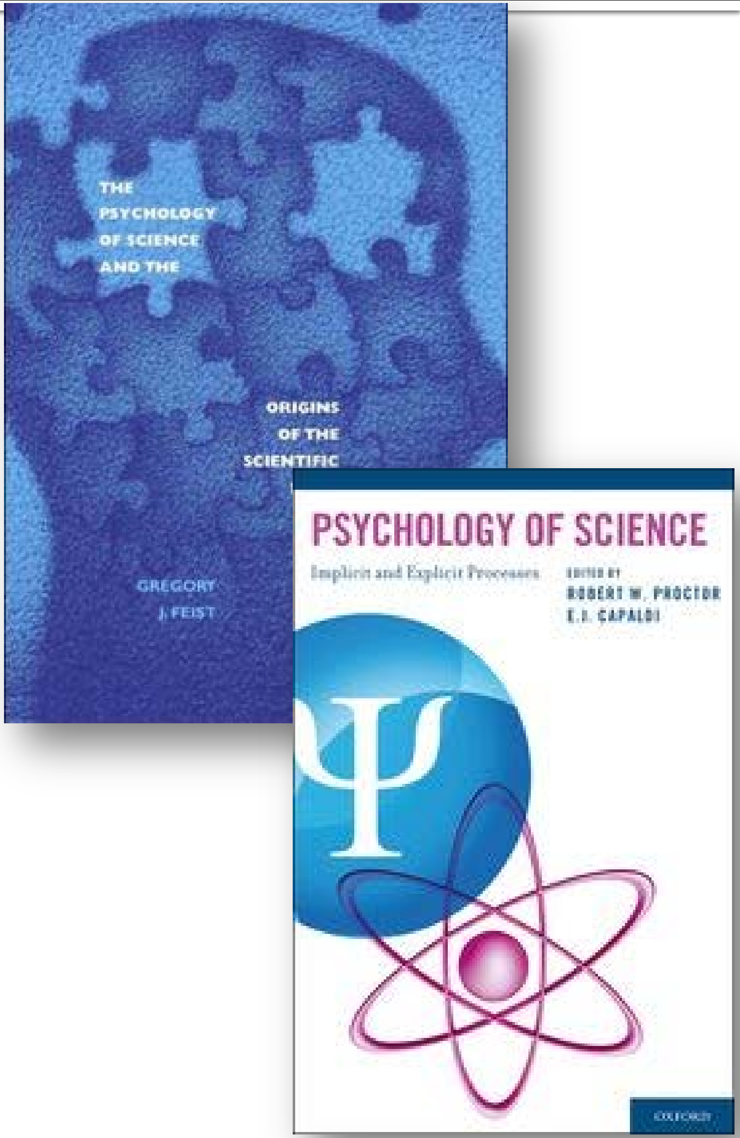
The Psychology of Science

- More recent addition to study of science
  - Focuses on **psychological constructs** like intelligence, motivation, personality
  - Studies psychological forces in an individual's **development of scientific interest, talent, and creativity**.
- *Goal is to unite psychological scholars of scientific and technological thought and behavior*



2. The Scholarly Study of Science
2.2. *Developing the Field of SciTS*

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The Science of Team Science

- Policy community saw greater **investment in research across scientific disciplines** and knowledge
  - "*the inherent complexity of contemporary public health, environmental, political, and policy challenges… [leads to] realization that an integration of multiple disciplinary perspectives is required to better understand and ameliorate these problems*" (Stokols et al., 2008).

- Recognized need to systematically integrate scholarly examination of scientific processes and outcomes.
  - **Commitment to understand** how to enhance the scientific capacity to **address complex problems**

2. The Scholarly Study of Science

2.2. 2003 - *Developing the Field of SciTS*

nature

3 July 2003 Volume 424 Issue no 6944

Who'd want to work in a team?

Biologists and their institutions are increasingly confronted by the challenges of working in major collaborations that other disciplines have already addressed. A gathering last week showed how much further there is to go.

