Kara L. Hall · Amanda L. Vogel
Robert T. Croyle *Editors*

Strategies for Team Science Success

Handbook of Evidence-Based Principles for Cross-Disciplinary Science and Practical Lessons Learned from Health Researchers

Springer

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Foreword

As a long-term social scientist and recent past director of the Institute for Social Research (ISR) at the University of Michigan, I was asked by the editors of this new book to write a foreword placing team science in the context of social and behavioral sciences research and applications. The ISR is a successful 75-year experiment in the utilization of team science principles to advance high-quality research on basic and applied behavioral and social science problems.

The need for, and implementation of, large research teams has been brought into sharp relief over the last few decades as the complexity and size of scientific problems have grown not only in the social and behavioral sciences but also in the biological and physical sciences. Significant advances in a wide variety of tools, approaches, and technologies combined with rapid growth in computing power, big data, data mining systems, imaging, and geographic information systems, has exponentially increased the need for interdisciplinary teams in order to investigate and address complex scientific questions.

ISR's use of team science did not grow strictly from conceptualization of organizational principles but instead evolved to conduct the work in basic and applied social and behavioral sciences needed to address complex human science problems in business organizations, the military, and other organizational contexts. For 75 years, the nature of problems addressed responded well to the development of interdisciplinary research teams spanning senior investigators to undergraduate students, where the nature of the problem dictated the organizational forms necessary for addressing particular problems. Over this same period, however, the larger context of universities, private and public funders, and public perceptions of science, as well as the size and scope of problems to be addressed, changed substantially. These changes are now dictating the need for more systematic investigations of the nature, context, and structure of the team science enterprise.

There is no reason to believe that science will move backward such that the lone investigator working either in a laboratory or armchair will ever again be the imagined norm for scientific investigation. Thus, the challenges of ensuring cooperation, composition of teams, proximity, scientific credit, reward systems for discoveries, rules of tenure, and promotion are all issues that have to evolve to meet the new reality of team science.

This book is an outstanding product of a massive undertaking examining the multiple facets of team science from a broad array of perspectives. It is a

large volume and not meant to be read from cover to cover in one sitting. Instead, the volume is to be used as a scientific and applications sourcebook and to be consulted and employed as a resource manual. The chapters focus on topics ranging from integrative science teams, expanding engagement in science teams, team characteristics, team formation, and team functioning to institutional influences and technological support. Within each of these broad topical areas, the chapters encompass "State of the Science" chapters focused on providing up-to-date evidence and conclusions on what we know scientifically about the nature of effective team science, "Special Topics" chapters that detail and suggest new directions for scientific exploration in team science, and "Practice-Oriented" chapters that are rooted in lived experiences of scientists and administrators – providing insights and examples of successful applications of team science approaches in developing key strategies in organizing, leading, implementing, managing, facilitating, and supporting cross-disciplinary social, behavioral, and health research teams. Each of the chapters within these three broad types discusses implications, lessons learned, and practical strategies for success in order to help guide readers who are interested in applying team science principles and practical action steps in establishing successful team science units.

Knowledge regarding evidence-based principles in the volume is drawn from and applied to team science across the scientific enterprise and research domains. NIH scientists have served as international leaders in studying as well as developing strategies for how to improve the support and conduct of team science. The book has a public health research and application orientation, and nearly half of the chapters draw from, or include, examples of research that integrates behavioral and social science with a broad range of disciplines. So although NIH scientists have utilized and applied their knowledge in the health context, the models, tools, and applications featured in this volume have been developed within and used across the sciences, humanities, and public health arenas.

The National Academies report, *Enhancing the Effectiveness of Team Science*, drew several conclusions addressing the need for more systematic research in the complicated nature, etiology, and context of team science. The growth in the breadth of interdisciplinary areas needed to address evolving scientific problems and questions ranging from the creation of the universe to the nature of cellular activity promoting the growth of cancerous cells portend even further complexity in the future. It is not clear that institutional support systems, policies, organizations, and individual scientists are keeping pace with the evolving needs of these science teams. This volume summarizes current scientific knowledge of effective team science approaches, areas of need for new research on science teams, and, perhaps even more importantly, examples like the ISR organization experiment that have promoted successful (as well as not so successful) team science applications over the years. There are lessons that have been learned, lessons to be learned, and compelling examples of systematic and non-systematic attempts to implement teams of scientists (both inter- and intradisciplinary) working on shared scientific problems.

