Team Science: Building Solid Collaborations that Produce Results

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The role of Science of Team Science (SciTS) to help inform the development of **effective collaboration practices** and policies.

Key findings from SciTS to highlight how **collaborating across boundaries** can result in positive outcomes while also introducing significant **challenges**, which can be mitigated by **TS strategies**.

Characterize teams in science to illuminate how teams vary across a range of dimensions, which create **unique profiles** and highlight how one-size fits all solutions not work.

Core principles and key strategies can be used to guide collaborative success.
Variations in Team Science
# Dimensions of Team Science

## Dimensions and Range

<table>
<thead>
<tr>
<th>Dimension</th>
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<tr>
<td>Diversity</td>
<td>HOMOGENEOUS</td>
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<tr>
<td>Integration</td>
<td>UNIDISCIPLINARY</td>
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<tr>
<td>Size</td>
<td>SMALL (≤)</td>
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<td>Proximity</td>
<td>CO-LOCATED</td>
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<td>Goal alignment</td>
<td>ALIGNED</td>
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<td>Boundaries</td>
<td>STABLE</td>
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<td>Task interdependence</td>
<td>LOW</td>
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National Research Council (2015). Enhancing the effectiveness of team science.
Collaboration Is Complex

Multi-level Contextual Factors

**Interpersonal**
- Members' attitudes toward collaboration and their willingness to devote substantial time and effort to TD activities
- Members' preparation for the complexities and tensions inherent in TD collaboration
- Participatory, inclusive, and empowering leadership styles

**Physical Environmental**
- Spatial proximity of team members' workspaces to encourage frequent contact and informal communication
- Access to comfortable meeting areas for group discussion and brainstorming
- Availability of distraction-free work spaces for individualized tasks requiring concentration or confidentiality
- Environmental resources to facilitate members' regulation of visual and auditory privacy

**Technological**
- Technological infrastructure readiness
- Members' technological readiness
- Provisions for high level data security, privacy, rapid access and retrieval

**Organizational**
- Presence of strong organizational incentives to support collaborative teamwork
- Non-hierarchical organizational structures to facilitate team autonomy and participatory goal setting
- Breadth of disciplinary perspectives represented within the collaborative team or organization
- Organizational climate of sharing
- Frequent opportunities for face-to-face communication and informal information exchange

**Societal/ Political**
- Cooperative international policies that facilitate exchanges of scientific information and TD collaboration
- Environmental and public health crises that prompt inter-sectoral and international TD collaboration in scientific research and training
- Enactment of policies and protocols to support successful TD collaborations (e.g., those ensuring ethical scientific conduct, management of intellectual property ownership and licensing)

**Collaborative Effectiveness of TD Science Initiatives**

The Science of Team Science is a cross-disciplinary field of study that aims to: (1) generate an evidence-base and (2) develop translational applications to help maximize the efficiency, effectiveness of team science.

- What is the added value of team science? Can it ask and answer new questions, produce more comprehensive knowledge, generate more effective applied solutions?

- What team processes (e.g., communication, coordination approaches) help maximize scientific innovation and productivity?

- What characteristics and skills of team leaders and team members facilitate successful team functioning?

- How can funding agencies and universities most effectively facilitate and support team science, in order to advance discovery? What policies are needed?
Teams produce more highly cited research & patents than individuals
Publications by teams of collaborators from different universities produced higher impact work than comparable co-located teams or solo scientists.
With Multidisciplinary projects superior to unidisciplinary projects in producing innovative new ideas and tools.
Gender diversity is associated with better outcomes.
Team size, characteristics, and composition can influence team performance.
The inclusion of different types of roles on team can impact team effectiveness and influence the kinds of outcomes produced (e.g., larger numbers of publications vs breakthrough publications).

Disciplinary Diversity

- **Cross-disciplinary teams:**
  - Found to be **more productive** than comparison teams, as indicated by publications
  - Produce **more innovative** products than unidisciplinary teams
  - Tend to generate publications with **greater scientific impact**
  - **Greater cross-fertilization** via publications with broader reach and decreased specialization
  - Identify **new previously unexplored areas** at the intersection of fields/domains

A Continuum of Disciplinary Integration

**Unidisciplinary**
Researchers from a single discipline work together to address a common problem.

**Multidisciplinary**
Researchers from different disciplines work sequentially, each from their own discipline-specific perspective, with a goal of eventually combining results to address a common problem.