Team science is everywhere these days. The trouble is, you'd never guess it from an inspection of the universities that house it or the agencies that fund and supposedly foster it. Last week, a meeting at the US National Institutes of Health (NIH) on "Catalyzing team science" highlighted the difficulties, and proposed some solutions. What should disturb everybody is how far from reality many of those solutions are.

In one sense the challenges are nothing new. Particle and space physicists have been doing team science for decades. But many of those enterprises grew up around major facilities or dedicated institutions. Their goals were clear at the outset, and structures, processes and cultures developed accordingly. Furthermore, the disciplines involved — physics, astronomy, engineering and computation — are far from alien to one another.

Now fundamental biology and biomedical research are more and more facing similar challenges. But the teams are emerging within frameworks established for a more traditional ethos of investigator- and hypothesis-driven research. What is more, progress requires that biologists, chemists, physicists and engineers mingle and even merge their disciplinary cultures and languages — sometimes an extremely tall order.

Whether in genomics, chemical biology, nanotechnology or imaging for cancer research, the case studies at the NIH meeting time and again highlighted the need for good communication across the collaborations — weekly video meetings over the web seemed a minimal requirement for success. And personality is everything. "Pick people you can rely on," said one leader. "You cannot regulate for personality," said another, "but you can foster generosity of spirit."

Predictably, many of the recommendations were aimed at the NIH. And so they should be: the agency has identified team science as a key element of its 'road map', whereas, as the meeting frequently highlighted, its rules either obstruct team science or do too little to facilitate it. The meeting's conclusions (see www.becon.nih.gov/

treated as part of the team, in order to minimize delays and obstacles further down the road. Bear in mind, said one participant, that technology-transfer revenues amount to only a few per cent of most institutions' income, and that there are very simple model agreements that can be applied in most cases, minimizing the need to reinvent wheels.

Another key aspect to be negotiated at the outset of a collaboration is the inescapable need for principles concerning team publications. Many collaborations progress splendidly, only to come to blows when it becomes necessary to list authors on a publication. The meeting highlighted how useless is the list of authors as a measure of their contributions, and urged journals to allow authors to publish lists of their respective contributions to a paper. *Nature* and its associated journals already do this, but will take further steps to encourage it, for example by including fields for such information in the electronic submission template. Indeed, many at the meeting urged that we and other journals should make such information compulsory. Only journal editors at the meeting expressed reservations on this. Readers are invited to send in their views.

Due recognition

But the big theme that emerged time and again related to the inability, because of the way science is currently done, to give credit and recognition to scientists who are part of a team. For example, too often, teams aim for a few high-profile publications that cover a lot of ground in a highly condensed manner. These miss opportunities not only to spell out interesting technical developments achieved along the way, but also to ensure that the people who delivered such innovations get any external recognition for them. Team leaders need to pay more attention to fostering additional publications in specialized journals, not as 'salami slices', but as appropriately focused accounts of genuinely innovative developments in techniques.