It is clear that training models for scientists will have to be adapted to meet the new organization of scientific research. In fact, traditional frameworks of individual and group-based contributions will have to be modified. What counts as scientific products may need to be enlarged, and researchers will need to make conscious decisions about their involvement in team science, whether with an interdisciplinary focus or not. Based upon this view, researchers may need to reevaluate what constitute paths to success, especially those in academic settings.

The institutional context of research will need to change as well. The notion of static, enduring research institutions will have to be rethought. Policies around rewards, especially promotion and tenure in universities, will have to be adapted. Business firms will have to rethink traditional private consultation frameworks of collaboration with the universities and government. Studies of alternate organizational structures and management approaches will be needed to inform efforts to integrate team science into scientific operations. Finally, the government, industry, and private funders of research all will need to adjust models for stimulating research to encompass team-based research. They will need to develop new models of awarding funding and monitoring accountability of research expenditures. New collaborative models, e.g., research networks and consortia, will also need to be evolved and tested. This will require the integration of disciplinary perspectives and methods throughout the life of research projects.

The agenda for evolving effective conceptual and practical approaches for implementing cross-disciplinary team science has not been fully written. This volume, however, outlines a roadmap for what the future will require and what the ultimate benefits may be in implementing effective cross-disciplinary team science across public health-related research.

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Janice Stern, a former senior editor at Springer, was instrumental in championing the initial concept for this book. Her invitation to Kara to propose a Springer Handbook on Team Science inspired the idea for this volume; to pair evidence from the SciTS field and allied fields with the rich experiences of successful leaders in cross-disciplinary team science. With this approach, the book aims to advance the application of evidence-informed strategies for an expansive range of activities in leading, implementing, managing, facilitating, and supporting collaborative scientific initiatives. We also thank Katherine Chabalko, Sara Yanny-Tillar, and Christina Tuballes, of Springer, all of whom contributed in moving this book to publication.

Many peer reviewers also generously donated their time to provide anonymous reviews of chapters for this volume, including incisive feedback that often led to new themes or avenues of thought in the chapters. They, too, contributed to the scientific content of the book, and we sincerely thank them. Listed alphabetically, they include: Nicholas Berente, Mike Conlon, Jay Goodwin, Stan Gully, Susan Jackson, Gaetano Lotrecchiano, Margaret Luciano, Steve Kozlowski, Jonathan Mote, Staša Milojević, Jihad Obeid, Marissa Shuffler, Daniel Stokols, Rick Szostack, Sheila Weber, and Kevin Wooten.

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We also are grateful to the many students, colleagues, and mentors who have had invaluable influence on our work and the Science of Team Science field we value so greatly for its promise to help accelerate science. Foremost, among these is Daniel Stokols. As a pioneer in the SciTS field and a preeminent scholar in both SciTS and social ecology, Dan has been unfaltering in his roles as an intellectual leader, inspirational mentor, and kind-hearted collaborator. Between 2004 and 2011, Dan served as a senior advisor to the NCI Division of Cancer Control and Population Sciences, providing invaluable leadership and guidance for the evaluation and enhancements of large transdisciplinary team science initiatives. Throughout his tenure as a consultant at NCI, and beyond, Dan has been a mentor to two of us (Kara and Amanda) in many ways. His mentorship and collaboration over the years have influenced the development of a number of key ideas that are reflected in this book. In fact, his intellectual influence is reflected throughout our work in the SciTS field.

