International Network-to-Network

Annotated Bibliography

to accelerate research, leverage resources, and maximize synergies

B. Jan Middendorf, Ph.D.
Rebekah Carnes, Ph.D.

Kansas State University
Sustainable Intensification Innovation Lab
National Science Foundation

Acknowledgements:

This material is based upon work supported by the National Science Foundation under Grant No. 1842111 - International Network-to-Network (N2N) Stakeholder Collaboration: Solutions to Accelerate Research, Leverage Resources, and Maximize Synergies.

Disclaimer:

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Readers should be aware that Internet Web sites offered as citations and/or sources for further information may have changed or disappeared between the time this was written and when it is read.

Suggested Citation:
Middendorf, B.J. and Carnes, R. (2020). International Network-to-Network Annotative Bibliography. National Science Foundation under Grant No. 1842111.

International Network-to-Network (N2N) Annotated Bibliography to Accelerate Research, Leverage Resources, and Maximize Synergies

Table of Contents

I. Introduction

Scientific questions loom larger than ever in a society that demands solutions to human-induced climate change problems, food insecurities, mounting inequalities, public health problems, and a variety of other issues that affect an increasingly globalized and inter-connected world (Kahn, 1994; Rosenfield, 1992). These questions ushered in the 4th age of research through their size and scope (Adams, 2013). They are unanswerable by single scientists or small teams, and they require large-scale collaborative data sharing, goal orienting, and aligned efforts. Grand questions demand the engagement of researchers and community stakeholders on a grand scale. Network-to-network collaborations hold the key to facilitating these efforts as they shape what we collectively know, the trajectory of what we will know, and the solutions that are possible. They establish knowledge-seeking priorities by funding new projects, and they can perpetuate or disrupt power structures within the scientific and development communities.

In an effort to catalogue these dynamics, this bibliography focuses primarily on examples of network-to-network collaboration in science, the effects of network participation on individual scientists (Impacts); the effects on science and on society as a whole (Motivation and Evidence); and the ways that the quality of knowledge produced can be evaluated by a variety of indicators capturing scientific consensus, impact on scientific literature, policy-making, diversity, etc. (Evaluation and Indicators) (Wagner et al. 2011). Wagner (2018) summarizes the scope and challenges of this "networked era" in science (also known as the 4th age of research, or the era of knowledge-abundance).

Following these key citations, an overview explains how the network-to-network literature builds upon existing team science literature and how the science of team science might scale up to the networked level. It considers how networks can best be understood, mapped, and visualized, and how the trajectory of future research is shaped by network clusters and collaborators. It discusses the variety of types of networks included in this bibliography along with their unique goals and structures, highlighting certain models and case studies that have been particularly effective.

This overview concludes with three challenges and areas for future research: (1) the need for a better understanding of the complex relationships that form the bridge between research and implementation- scientific networks and community stakeholders; (2) the need for a more holistic and qualitative understanding of the impacts of network participation on diverse researchers; and (3) the need for more detailed documentation that can be used as a blueprint for network-to-network collaborations of how team science scales as it gets larger and more complex.

II. Definitions: How are research groups, networks, and networks of networks defined?

Bozeman, B. (2003). ***Managing the New Multipurpose, Multidiscipline University Research Centers: Institutional Innovation in the Academic Community*** **(Transforming Organizations, pp. 1–60). IBM Center for the Business of Government. http://www.businessofgovernment.org/sites/default/files/UniversityResearchCenter.pdf**

Research Center is defined as "a formal organizational entity within a university, which exists principally to serve a research mission, being defined beyond the departmental organization and includes researchers from more than one department" (Bozeman, 2003).

These are the primary sources of knowledge creation, which is done by students and researchers under the guidance of a professor who also teaches in medium and small-scale centers, and by more focused individuals in larger centers. Cooperation between such places is key in the creation of networks.

