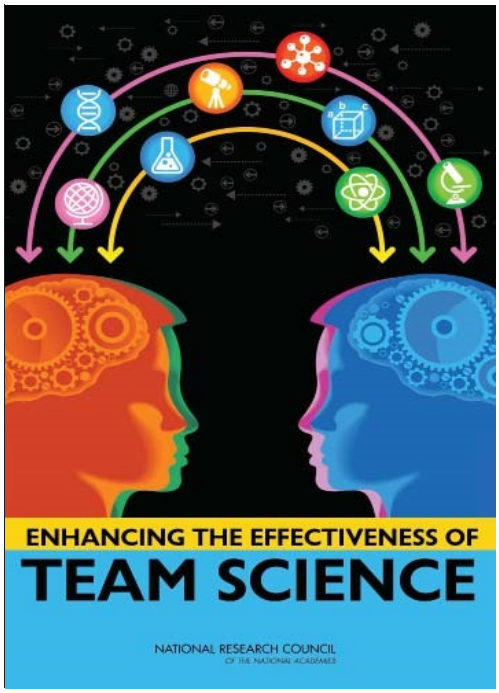
REPORT BRIEF

Enhancing the Effectiveness of Team Science



Over the past six decades, as scientific and social challenges have become more complex and scientific knowledge and methods have advanced, scientists have increasingly joined with colleagues in a collaborative research approach referred to as team science. Today, over 90 percent of all publications in science and engineering are co-authored by teams of two or more. Team science has led to scientific breakthroughs that would not otherwise have been possible, such as the discovery of the transistor effect, the development of antiretroviral medications to control AIDS, and confirmation of the existence of dark matter. Emerging research shows that team science can lead to results with greater scientific impact, innovation, productivity, and reach than single-investigator approaches. When team science works, it works very well.

Although team science promises to address increasingly complex scientific questions, conducting research collaboratively can introduce challenges that slow or prevent projects from achieving their scientific goals. To help scientists, universities, research institutions, policy makers, and research funders address these challenges, the National Science Foundation requested that the National Research Council (NRC) appoint a committee of experts to conduct a study and recommend ways to enhance the effectiveness of collaborative research in science teams, research centers, and institutes. The committee's conclusions and recommendations are detailed in its report, *Enhancing the Effectiveness of Team Science* (2015).

DEFINING TEAM SCIENCE

The committee defined team science as research conducted in an interdependent fashion by more than one individual. Most team science is conducted by small science teams composed of two to ten individuals, but team science is also conducted by larger groups of more than ten. This simple definition belies the considerable variation within and among science teams and larger groups. For example, teams may be either *unidisciplinary*, reflecting the expertise of a single discipline, or *multidisciplinary*, incorporating expertise from two or more disciplines. Multidisciplinary teams vary in the degree to which their work integrates the contributions of multiple disciplines; those that are *interdisciplinary* or *transdisciplinary* aim to deeply integrate knowledge across disciplines.

A science team or group may incorporate one or more of the following seven features that are beneficial to achieving their scientific and translational goals, but can also generate challenges for effective scientific collaboration.

High diversity of membership. Addressing complex scientific problems sometimes requires contributions from different disciplines, communities, or professions. Science team members may come from different organizations and perspectives (such as stakeholder vs. researcher). Members may also be diverse in age, gender, culture, and other demographic characteristics. Diverse team members may lack a common vocabulary, posing a challenge to effectively communicating about the research.

Deep knowledge integration. Although all science teams and groups integrate knowledge to some extent, interdisciplinary and transdisciplinary teams require deep knowledge integration, encountering the challenge of coordinating research tasks and communicating ideas despite the different research methods, assumptions, and languages of the different disciplines.

Large team size. While most team science is conducted by small teams of less than ten, some larger groups include hundreds or even thousands of scientists. Large size creates challenges, as members may have few opportunities to meet and work face-to-face in ways that build trust and cohesion.

Goal misalignment across teams. Research centers and institutes are typically composed of multiple science teams engaged in related research projects. Each individual team brings valuable insights, methods, and perspectives and may have its own distinct goals. If the goals of these teams are not aligned, this can generate conflict, requiring careful management.

Permeable boundaries. The boundaries of science teams and larger groups are often permeable, reflecting changes in the project goals over time. The membership of a group or team may change as the project moves from one phase, requiring a certain type of expertise, to another that may require different expertise. Although these changes have the benefit of matching expertise to scientific or translational problems as they arise, they can also create challenges for effective team or group interaction.

Geographic dispersion of team members. Many science teams and initiatives are geographically dispersed, with members located across multiple universities or research institutions. Although crossing institutional boundaries can bring needed expertise, scientific instrumentation, data sets, or other valuable resources to the project, it also can create challenges to effective research collaboration. Geographically-dispersed teams are more reliant on electronic modes of communication, which have attendant challenges. In addition, the team may find it difficult to coordinate work across institutions with varying work styles, time zones, and cultural expectations about scientific work.

High task interdependence. The members of science teams or groups are dependent on each other to carry out tasks and accomplish a shared research goal. When a group or team conducts highly interdependent tasks, coordinating the work of individuals may be challenging.