We are grateful for our colleagues at the National Cancer Institute – Linda Nebeling, Shobha Srinivasan, Bradford Hesse, and Glen Morgan – for their groundbreaking contributions to the development, management, and leadership of the NCI Division of Cancer Control and Population Sciences' flagship transdisciplinary team science initiatives, the Transdisciplinary Research on Energetics and Cancer (TREC) initiative, the Centers for Population Health and Health Disparities (CPHHD) initiative, the Centers of Excellence in Cancer Communication Research (CECCR) initiative, and the Transdisciplinary Tobacco Use Research Centers (TTURC) initiative. Their steadfast support and collaboration in SciTS research provided the opportunity for us to engage with these transdisciplinary team science initiatives to conduct SciTS studies that have contributed to advancing the evidence base for team science. We also thank the following NCI advisors, staff, and fellows who have provided critical leadership and collaboration for novel evaluation studies of team science initiatives: William Trochim, Ginny Hsieh, Scott Marchand, Stephen Marcus, Louise Masse, Rick Moser, Brandie Taylor, and Patrick Weld. We are so grateful to have been a part of this exceptional group of colleagues who, together, generated early SciTS work that helped launch the field by providing new models, measures, and methods to study team science.

Over the next decade, new members joined us and formed the NCI SciTS team. The team continued to conduct research on team science initiatives and advance scholarship in the SciTS field. They brought a diversity of perspectives and subject matter and methodological expertise to the NCI SciTS team that contributed to our work thematically, methodologically, and conceptually. We wish to thank our team members, including: Annie Feng, Grace Huang, Kenny Gibbs, Janet Okamoto, Elise Rice, and Brooke Stipelman for their collaboration over the years. We also thank our long-standing collaborator, Sophia Tsakraklides.

We are also grateful to the SciTS professional community for their commitment to and passion for the development of a collegial and collaborative environment and generative knowledge exchange through their active

engagement on the SciTS listserv[1] and at the annual SciTS conference.[2] We thank the founding board of directors of the newly formed International Network for the Science of Team Science (INSciTS), the new professional society for the SciTS field[3]. The founding board members of INSciTS include Maritza Salazar Campo, Holly J. Falk-Krzesinski, Stephen M. Fiore, Andi Hess, Julie Thompson Klein, Gaetano R. Lotrecchiano, Shalini Misra, Zaida Chinchilla Rodriguez, Pips Veazey, and Kevin C. Wooten. With Kara also serving on the founding board and Amanda serving as founding membership chair for the organization, we are honored to have the opportunity to serve alongside these colleagues who provide leadership for maintaining and enhancing the vitality of the growing SciTS community. Their dedication benefits those committed to advancing SciTS research as well as those committed to supporting and conducting cutting-edge cross-disciplinary team science.

So much of the work of building the SciTS field that has been accomplished over the past 10–15 years could not have happened without the vision and support of NCI leaders, including Linda Nebeling, Bill Klein, Bill Riley, and Susan Czajkowski. We thank them for their long-standing support.

Finally, we thank our families for their gift of time that made our work on this book possible. We are deeply grateful for their love and support.

[1] https://www.teamsciencetoolkit.cancer.gov/public/RegisterListserv.aspx

[2] https://www.inscits.org/

[3] https://www.inscits.org/inscits-board-of-directors

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Part I

Introduction

Introduction

1

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Contents

1.1 Introduction

Science is the cornerstone of progress, and collaboration is becoming the defining approach in science today. Whether the aim of a given research project is to advance fundamental knowledge or to develop actionable solutions to real-world problems, scientific initiatives are increasingly turning to collaboration to achieve their goals.

Progress in the leading scientific initiatives of our age—including the Human Genome Project, the BRAIN (Brain Research through Advancing Innovative Neurotechnologies) Initiative, the experiments at the Large Hadron Collider, the Mars Exploration Rover Mission, and many others—has been predicated upon collaboration. Further, when we go beyond the scientific headlines and look at the entirety of the scientific enterprise, we find that it has been driven, increasingly, by collaborative approaches. Since the mid-twentieth century, collaboration has eclipsed solo work as the main approach to generate new scientific knowledge. More scientists are collaborating within and across all disciplines and fields. Scientific articles by co-author teams are more often cited and have greater impact, overall, than individually authored articles, and these advantages have been increasing over time. Further, team authored articles now dominate among exceptionally high impact research (Wuchty et al. 2007).