**Interdisciplinary**
Researchers from different disciplines work jointly to develop & use a shared conceptual framework that synthesizes & extends discipline-specific theories, concepts, & methods to create new approaches to address a common problem.

**Transdisciplinary**
Researchers from different disciplines work jointly to address a common problem. Some integration of perspectives occurs, but contributions remain anchored in their own disciplines.

**Within**

**Across**

Adapted from: Rosenfeld, 1992; Hall et al., 2008; Falk-Krezsinski, 2012; Austin et al., 2008; Nissani, 1995
Productivity of TD Center Grants and R01 Investigator-Initiated Grants

**TD center publications have longer start up period compared to R01s but become more productive over time**

Centers initial lag in number of publications is eliminated around Project Year 4.

Method: Quasi-experimental design comparing number of publications of TTURC initiative with matched R01 projects from the tobacco field over 10-year period.

Predicted number of publications as a function of research group size and heterogeneity as measured by number of disciplines of the investigators

Predicted number of publications as a function of research group size and group heterogeneity as measured by number of institutions involved in the research

Key Findings: **On average**, as the number of investigators increase, greater numbers of disciplines and institutions, results in less productivity **(important caveat!)**

The projects that used more coordination mechanisms had more successful outcomes:
- e.g., direct supervision, face-to-face mechanisms, division of labor, knowledge transfer
- Less coordination especially predicted less training and project outreach.

Yet, the greater number of universities involved in a collaboration predicted fewer coordination activities and fewer project outcomes:
- Dispersed projects that used more coordination mechanisms were more successful than dispersed projects that used fewer coordination mechanisms.

Increases in complexity such as communication, team dynamics, organizational and global bureaucratization occur as the number of team dimensions (e.g., size, disciplines, distribution) increase.
- Thereby, complex teams require more resources for coordination and management.

Take aways:
- The use of coordination mechanisms is critical for success.
- The number of coordination mechanisms should increase as the complexity of the project increases.
Team Size & Composition
Scientific progress and breakthroughs

- **Team size**: “small teams are more likely to produce articles, patents and software that disrupt the system by drawing inspiration from older and less popular ideas, while larger teams build on, solve and refine important ideas from the immediate past.”

- **Networks**: Nobel prize winning breakthroughs often come from papers that are not highly cited and emerge from a small network of researchers.

- **History of collaboration**: Enhances impact and productivity, yet decreases breakthrough products.

- **Newcomers**: A combination of members with a history of collaboration and new team members increase the likelihood of publishing in the most prominent journals.

Wu, Wang & Evans, 2017; Winnek et al., 2016; Onal Vural et al., 2013; Guimera, et al., 2005
NCI Transdisciplinary (TD) Center Initiatives
*in collaboration with NIDA, NIAAA & RWJF (TTURCs) and NHLBI & OBSSR (CPHHD)

**Transdisciplinary Research on Energetics and Cancer Centers (TREC) U54** - $74,811,868

**Centers of Excellence in Cancer Communication Research (CECCR) P50 & P20** - $83,880,445

**Centers for Population Health and Health Disparities (CPHHD) P50** - $66,298,321

**Transdisciplinary Tobacco Use Research Centers (TTURC) P50** - $68,995,753

**SciTS Studies:**
- Interview
- Survey
- Bibliometric
- Financial
- Science Mapping
- Written Products Protocol
- Social Network Analysis
- P&T Policies

**Disciplinary Orientation**
- Training and Publications
Challenges in TD Team Science

- **Conceptual and Scientific Challenges**
  - Lack of *clarity* about “what TD is” & “how you get there”
  - TD science “*stretches*” investigators’ intellectual “capacity” more than UD research
  - TD research is *more complex* than UD research

- **Different Disciplinary Cultures Among Collaborators**
  - Differences in *values, language, traditions*
  - Team members want to stay in their “*comfort zone*” (re: disciplinary culture)

- **Management Challenges**
  - TD research = *more* time, resources, planning, and management than UD research
  - *Compromise*, change in routines (e.g., data management)
  - Physical distance = communication challenges, slowed research process

- **Incentive and Recognition Systems and Academic Norms**
  - Academic incentives have *not yet “caught up”* to TD research (e.g., P&T criteria, limited funding opportunities, pub venues)
  - Colleagues may be *unfamiliar with TD research* (e.g., IRB, grant/manuscript review)

*Vogel, Stipelman, Hall et al., 2014*
What does this mean?