IMPROVING TEAM AND GROUP EFFECTIVENESS

Team effectiveness is a team or larger group's capacity to achieve its goals and objectives. This capacity leads to improved outcomes for the members, such as satisfaction, as well as scientific outcomes such as new research findings or methods. Factors at the team and organizational level, including team processes, organizational supports, virtual collaboration, and funding approaches can all significantly influence the effectiveness of science teams and larger groups.

Team processes. A strong body of research on teams outside of science has demonstrated that team processes, such as shared understanding of team goals and member roles, are related to team effectiveness. This research has also identified interventions in team composition, team professional development, and team leadership that foster positive processes and hence improve team effectiveness. These interventions have been translated and extended across contexts (for example, from aviation teams to health care teams). Based on this history of generalization across contexts, the committee assumes that research on teams in other contexts provides a

rich foundation of knowledge that can inform strategies for improving the effectiveness of science teams.

Team composition. Research in non-science contexts has shown that team composition influences team effectiveness. Task analytic methods and tools—such as task analysis, cognitive modeling, and cognitive work analysis—that allow practitioners to consider team composition systematically appear promising for science teams and initiatives. Team science leaders and others involved in assembling science teams should consider making use of such tools and methods to help identify the knowledge, skills, and abilities required for effective performance of the project. They should also consider using research networking systems to facilitate team assembly.

Professional development. Research in contexts outside of science has demonstrated several types of team professional development, such as knowledge development training to increase sharing of individual knowledge in ways that improve problem solving and enhance team effectiveness. Team-training researchers, universities, and science team leaders should partner to translate, extend, and evaluate these promising training strategies to create professional development opportunities for science teams.

Leadership. Currently, most science team and group leaders are appointed to their positions based solely on scientific expertise and lack formal leadership training. Research on team and organizational leadership in non-science contexts has illuminated leadership styles and behaviors that foster positive interpersonal processes, thereby enhancing team effectiveness. This body of research provides a robust foundation of evidence to guide professional development for leaders of science teams and larger groups. Leadership researchers, universities, and leaders of team science projects should partner to translate and extend the leadership literature in order to create and evaluate leadership development opportunities for team science leaders and funding agency program officers.

Organizational Supports for Team Science. Science teams and larger groups are often housed within universities. However, university policies for promotion and tenure review typically do not provide comprehensive, clearly articulated criteria for evaluating individual contributions to team-based research. The extent to which researchers are rewarded for team-based research varies widely across and within universities. Where team-based research is not rewarded, young faculty may be discouraged from joining those projects. Universities and disciplinary associations should proactively develop broad principles and more specific criteria for allocating credit for team-based work to assist promotion and tenure committees in reviewing candidates.

Supporting Virtual Collaboration. When members of science groups or teams are geographically remote from one another, communication and developing trust are more challenging relative to face-to-face teams. Leaders of geographically dispersed (or virtual) science teams and groups should provide activities shown by research to help team members develop shared knowledge (such as a common vocabulary and work style). When selecting technologies to support virtual science teams, leaders should carefully evaluate the needs of the project and the ability of the individual participants to embrace new technologies. Organizations should promote human-centered collaboration technologies, provide technical staff, and encourage use of the technologies by providing ongoing training and technology support.

Funding for Team Science. Funders of team-based research, when awarding grants through peer review, focus almost entirely on scientific merit, with little attention to how the participants will work together (collaborative merit). Research has shown that explicitly planning in advance for collaboration enhances team effectiveness. Therefore, funders should require proposals for team science to present collaboration plans and provide guidance to scientists for the inclusion of these plans in their proposals, as well as guidance and criteria for reviewers' evaluation of these plans. Funders should also require authors of proposals for interdisciplinary or transdisciplinary research projects to specify how they will integrate disciplinary perspectives and methods throughout the life of the research project.

ADVANCING RESEARCH ON TEAM SCIENCE EFFECTIVENESS

The committee identified several areas in which further research is needed to enhance the understanding of team science and how to improve its effectiveness. Continued research and evaluation will be needed to refine and enhance the actions, interventions, and policies discussed above. At the same time, research is needed to enhance basic understanding of team science processes to provide a foundation for developing new interventions. Funders of scientific research, policy makers, and the scientific community need appropriate criteria for evaluating the outcomes of team science along with more rigorous evaluations incorporating experimental or quasi-experimental methods. An essential first step toward meeting these needs is increasing researchers' access to practicing science teams and groups to study their interactions and innovations.

Public and private funders should support research on team science effectiveness. As critical first steps, they should support ongoing evaluation and refinement of the interventions and policies recommended above and research on the role of scientific organizations (such as research centers and networks) in supporting science teams and larger groups. They should also collaborate with universities and the scientific community to facilitate researchers' access to key team science personnel and data sets.

In summary, team science can be challenging, but the rich scientific literature on improving teamwork, together with emerging research on collaboration and innovation in larger scientific and technical organizations, can be applied to enhance the effectiveness of team science.

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For More Information . . . This brief was prepared by the Board on Behavioral, Cognitive, and Sensory Sciences (BBCSS) based on the report *Enhancing the Effectiveness of Team Science* (2015). The study was sponsored by the National Science Foundation and Elsevier. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not reflect those of the sponsors. Copies of the report are available from the National Academies Press, (800) 624-6242; *http://www.nap.edu* or via the BBCSS web page at *http://www.nationalacademies.org/bbcss*.