What has contributed to this trend? Today's ambitious societal and scientific goals, such as eliminating health inequities, understanding nanostructures, arresting climate change, and exploring distant planets have led to increasingly large, complex, and ambitious scientific initiatives. Furthermore, our scientific goals and approaches have been influenced, altered, and enabled by advances in technological and computational capabilities; these include dramatic advances in our ability to capture, store, and analyze data.

As an example, with computing devices embedded in more and more everyday objects in our lives, the Internet of Things (IoT) enables us to collect and connect vast amounts of data. In the domain of health research, we can now monitor and report geocoded health data and use these

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data, including actively reported behavioral data and passively recorded biological sensor data, to address a wide array of scientific questions. The aggregation of multiple "big data" sources such as, geospatial, environmental exposure, and electronic health record data afford tremendous opportunities to population science but also present methodological challenges inherent to aggregating data from across disciplines and levels of analysis. As another example, unprecedented advances in science and technology enable us to envision and develop healthcare systems and public health strategies of the future that rely upon artificial intelligence systems, provide 3D bioprinted organ transplants, and use genetic engineering to alter disease processes. To capitalize on these opportunities requires cross-disciplinary collaboration.

For science to fully realize its most ambitious goals, scientific perspectives reflecting all influences on the human experience—from genetics to behavior, from individual experiences to interpersonal interactions, from organizational structures to political institutions—must be brought to bear and integrated. As such, novel discoveries and innovative developments increasingly will rely on collaborations that span boundaries and require complex skills and structures. Collaborations will need to include team members with expertise that spans multiple disciplines and fields, crosses organizational and geographic boundaries, and integrates multiple levels of analysis and methodologies. The exciting news is that teams with these characteristics generally yield better outcomes, including greater productivity and scientific impact, compared with less diverse, less distributed teams, or solo scientists (Hall et al. 2018).

Disciplinary specialization has the potential to enrich and deepen scientific knowledge, but it also fragments expertise. Collaboration harnesses the power of specialization by integrating seemingly disparate expertise to address shared research goals. New technological capabilities can facilitate such integration as through dataset integration and collaborative data analysis. All of this can help to answer scientific questions in more novel, holistic, and sophisticated ways. Further, technologies enable virtual communication and support the coordination of tasks among collaborators with the most relevant expertise for a particular scientific question regardless of geographic location (Hall et al. 2018).

While collaboration in science introduces enormous opportunities for scientific advancement, it also introduces greater complexity into the scientific process. In order to maximize the scientific successes of collaborations, we must know how best to manage this complexity. This includes how best to organize, conduct, facilitate, and support collaborative science, given a range of contextual factors, beginning with the scientific problem space, and extending to institutional influences, funding opportunities, and scientific culture and policies. This book offers the state of the art on what we know about how to manage these factors to maximize the effectiveness of team science.

1.1.1 What Is Cross-Disciplinary Team Science?

"Team science" refers to both the *approach* of conducting research in teams, and the complex social, organizational, political, and technological *milieus* that heavily influence how that work occurs (Hall et al. 2018). The team science approaches involves two or more individuals working interdependently toward a shared scientific goal. Team size spans from dyads to small teams, and from large groups to teams of teams. Teams also vary in their disciplinary composition and degree of disciplinary integration. (NRC 2015)

In this book, the term "cross-disciplinary" is used to refer to any type of scientific knowledge integration among disciplines, fields, domains, professions, and other stakeholders in the scientific problem space (see Box 1.1). Collaborators may span scientific disciplines and fields, and work in academia, industry, policy, and community organizations. Cross-disciplinary team science brings together concepts, theories, approaches, and/or methods from across these diverse perspectives. The term "integrative science" is understood similarly to reflect integration of knowledge across disciplines and fields, as well as the expertise of other scientific collaborators, such as translational partners (e.g., practitioners, policy makers, industry, and community organizations). Likewise, the term "convergence research"

(NRC 2014) has been taken up by organizations like the National Science Foundation (NSF) to describe integrative scientific work aimed at addressing scientific and societal challenges through "deep" integration across disciplines (NSF 2018; see also Box 1.1).