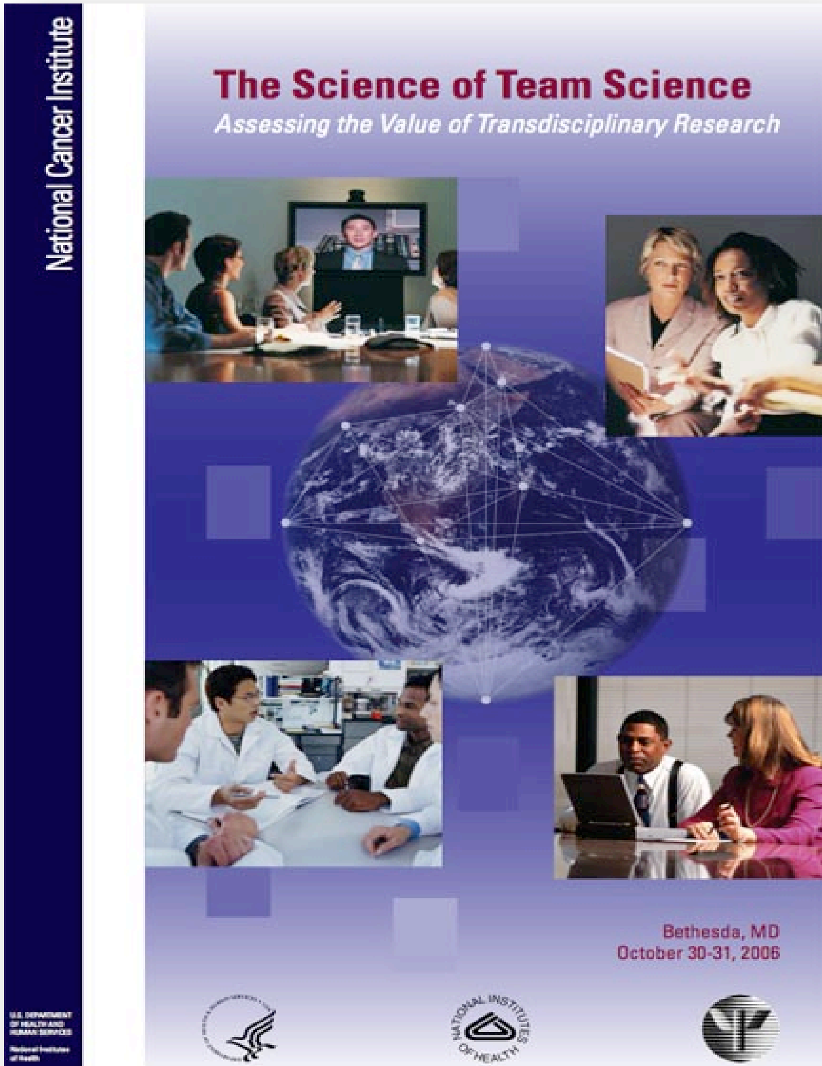
But the biggest challenge highlighted in the discussions is a scan-

- **Catalyzing Team Science** - Report from The 2003 BECON Symposium National Institutes of Health (NIH) Bioengineering Consortium
  - Discussed **<u>forces encouraging and discouraging</u>** team approaches to biomedical research
  - Examined ways to **<u>stimulate and reward</u>** team efforts

Factors identified as essential to success:

- A **<u>management structure</u>** that integrates leadership with communication
- **<u>Team environment</u>** incorporating integrity, trust, respect, and sharing
- **<u>Institutional commitment</u>** including space, administrative support, and faculty investment

2. The Scholarly Study of Science
2.2. 2006 - *Developing the Field of SciTS*



2006 NCI Conference on the Science of Team Science: Assessing the Value of Transdisciplinary Research

Examine:

- <u>State of the art</u> knowledge concerning transdisciplinary team science and training
- <u>Methods and metrics</u> available for evaluating transdisciplinary collaboration
- <u>Priorities</u> for transdisciplinary research

2. The Scholarly Study of Science

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2.2. 2007-2008 - Developing the Field of SciTS

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The Science of Team Science
Assessing the Value of Transdisciplinary Research

Guest Editors

Daniel Stokols, Kara L. Hall, Brandie K. Taylor, Richard P. Moser, and S. Leonard Syme

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Interdisciplinarity as Teamwork

How the Science of Teams Can Inform Team Science

Stephen M. Fiore
University of Central Florida

This essay discusses interdisciplinary research in the context of science policy and the practice of science. Comparisons between interdisciplinary research and other forms of cross-disciplinary research are made, and a brief discussion of the development of the concept of interdisciplinarity is provided. The overarching thesis of this essay is that interdisciplinary research is *team* research, that is, research conducted by a team. This notion is developed via recent policy discussions of *team science* and the need to understand interdisciplinary research in action. The author shows how it may be possible to consider the implementation of principles from teamwork and team training to improve interdisciplinary research and the practice of team science.