- Contextual factors (academic structures, disciplinary cultures, and science policies) influence how team science is supported and conducted.

- The way teams are constructed and organized can influence the degree and type of outcomes achieved.

- Opportunities exist for participants and leaders of team science to prepare and engage in team science strategically to maximize success.
Four Phase Model of Transdisciplinary Research

Development Phase:
Goals & Key Processes

Goal: Define the scientific or societal problem space of interest, including identifying the intricacies & interconnections of concepts that fall within the problem space & establishing the boundaries of the problem space to be addressed.

Key Processes: Encourage information sharing & integrative knowledge creation among diverse participants:
- Generate shared mission & goals
- Develop critical awareness
- Externalize group cognition
- Developing group environment of psychological safety

Team Type:
- Network, working group, advisory group, emerging team

**Conceptualization Phase:**

**Goals & Key Processes**

**Goal:** Develop novel research questions, hypotheses, & a conceptual framework & research design that integrate collaborators’ disciplinary perspectives & knowledge domains to address the target problem in innovative ways.

**Key Processes:** Facilitate integrative knowledge creation among team members & development of a research plan

- Create shared mental models
- Generate shared language
- Develop compilational transactive memory
- Develop team TD ethic

**Team Type:**
- Emerging team, evolving team

*Use public seminars among collaborators to help develop compilational transactive memory, shared language for a TD research collaboration, team TD ethic, & shared mental model of research collaboration.*

Implementation Phase:
Goals & Key Processes

**Goal:** Launch, conduct, & refine the planned TD research

**Key Processes:**
Developing a shared understanding (transactive memory)
- *who knows what* (compilational)
- *who does what* (compositional)
- *how things get done* (taskwork)
- *how interactions occur* among the team (teamwork)
  - Conflict Management
  - Team Learning (e.g., reflection, action, feedback, discussion)

**Team Type:**
Real team

“Real” vs “Pseudo” team

Characteristics that lead to increased performance & innovation:

- **Interdependence**
- **Iterative reflection** (systematic consideration of team performance & participation in related adaptation to team goals & processes)
- Demonstrated clear understanding of team membership

Goal: Apply research findings to advance progress along the discovery–development–delivery pathway to ultimately provide innovative solutions to real-world problems.

Key Processes:
- The evolution of the team, as needed, to identify & pursue translational goals
- Development of shared goals for the translational endeavor
- Development of shared understandings of how these goals will be pursued

Team Type: Adapted team, new team
Tools For Setting Expectations, Preventing Conflict, and Planning For Success in TS

- **Investigator level:** “Welcome to my Team” Letter
  - Provides a scaffold for building deeper trust including: what you can expect of the team, what the team expects of you, and what to do if we disagree

- **Team level:** Pre-collaboration Agreement (AKA Prenup for Scientists)
  - Jointly created agreements among collaborators (formal or informal)
Tools For Setting Expectations, Preventing Conflict, and Planning For Success in TS

- **Initiative level: Operating Manual**
  - Describe expected roles, responsibilities, procedures, etc. for investigators and staff across research centers
    - Ideal for large, complex collaborations that may include multiple institutions/centers

- **All levels: Collaboration Plan**
  - Detailed plan that describes multi level ways the group will plan for and support effective collaboration
1 Rationale for Team Approach & Configuration

- Justify why a team approach is necessary to meet the research objectives.
- Describe why the team configuration meets the proposed research objectives (e.g., how each team member uniquely contributes).
- As the number of collaborators increases, so do the potential challenges.
- For interdisciplinary teams, the disciplines must be "scientifically ready" for collaboration.
- Not all research questions are best addressed using a team approach or require a large, complex, or distributed team.
- Generally, a team should not include more researchers than necessary, but should include sufficient breadth to gather the needed scientific expertise.