Box 1.1 The Continuum of Disciplinary Integration[a]

Unidisciplinary team science refers to an endeavor in which two or more researchers, sharing the same disciplinary perspective, work interdependently to address a scientific problem.

Cross-disciplinarity is an overarching term that encompasses three types of disciplinary integration: multidisciplinary, interdisciplinary, and transdisciplinary.

Multidisciplinary team science occurs when two or more researchers from different disciplines work sequentially to address a scientific problem, staying rooted in their own discipline-specific perspectives, with the goal of addressing the scientific problem from each perspective.

Interdisciplinary team science aims for a degree of cross-disciplinary integration, with team members from different disciplines working together to combine perspectives, concepts, and methods from across disciplines. Contributors remain anchored in their disciplinary perspectives, which may limit the degree of integration achieved.

Transdisciplinary team science (TD TS) represents the greatest degree of cross-disciplinary integration in the continuum. Researchers from different disciplines work interdependently to develop and apply conceptual frameworks, theories, methods, and measures that both synthesize and extend beyond discipline-specific approaches to create new approaches to address the scientific problem. Some scholars characterize transdisciplinary research as including an emphasis on the translation of research findings into practical solutions for social problems. For instance, Stokols (2006) characterizes TD TS as a form of action research, while Pohl and Hirsch Hadorn (2007) define TD TS as addressing "problems of the life world" and stipulate that this approach requires that "real-world actors" (e.g., community stakeholders) be involved throughout the research endeavor.

[a]c.f., Hall et al. (2008, 2017), Stokols et al. (2013)

Teams vary in the degree or "depth" to which they integrate knowledge, depending on what is needed to address the research problem at hand, with this integration occurring along a continuum from unidisciplinary research (no cross-disciplinary integration) to transdisciplinary research (maximal integration among participating disciplines) (Stokols et al. 2013; Hall et al. 2017). As summarized in Box 1.1, scholars typically define four degrees of cross-disciplinary integration along this continuum: unidisciplinary, multidisciplinary, interdisciplinary, and transdisciplinary.

Cross-disciplinary team science has the potential to produce holistic study designs and findings that often cannot be achieved using unidisciplinary team science. These, in turn, help to advance scientific methods and knowledge relevant to solving complex scientific problems (Vogel et al. 2014). This approach to science offers tremendous opportunity to advance science along the translational continuum, as it has the potential to engage collaborators whose approaches span multiple translational stages.

Support for the cross-disciplinary team science approach is shaping the landscape of science. Universities are developing team-based problem-focused units that cut across disciplines and fields (Crow and Dabars 2015) and are revising their hiring, promotion, and tenure policies to recognize cross-disciplinary team science (Klein and Falk-Krzesinski 2017; Vogel, Hall, Falk-Krzesinski, and Klein 2019), and government agencies are increasing their investments in collaborative and often innovative cross-disciplinary and cross-field approaches (Croyle 2008), to highlight just a few

examples. When structures, support, and rewards are aligned, the value-add of team science can be maximized, as reflected in scientific productivity, dissemination of findings across disciplines and fields, and translation of findings into real-world applications in the forms of patents, products, interventions, and policies (Hall et al. 2018).

1.1.2 What Leads to Success in Cross-Disciplinary Team Science?

As with all scientific endeavors, collaborative endeavors vary in their success. Cross-disciplinary science teams can maximize their success by working collectively to ask research questions and utilize scientific approaches that leverage the unique expertise of the group. Yet to maximize the likelihood that the scientific and technical merit of a team science initiative is realized, teams must attend to a range of critical influences on the collaborative process. These occur across multiple levels of influence, including intrapersonal, interpersonal, organizational, social, political, and technological (Stokols et al. 2008). For example, team members' attitudes about team science, their history of prior collaboration, and departmental and institutional policies around cross-disciplinary scholarship all influence the success of cross-disciplinary team science.