Keywords: *team science; interdisciplinary; teamwork; team training; graduate education*

Interdisciplinarity in research continues to influence both the practice of science and the production of knowledge. Yet, despite this influence, much remains unknown with regard to interdisciplinary research. Part of the problem stems from the difficulty in defining *what* is meant by interdisciplinarity. But perhaps the larger problem comes from understanding *how* to do interdisciplinary research. To illustrate, consider what was published on this issue in one of our more influential scientific journals, *Science*:

Author's Note: Development of this article was supported by Grant N000140610118 from the

2. The Scholarly Study of Science

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2.2. 2007-2008 - Developing the Field of SciTS

Science AAAS

The Increasing Dominance of Teams in Production of Knowledge
Stefan Wuchty, *et al.*
Science **316**, 1036 (2007);
DOI: 10.1126/science.1136099

The Increasing Dominance of Teams in Production of Knowledge

Stefan Wuchty,[1]* Benjamin F. Jones,[2]* Brian Uzzi[1,2]*†

We have used 19.9 million papers over 5 decades and 2.1 million patents to demonstrate that teams increasingly dominate solo authors in the production of knowledge. Research is increasingly done in teams across nearly all fields. Teams typically produce more frequently cited research than individuals do, and this advantage has been increasing over time. Teams now also produce the exceptionally high-impact research, even where that distinction was once the domain of solo authors. These results are detailed for sciences and engineering, social sciences, arts and humanities, and patents, suggesting that the process of knowledge creation has fundamentally changed.

An acclaimed tradition in the history and sociology of science emphasizes the role of the individual genius in scientific discovery (*1*, *2*). This tradition focuses on guiding contributions of solitary authors, such as Newton and Einstein, and can be seen broadly in the tendency to equate great ideas with particular names, such as the Heisenberg uncertainty principle, Euclidean geometry, Nash equilibrium, and Kantian ethics. The role of individual contributions is also celebrated through science's award-granting institutions, like the Nobel Prize Foundation (*3*).

Several studies, however, have explored an apparent shift in science from this individual-based model of scientific advance to a teamwork model. Building on classic work by Zuckerman and Merton, many authors have established a rising propensity for teamwork in samples of research fields, with some studies going back a century (*4*–*7*). For example, de Solla Price examined the change in team size in chemistry from 1910 to 1960, forecasting that in 1980 zero percent of the papers would be written by solo authors (*8*). Recently, Adams *et al.* established that over time, teamwork had increased across broader sets of fields among elite U.S. research universities (*9*). Nevertheless, the breadth and depth of this projected shift in manpower remains indefinite, particularly in fields where the size of experiments and capital investments remain small, raising the question as to whether the projected growth in teams is universal or cloistered in specialized fields.

A shift toward teams also raises new questions of whether teams produce better science. Teams may bring greater collective knowledge and effort, but they are known to experience social network and coordination losses that make them underperform individual complex tasks (*10*–*12*), as F. concisely observed when he sta idea was ever born in a confer this viewpoint, a shift to tear costly phenomenon or one th impact science, whereas the hig remain the domain of great min

We studied 19.9 million re the Institute for Scientific Infor of Science database and an add patent records. The Web of Sc research publications in scienc since 1955, social sciences sin and humanities since 1975. The all U.S. registered patents since was defined as having more thai (publications) or inventor (pater ISI classification system, the ur publications is divided into thr and their constituent subfiel engineering (with 171 subfield: (with 54 subfields), and arts anc 27 subfields). The universe of treated as a separate category (v See the Supporting Online Mat for details on these classificat

For science and engineerin and patents, there has been a toward collective research. In t size has grown steadily each

Table 1. Patterns by subfield. For the three broad ISI categories and for patents number (*N*) and percentage (%) of subfields that show (i) larger team sizes in compared to the first 5 years and (ii) RTI measures larger than 1 in the last 5 ye measures both with and without self-citations removed in calculating the citatio entries indicate data not applicable.