The Science of Team Science
Commentary on Measurements of Scientific Readiness
Timothy C. Hayes, PhD

Introduction

Some topics in this supplement to the American Journal of Preventive Medicine focus on the rigorous analysis of various contextual factors influencing the design, implementation, and sustainability of transdisciplinary research; however, an additional area of scientific exploration that may benefit Team Science and the transdisciplinary research field is the formal investigation of factors that elucidate when scientific areas are merging and/or ripe for collaborative study. This precursor of collaboration readiness could play a significant role in understanding why and how team science collaborations break over these fields of the potential for more, improved, or quicker research outcomes.

Study elements. Investigate the metrics or identifiers that are used or could be used by researchers and funding organizations to determine when areas of science are ripe for collaborative research and, more specifically, transdisciplinary research.

One of the initial challenges for Phase 1 is to identify good metrics or science markers that can demonstrate connections between fields of research. Some metrics might include markers of when (1) two scientific fields share system pathways or molecular interactions, (2) a gap in evidence exists for a condition or problem, (3) two scientific fields share a common problem, (4) a research question has been posed within one field that needs investigation in another field, or (5) two scientific fields are approaching the same conclusion.
Online diagnostic tool that aims to enhance collaborative practices in geographically distributed science teams, to enhance teams’ productivity and success.

Online survey probes factors that may strengthen or weaken the collaboration. Each member of the team completes the survey. The Wizard provides both individual and project-level reports offering constructive strategic feedback to address any collaboration problems.
3 Technological Readiness

Document the availability and planned use of technological resources to facilitate:

- Data sharing and collaborative data analysis (e.g., data sharing agreements, common data analysis and management software);
- Communication (e.g., video- and teleconferencing, calendaring tools); and
- Coordination (e.g., calendaring, workflow or project management tools).

- TR includes three components:
  1. technology must be available;
  2. members must be willing to use the technologies;
  3. members must have the skills to use them.

- Additional issues may include: compatibility and interoperability of systems across collaborators; decisions concerning whose systems or processes will be used.

What is Trellis?
Trellis is an exciting, new, digital platform that connects you to the rest of the scientific community so that you can communicate and collaborate more effectively.

What can you do?
- Create and manage your professional profile
- Meet new people and build your professional network
- Quickly find the latest news and updates in science
- Participate in online conversations about your interests
- Upload and manage your personal library of documents
- Host a journal club, a live chat-based Q&A, or a presentation series

What can you or your organization do?
- Establish a working group of any size – with your own newsletter, notifications, discussions, shared libraries and calendars
- Create and share agendas, proposals, reports, articles or other documents with your group to get feedback and make edits
- Keep in touch with your group's members – and gather their input – in one convenient place
- Share news and resources from your lab, group, or organization with the entire Trellis community
4 Team Functioning

- Describe strategies that will be used to address key team processes that are essential to effective team functioning.
- Examples of strategies include: development of cooperative agreements and operating manuals, participation in the Toolbox Project-facilitated workshops, and implementation of team diagnostic surveys for quality improvement.

- Strategies should take into account the unique characteristics of the team and the scientific work, such as collaborative history, complexity of the team (e.g., size, diversity, dispersion, task interdependence), phase of the research process.
- Strategies should be directly tied to achieving key team processes (e.g., generating a shared mission and goals, externalizing group cognition, creating shared mental models, generating shared language).

About td-net’s toolbox for co-producing knowledge

Why a toolbox for co-producing knowledge?
At a conference in transdisciplinary research would have asked for a definition of transdisciplinary projects. Over the recent years this question has become less urgent! Today, more than ever, transdisciplinary research is well accepted and is not a rare phenomenon. The question is more how it can be done, and how knowledge can be produced and how it can be used. The purpose of the toolbox is to help teams and researchers to systemize and systematize knowledge and to use it.
In this blog, the first in our “Voices from the Field” series, Dr. Christine Hendren makes the case for a new professional role— that of Interdisciplinary Executive Scientist—to facilitate effective interdisciplinary research.

The Interdisciplinary Executive Scientist is an emerging scientific career pathway that focuses on providing leadership for large, interdisciplinary team-based endeavors. IESs provide both scientific and administrative leadership to facilitate successful integrative team science.