For decades, leaders across the scientific enterprise have sought to understand how best to facilitate and support effective cross-disciplinary team science. Yet the research needed to inform development of effective strategies was scant until relatively recently (e.g., NASEM 2005; NRC 2014). Then, over the past fifteen years, a number of strategic efforts emerged to generate evidence-based strategies to maximize the success of team science. These have now coalesced into a relatively new field of scholarship, called the Science of Team Science (c.f., Hall et al. 2018; Kaiser 2017; NRC 2015).

The Science of Team Science (SciTS, pronounced, "sights") field aims to generate evidence for what leads to effective team science through the empirical study of science teams. Studies are informed by theories and methods from research on teams in other settings and by original theories and methods tailored to the study of science teams, in particular. Ultimately, the "opportunity and promise of SciTS [is] to use science to transform the ways researchers do science" (Hall 2017, p. 563).

Key research questions in the SciTS field include the following: What contextual factors are important influences on team science, such as organizational policies, culture, and workspace, as well as funding opportunities and broader scientific trends? And in what ways do they influence science teams? What team leadership and management approaches contribute to success? And how might these vary based on the scientific goals at hand (e.g., innovation vs. replication)? What are the best approaches to team composition (e.g., team size, diversity, history of collaboration) to maximize the likelihood of success? How does training for scientific collaboration shape success, and what approaches to training are most effective (e.g., individual vs. team training)? What team processes and interactions, such as communication and coordination mechanisms and conflict management approaches, are most effective? What approaches for data sharing, collaborative data analysis, and related attribution/credit contribute to success? What strategies are effective to facilitate integration of multiple discipline-based approaches (e.g., communication strategies, approaches to develop shared terminology and shared mental models of the science)? What are the most effective ways to integrate and leverage knowledge from team members from the professional, policy, and community settings? To what degree are these keys to success stable or variable across organizational settings, teams, and scientific contexts (e.g., disciplines, scientific goals), and what adaptations are effective given particular combinations of team factors and key influences? (Hall 2017; Hall et al. 2018)

The SciTS field seeks to build on research and engage researchers from a wide range of disciplines and fields. The early development of the SciTS field has drawn from fields such as economics, management and organizational science, psychology, science policy, computer science, and the humanities. In particular, the SciTS field

has drawn heavily from what has been learned about teamwork over the past half century from the study of groups and teams in other contexts (e.g., military, industry, healthcare) (Fiore 2008). In addition, SciTS studies have integrated analytic methods from network science, perspectives from community stakeholders, theories from economics, and research designs from behavioral and social sciences (Hall et al. 2018).

Although a significant amount of effort has been devoted to studying teams, it is critical to develop evidence for science teams, specifically. Based on literature from teams broadly, we now know that some effective practices apply across many types of teams (e.g., practices around team communication and coordination). But team science operates within the unique conditions of the scientific enterprise, including the legacy structures of academia (e.g., disciplines, departments), sources of financial support, intellectual property issues, rewards and incentives, metrics of success, motivations for collaboration, and collaborators who are also competitors. As such, experts emphasize that while there are opportunities to apply what is known from non-science teams to science teams, it is important to devote resources to studying science teams, in particular (Fiore 2008; Hall et al. 2018; Kozlowski and Bell 2019).

While some scholarship on scientific collaboration emerged prior to 2006 (e.g., Pelz 1967; Pelz and Andrews 1966; Payne 1990), the origins of the SciTS field can be traced to a US National Institutes of Health (NIH) conference held in 2006 entitled *The Science of Team Science: Assessing the Value of Transdisciplinary Research*. The conference led to a special issue of the *American Journal of Preventive Medicine* (Stokols et al. 2008), which provided the conceptual and empirical foundations for the SciTS field. More recently, the National Academies convened a consensus study committee on the Science of Team Science,[1] which culminated in the development of the report *Enhancing the Effectiveness of Team Science* (NRC 2015). This report was recently listed in the top 25 most downloaded reports (out of more than 9000 reports available online) published by the National Academies Press since 1994. This demonstrates the demand for evidence-based guidance for effective team science, as well as growing interest in SciTS scholarship.