		Increasing team size		RTI > 1 (with self-citations)		(n
	N_{fields}	N_{fields}	%	N_{fields}	%	N
Science and engineering	171	170	99.4	167	97.7	1
Social sciences	54	54	100.0	54	100.0	
Arts and humanities	27	24	88.9	23	85.2	
Patents	36	36	100.0	32	88.9	

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News Feature

Collaboration: Group theory

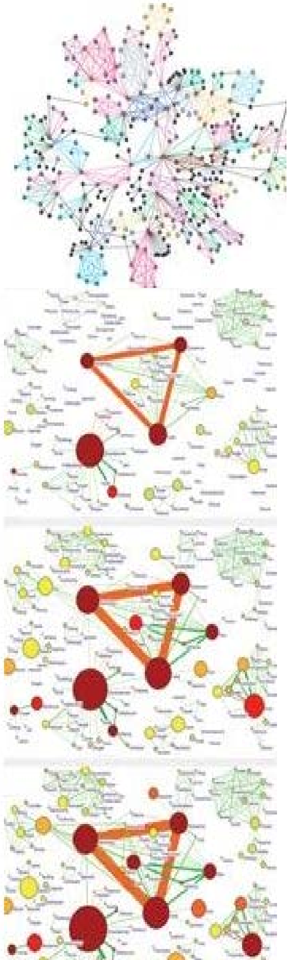
What makes a successful team? John Whitfield looks at research that uses massive online databases and network analysis to come up with some rules of thumb for productive collaborations.

John Whitfield

J. H. VAN DIERENDONCK

Flip through any recent issue of *Nature*, including this one, and the story is there in black and white: almost all original research papers have multiple authors. So far this year, in fact, *Nature* has published only six single-author papers, out of a total of some 700 reports. And the proportions would be much the same in any other leading research journal.

Of course, there is nothing new about this: the scholars who study the folkways of science have been tracking the decline of the single-author paper for decades now. And they have followed the parallel growth of 'invisible colleges' of researchers who are separated by geography yet united in interest. But what is new is how their studies have been turbo-charged by the availability of online databases containing millions of papers, as well as analytical tools from network science — the discipline that maps the structure and dynamics of all



2. The Scholarly Study of Science

2.2. 2010 - *Developing the Field of SciTS*

FINAL REPORT

<u>NSF Workshop</u>

Applying the Science of Teams to Inform Policy and Research on Team Science

Stephen M. Fiore
University of Central Florida

Joann Keyton
North Carolina State University

Report: May 2011
Workshop: March 4-5 2010

Please join us for the First Annual International
SCIENCE OF TEAM SCIENCE CONFERENCE

LAMBERT FAMILY COMMUNICATION CONFERENCE in collaboration with Research Team Support (RTS) within the Northwestern University Clinical and Translational Sciences (NUCATS) Institute on the Science of Team Science

THURSDAY AND FRIDAY, APRIL 22-23, 2010
Wyndham Chicago

2. The Scholarly Study of Science

UCF Cognitive Sciences

2.2. 2010-2011 - *Developing the Field of SciTS*

Advancing the Science of Team Science

Holly J. Falk-Krzesinski, Ph.D.[1], Katy Börner, Ph.D.[2], Noshir Contractor, Ph.D.[3], Stephen M. Fiore, Ph.D.[4], Kara L. Hall, Ph.D.[5], Joann Keyton, Ph.D.[6], Bonnie Spring, Ph.D.[7], Daniel Stokols, Ph.D.[8], William Trochim, Ph.D.[9], and Brian Uzzi, Ph.D.[10]

Abstract
The First Annual International Science of Team Science (SciTS) Conference was held in Chicago, IL April 22–24, 2010. This article presents a summary of the Conference proceedings. Clin Trans Sci 2010; Volume 3: 263–266