- Describe ways communication will occur (e.g., meeting frequency and modality).
- Describe strategies to coordinate day-to-day operations and the achievement of scholarly benchmarks (e.g., work flow, coordination of data).

- Plans should be specific to your team. For example, distance collaborations increase potential communication and coordination challenges. Communication and coordination styles may vary among collaborators who vary in age, gender, and culture, and for collaborators from different disciplines.
- Greater use of coordination mechanisms leads to more successful outcomes. Direct supervision and face-to-face mechanisms have demonstrated effectiveness. As team complexity and size increase, so does the need for more coordination.
6 Leadership, Management, & Administration

- Describe the leadership and management approaches that will be used to address the other components in the collaboration plan, given the specific team context that has been proposed (e.g., the individual team members, team characteristics, involved institutions and organizations).

- There are numerous approaches to leadership (e.g., hierarchical, heterarchical, transformational, transactional). The most successful outcomes are produced by combining various approaches as appropriate to the context.
- Leadership and management are key influences on the success of a scientific collaboration.
- More complex team science initiatives require more sophisticated leadership and management approaches.

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References & Additional Resources
Appendix: Collaborative Agreement Template
Offers discussion questions to help collaborators commence a project by anticipating, discussing, and resolving possible areas of disagreement common to many collaborations. Helps define expectations related to goals, roles, products, authorship, etc.

**Example Questions:**

- What are the expected contributions of each participant?
- What will be your mechanism for routine communications among members of the research team (to ensure that all appropriate members of the team are kept fully informed of relevant issues)?
- What will be the criteria and the process for assigning authorship and credit?
- When and how will you handle intellectual property and patent applications?
- How and by whom will data be managed? How will access to data be managed? How will you handle storage and access to data after the project is complete?
Teamscience.net provides online training modules in transdisciplinary, team-based translational science relevant to investigators at any career stage and institutional development officers. It is designed to help learners envision how transdisciplinary collaboration can work and prepare them to overcome communication challenges that are common to multidisciplinary team collaborations.

Training

- Describe a training plan for team members at the start of the collaboration and throughout (e.g., training relevant to team processes, leadership, management, communication, coordination).
- For interdisciplinary (ID) teams, this plan should involve cross-training in multiple scientific areas, and training in ID science competencies (e.g., critical awareness of the strengths and weaknesses of all disciplines, strategies for combining approaches from multiple disciplines).

- Ongoing, rather than one-off, training is needed to maintain and build competencies and address evolving needs.
- Training should be designed to meet a wide variety of needs—by career stage, learning style, interests, and practical constraints (e.g., web-based training for distributed teams).
- Evidence-based training approaches exist for both individuals and teams (e.g., team coordination training, team reflectivity training, cross-training).
Team Diagnostic Survey

Free online survey completed by all members of a team. Generates a summary report diagnosing team’s strengths and weaknesses. Based on model of team effectiveness in Richard Hackman’s authoritative book, "Leading Teams" (2002).
10 Budget & Resource Allocation

- Allocate funds in the budget for activities that facilitate the success of the team, as identified in components one through nine.

- The previous nine components all require investments of resources that require financial support. It is necessary to allocate funds to these activities to ensure their successful implementation.

- Clear but flexible plans for funds may produce optimal results. This can be particularly important in larger and more complex initiatives, where there is a greater likelihood for changes to the collaboration over the course of the initiative.
The Team Science Toolkit is an interactive website that provides resources to help users support, engage in, and study team-based research.
In Sum

- **Research that spans boundaries has the potential to enhance outcomes**
  - As the *complexities of team* composition and distribution, support teams require comparatively *more care and consideration of mechanisms*.
  - These are based on *common core principles* (e.g., team functioning, coordination).

- **Strategies to advance team science**
  - With *competencies, processes, and policies* in place to help barriers, we can enhance the way investigators conduct science, increase collaboration, and advance science.
  - There are *conceptual models, practical strategies, and resources* to help guide and support the conduct of research at the team, center, and initiative levels.
For More Information

• Kara L. Hall, PhD
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• Team Science Toolkit
  • www.teamsCiencetoolkit.cancer.gov

• SciTSlist listserv hosted by NIH. Subscribe in one click:
  • www.teamsCiencetoolkit.cancer.gov/Public/RegisterListserv.aspx