Since 2010, the Annual International Science of Team Science Conference[2] has brought together a community of SciTS scholars and team science stakeholders, including practitioners, facilitators, administrators, and funders, to advance SciTS research and evidence-informed team science practices. Overall, the SciTS field is generating and disseminating actionable evidence-based resources and strategies for success that can be used by team science stakeholders across the scientific enterprise to enhance the effectiveness of team science (Hall et al. 2018). Many of these can be found on the US National Cancer Institute's Team Science Toolkit[3] (Vogel et al. 2013).

1.1.3 What You Will Find in This Book

Cumulative developments in the SciTS field and allied fields that study teams in other contexts, as well as growing investments in team science by academia, industry, and government, led us to believe that the time is ripe for a book that pairs scholarship on effective practices in cross-disciplinary team science with practical strategies and lessons learned from those actively involved in conducting, leading, and supporting team science.

Building on more than a decade of work in the SciTS field and decades of research in allied fields, this handbook provides readers with an evidence-based understanding of effective practices in cross-disciplinary team science. It includes practical how-tos for engaging in these teams as well as recommendations for managing, facilitating, and supporting cross-disciplinary research collaborations in varied contexts. The book is therefore relevant to a range of audiences, including principal investigators, science team members, academic administrators, and research funders, among others.

[1] http://sites.nationalacademies.org/dbasse/bbcss/current-projects/dbasse_080231

[2] https://www.inscits.org/

[3] https://www.teamsciencetoolkit.cancer.gov/

The handbook is structured around thematic sections that focus on key influences on the success of cross-disciplinary team science, such as team formation, leadership, communication and coordination, training, and institutional policies and structures. Each section includes one or more *State of the Science* chapters that summarize the evidence base for effective practices for team science from the range of disciplines (e.g., management and organizational sciences, psychology) contributing to the scholarship on that topic. Real-world examples of successful application of these practices are provided in *Practice-Oriented* chapters written by individuals who have engaged in, managed, facilitated, or supported successful cross-disciplinary team science initiatives. In addition, each section highlights Special Topics, including cutting-edge and emerging issues in cross-disciplinary team science. (For more detailed descriptions of each of the three types of chapters, see Box 1.2; and for a list of each State of the Science, Practice-Oriented, and Special Topics Chapters, see Box 1.3).

Following this introductory chapter (Part I), Part II further sets the stage for the book by illuminating how research conducted by *integrative science teams* can lead to unanticipated discoveries and innovative new programs of research. Part II also highlights strategies used by leading researchers to overcome some of the challenges of cross-disciplinary collaboration and facilitate scientific success while moving into new scientific frontiers. The section begins with a chapter that summarizes the state of the science on managing cross-disciplinary diversity in science teams, including practical steps for addressing challenges that emerge with disciplinary diversity. The chapter highlights key processes for identifying appropriate experts, preparing cross-disciplinary teams for collaboration, and enabling the integration of discipline-based perspectives (O'Rourke et al. 2019, Chap. 2). Several chapters in this section are written by experts engaged in cross-disciplinary health research. These chapters showcase the kinds of novel discoveries that can occur with cross-disciplinary team science when scientific perspectives and methods from two or more a different fields or disciplines are integrated into a new or existing program of research (James and Redline 2019, Chap. 3; Falcone et al. 2019; Chap. 4; Arriaga and Abowd 2019, Chap. 5). For example, chapter 5 (Arriaga and Abowd 2019) highlights collaborative strategies used in a collaboration involving computer science and medicine that led to the design of new technologies as well as the development of clinically significant applications to health behavior. Finally,

Box 1.2 Three Types of Handbook Chapters

State of the Science chapters are written by Science of Team Science (SciTS) scholars and/or scholars from allied fields and provide in-depth exploration of the evidence base around key influences on the success of cross-disciplinary team science. Readers can turn to these chapters to find examples of strategies for effective team science, and to get an in-depth understanding of the evidence base that informs effective team science practices.