Keywords: editorial, editorials, translational research

The public health, social, technological, and environmental problems that impact our world are complex, but increasingly we are able to address them through scientific pursuit.[1] The sophistication of these challenges necessitates cross-disciplinary engagement and collaboration, and the longer-term interaction of groups of investigators—what is termed *team science*.[2-9] Such team-based research collaborations are also an essential feature of a robust translational research enterprise.[10,11]

The emerging field of the *Science of Team Science* (SciTS) encompasses both conceptual and methodological strategies aimed at understanding and enhancing the processes and outcomes of collaborative, team-based research.[12,13,28] SciTS is concerned with understanding and managing circumstances that facilitate or hinder the effectiveness of collaborative cross-disciplinary science,[14-19,28] and the evaluation of collaborative science outcomes.[20-27] Its principal units of analysis are the research, training, and community-based translational initiatives implemented by both public and private sector organizations. SciTS focuses on understanding and enhancing the antecedent conditions, collaborative processes, and outcomes associated with initiatives rooted in team science, including scientific discoveries, educational outcomes, and translations of research findings into new practices, patents, products, technical advances, and policies.[18,21]

In an effort to enhance the understanding of how best to engage in team science to promote collaborative translational research and meet society's needs, the First Annual International SciTS Conference was convened on April 22–24, 2010 in Chicago, Illinois. The event was produced by Research Team Support (RTS) of the Northwestern University Clinical and Translational Sciences (NUCATS) Institute, in partnership with the NIH National Cancer Institute, Division of Cancer Control and Population Sciences and the Lambert Family Communication Conference of the School of Communication at Northwestern University. A Program Conference Committee of twelve renowned investigators in SciTS served as advisors.

The 3-day conference marked the first international, multi-agency forum dedicated to the emerging empirical field of SciTS, bringing together thought leaders from a broad range of disciplines, including: translational research, evaluation, communications, social and behavioral sciences, complex systems, technology, and management. The goals of the conference were to serve as a point of convergence for team science practitioners and investigators studying science teams,

COMMENTARY

TEAM SCIENCE

A Multi-Level Systems Perspective for the Science of Team Science

Katy Börner,[1*] Noshir Contractor,[2] Holly J. Falk-Krzesinski,[2] Stephen M. Fiore,[4] Kara L. Hall,[5] Joann Keyton,[6] Bonnie Spring,[7] Daniel Stokols,[8] William Trochim,[9] Brian Uzzi[10]

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This Commentary describes recent research progress and professional developments in the study of scientific teamwork, an area of inquiry termed the "science of team science" (SciTS, pronounced "sahyts"). It proposes a systems perspective that incorporates a mixed-methods approach to SciTS that is commensurate with the conceptual, methodological, and translational complexities addressed within the SciTS field. The theoretically grounded and practically useful framework is intended to integrate existing and future lines of SciTS research to facilitate the field's evolution as it addresses key challenges spanning macro, meso, and micro levels of analysis.

RESEARCH PROGRESS IN THE SCIENCE OF TEAM SCIENCE

At its most general, the production of knowledge can involve either an incremental change in understanding or a more radical, discrete change. Recently, a change of the second sort occurred that altered our perception of the workings of science itself. A study of more than 21 million papers published worldwide from 1945 to the present reveals a fundamental and nearly universal shift in all branches of science: Teams increasingly dominate solo scientists in the production of high-impact, highly cited science; teams are growing in size; and teams are increasingly located across university boundaries rather than within them (*1*). Similar patterns were found for all the patents published worldwide (*2*). Speculation as to why this shift occurred centers on the nature of the problems increasingly studied: complex problems that cut across disciplinary areas and require multiple divergent perspectives. Cross-disciplinary teams, whether utilizing approaches that are multidisciplinary (in which experts from different scientific fields collaborate yet reside in their topic areas), interdisciplinary (results and expertise from two or more scientific fields are combined), or transdisciplinary (disciplinary boundaries are crossed to create a holistic approach) (*3*) are expected to hold the key to success. More specifically, "team science" is expected to combine specialized expertise, theoretical approaches, and research methods across disciplinary boundaries, solving these complex problems and producing high-impact science.

In order to realize the unprecedented opportunities posed by team science, we need

have as a major goal "… to develop teams of investigators from various fields of research who can take scientific discoveries in the laboratory and turn them into treatments and strategies for patients in the clinic" (*5*). The National Science Foundation invites projects on Cyber-Enabled Discovery and Innovation that place an "emphasis on bold multidisciplinary activities that, through computational thinking, promise radical, paradigm-changing research findings." The MacArthur, Robert Wood Johnson, and W.T. Grant Foundations all support interdisciplinary research networks. The National Academies' KECK Futures Initiative promotes interdisciplinary research related to science, engineering, and medicine. At the same time, according to a White House memorandum, funding agencies, academic leadership, and industry must manage their portfolios in an objective, evidence-based manner to address science and technology priorities of our nation and increase the productivity of our research institutions (*6*). The confluence of these developments is the critical need to understand, support, and measure the investment, return, and effect of team science projects.

PROFESSIONAL DEVELOPMENT IN THE SCIENCE OF TEAM SCIENCE

The "science of team science" (SciTS, pronounced "sahyts") is an emerging area of research centered on examination of the processes by which scientific teams organize, communicate, and conduct research (*7–9*). The field is concerned with understanding and managing circumstances that facilitate or hinder a range of collaborative research efforts—from determining the effectiveness of large-scale collaborative research, training, and translational initiatives to understanding how teams connect

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Mapping a research agenda for the science of team science

Holly J Falk-Krzesinski, Noshir Contractor, Stephen M Fiore, Kara L Hall, Cathleen Kane, Joann Keyton, Julie Thompson Klein, Bonnie Spring, Daniel Stokols and William Trochim

way that their efforts are coordinated and integrated (Fiore, 2008; NAS, 2004). Although it is possible for team science to be unidisciplinary, team science most often connotes cross-disciplinarity (multi-, inter-, and trans-disciplinarity), a composite term for team science programs and projects that differ in the degree to which they interact and integrate across disciplinary, professional, and institutional boundaries (Crowley *et al*, 2010; Fiore, 2008; Klein, 2010; Rosenfield, 1992; Stokols *et al*, 2008a; Wagner *et al*, 2011).

Despite this growth in collaborative research, the scientific community continually struggles with overcoming the challenges arising from this complex form of teamwork (Cummings and Kiesler, 2005, 2007, 2008; Olson and Olson, 2000). As such, science policy must be developed to help address the theoretical and practical challenges emerging from this form of collaborative endeavor. Further, scientific, social scientific, philosophical, and humanistic research is needed to help understand the team processes that drive knowledge production in such teams; that is, help examine how new knowledge is generated in collaborating teams of scientists. This need has given rise to an empirical area of inquiry referred to as the *science of team science — SciTS*, pronounced 'sights' (Annual International Science