Practice-Oriented chapters are written by scientists who have successfully used team science approaches in their work; administrators including academic vice presidents, provosts, and center directors, who are involved in the work of facilitating and managing cross-disciplinary team science; and funders with insights to share related to successfully supporting the team science approach. These chapters highlight key strategies for success and lessons learned related to organizing, leading, implementing, managing, facilitating, and supporting cross-disciplinary team science, based on the real-world experiences of their authors.

Special Topics chapters are written by health scientists, SciTS scholars, and scholars in related fields and disciplines. These chapters highlight cutting-edge topics, emerging issues, and current trends in cross-disciplinary team science (e.g., open science, citizen science), as well as other trends in science and technology more broadly, that impact the practice of cross-disciplinary team science.

Box 1.3: A complete listing of the *State of the Science*, *Practice-Oriented*, and *Special Topics* chapters included in this handbook

Type of chapter	Chapter number	Chapter title
Integrative Science Teams		
State of the Science	2	Disciplinary Diversity in Teams: Integrative Approaches from Unidisciplinarity to Transdisciplinarity
Practice-Oriented: Integrating Disciplines, Fields, and Levels of Analysis	3	The Introduction of a New Domain into an Existing Area of Research: Novel Discoveries Through Integration of Sleep into Cancer and Obesity Research
	4	The Integration of Research from Diverse Fields: Transdisciplinary Approaches Bridging Behavioral Research, Cognitive Neuroscience, Pharmacology, and Genetics to Reduce Cancer Risk Behavior
	5	The Intersection of Technology and Health: Using Human Computer Interaction and Ubiquitous Computing to Drive Behavioral Intervention Research
	6	Research Spanning Animal and Human Models: The Role of Serendipity, Competition, and Strategic Actions in Advancing Stroke Research
	7	Collaborating to Move the Laboratory Findings into Public Health Domains: Maxims for Translational Research
Approaches for Expanding Engagement in Team Science		
State of the Science	8	Methods for Co-Production of Knowledge among Diverse Disciplines and Stakeholders
Special Topics: Engagement Approaches	9	Engaging the Community: Community-Based Participatory Research and Team Science
	10	Engaging the Patient: Patient-Centered Research
	11	Engaging the Practitioner: "But Wait, That's Not All!"— Collaborations with Practitioners and Extending the Reasons You Started Doing Research in the First Place
	12	Engaging the Public: Citizen Science
Individual Competencies and Team Characteristics		
State of the Science	13	Individual-Level Competencies for Team Collaboration with Cross-Disciplinary Researchers and Stakeholders
Special Topics: Personality Traits	14	The Role of Team Personality in Team Effectiveness and Performance
Practice Oriented: Demographic Diversity	15	Demographic Diversity in Teams: The Challenges, Benefits, and Management Strategies
	16	The Added Value of Team Member Diversity to Research in Underserved Populations
Team Formation		
State of the Science	17	Team Assembly
Practice-Oriented: Strategies to Facilitate the Development of New Teams	18	Innovative Collaboration Formation: The National Academies Keck Futures Initiative
	19	Facilitating Cross-Disciplinary Interactions to Stimulate Innovation: Stand Up to Cancer's Matchmaking Convergence Ideas Lab
	20	Retreats to Stimulate Cross-Disciplinary Translational Research Collaborations: Medical University of South Carolina CTSA Pilot Project Program Initiative
Team Functioning and Performance		
State of the Science	21	Evidence-Based Principles and Strategies for Optimizing Team Functioning and Performance in Science Teams
Practice-Oriented: Preventing Conflict	22	Conflict Prevention and Management in Science Teams
	23	Precollaboration Framework: Academic/Industry Partnerships: Mobile and Wearable Technologies for Behavioral Science
Leadership and Management of Teams		
State of the Science	24	Leader Integrative Capabilities: A Catalyst for Effective Interdisciplinary Teams