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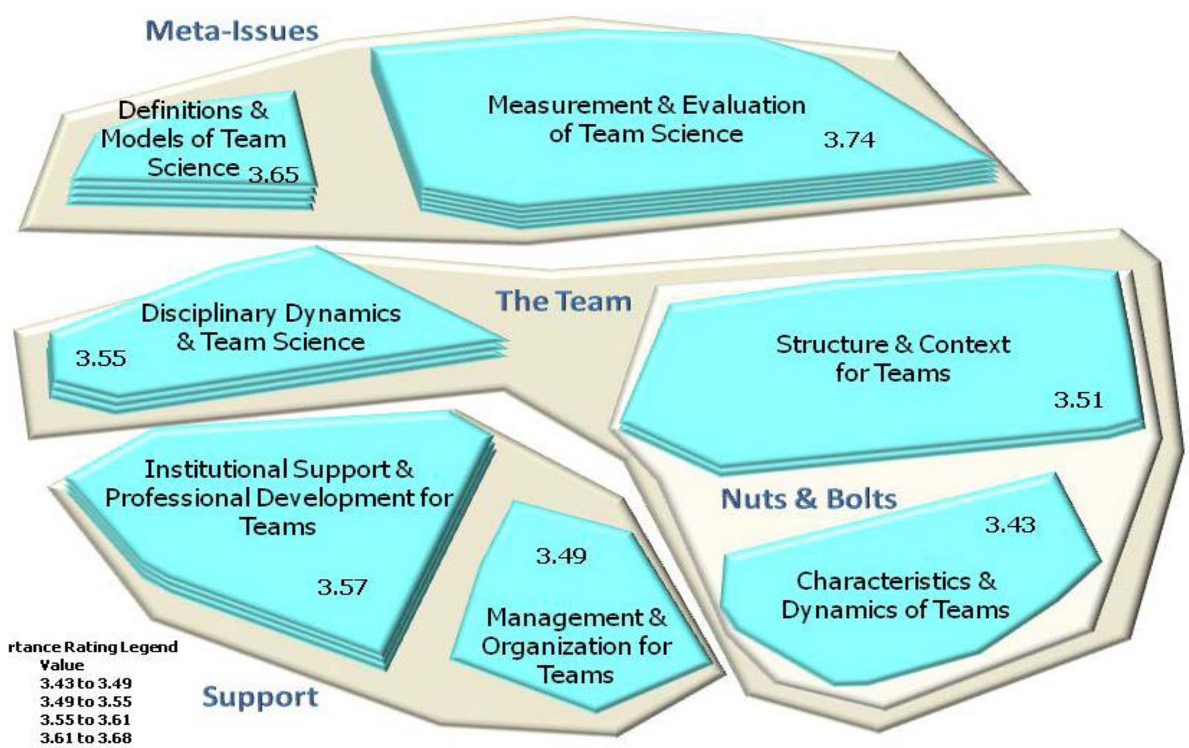
2. The Scholarly Study of Science
2.2. *Developing the Field of SciTS*

- Where are we now?
  - *Need to identify and synthesize the "known-knowns", "known unknowns" and the "unknown-unknowns" to move forward along theoretical and translational lines*
- Requires contributions from foundational fields:
  - History and Philosophy of Science and STS
  - Interdisciplinary Studies
  - Groups and Teams Studies
- Requires contributions from variety of disciplines
  - Life Sciences
  - Physical Sciences
  - Social Sciences
  - Computational Sciences
  - Design and Engineering



Falk-Krzesinski, H. J., Contractor, N. S., Fiore, S. M., Hall, K. L., Kane, C., Keyton, J., Klein, J. T., Spring, B., Stokols, D., Trochim, W. (2011). Mapping a Research Agenda for the Science of Team Science. *Research Evaluation*.

The Road Ahead

- View the SciTS Consensus Study as a Transdiscplinary Endeavor
  - *Necessary to develop a coordinated and comprehensive R&D agenda*
- Beware the Barriers and Bumps
  - *Do not equate "team science" with "big science"*
    - Collaboration in science ranges from small team, to teams of teams, and up
  - *Do not get bogged down in false dichotomies*
    - Forgot beliefs about "basic vs. applied" research
    - Consider ideas such as "use-inspired" or "problem-driven" science
    - Remember that foundational knowledge can come from all forms of inquiry
  - *Do not forgot about the role of non-scientist team members*
    - Professionals and/or Stakeholders can provide perspectives that lead to important insights
- Pursue the Promise and the Possibilities
  - ***The SciTS consensus study has the potential to transform not only the practice of science but also our understanding <u>and</u> improvement of the world around us***

Thank You!

Questions or Comments?

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