Tags: collaboration, research centers

Abstract: Since the creation of the IBM Center for The Business of Government five years ago, we have been interested in the study of new ways to operate within large institutions. A recent IBM Center report by William Snyder and Xavier de Souza Briggs, "Communities of Practice: A New Tool for Government Managers," examines the use of informal communities of practice as a new way to work within traditional hierarchies. In this report, Professor Bozeman and Mr. Boardman look at the evolution of the multipurpose, multidiscipline university research center (MMURC) as a new, more formal approach to organizing research centers in the academic community. Bozeman and Boardman contrast the new MMURCs with the traditional university research center (URC) and academic departments, which tend to be more disciplinary and single-problem focused. In contrast, the new MMURCs are almost entirely problem driven and do not track closely to existing disciplines and established scientific and technical specializations. Because of this, Bozeman and Boardman conclude that the potential for the MMURC is great. They write, "The MMURC has the potential to harness the historical advantages of university research and at the same time transform university research into a mechanism for solving a broader and deeper array of scientific, technical, and social problems." This report is aimed at two distinct sets of audiences. One is university officials and university administrators, including MMURC directors, who deal directly with university research centers. The second is government program managers who are either currently managing an MMURC or considering establishing one. The report presents reasons why MMURCs are a potentially important tool for the government to use as it seeks to collaborate with the academic community in addressing national problems. We trust that this report will be helpful and useful to both audiences as they face the challenge of marshaling the nation's research community to address large-scale science and technology problems that require an integrated research approach.

DOA: 5.26.2020
http://www.businessofgovernment.org/sites/default/files/UniversityResearchCenter.pdf

Clauset, A., Newman, M. E. J., & Moore, C. (2004). Finding community structure in very large networks. ***Physical Review E*****,** ***70*****(6), 066111. https://doi.org/10.1103/PhysRevE.70.066111**

[See notes in "Measures and Indicators"]

Graf, H., & Kalthaus, M. (2018). International research networks: Determinants of country embeddedness. ***Research Policy*****, 47(7), 1198–1214. https://doi.org/10.1016/j.respol.2018.04.001**

Definitions:

Embeddedness: a measure of network centrality that emphasizes different aspects of knowledge access, in this study, it is measured by the number of collaborating countries, the relative position and intensity of collaboration (flow betweenness).

Analyzing research networks related to photovoltaics, the researchers found that embeddedness related to macro and meso country-level network structure and national policies towards PV and climate change, implemented to fix market failures. The multimodal network structure of publication data is used to link meso structures with macro positions. Cohesion of the national research network has a positive influence on international embeddedness. Countries with centralized research systems are less embedded than those with a diffusion-oriented research system (Graf & Kalthaus, 2018).

Tags: international collaboration, multimodal networks, photovoltaics, policy mix, research system

Abstract: Research activities are increasingly global so that embeddedness in international knowledge networks is decisive for inventive and innovative performance. We analyze determinants of countries' embeddedness in the global photovoltaics knowledge network for the period 1980–2015 and argue that positions in this network are determined by the structure and functionality of national research systems and by instruments within the policy-mix for renewable energies. We show that cohesion and connectedness of the national research system positively affect international embeddedness, whereas centralized systems are detrimental to embeddedness. This indicates that a diffusion-oriented research system allows better access to international knowledge flows. Policy instruments, especially demand side instruments, show a positive effect on embeddedness.

DOA: 4.28.2020
https://www-sciencedirect-com.er.lib.k-state.edu/science/article/pii/S0048733318300829#sec0120

Kyvik, S., & Reymert, I. (2017). Research collaboration in groups and networks: Differences across academic fields. Scientometrics, 113(2), 951–967. https://doi.org/10.1007/s11192-017-2497-5

Across academic fields, collaboration patterns differ across networks and between academic fields in Norwegian research universities. The research group is important in medicine and health; the international network is most important in the natural sciences. This comparison makes a distinction between groups- which have "long traditions in the experimental sciences, and [have] been called the engine of productivity in research and of effective graduate training" and networks- which operate with greater flexibility across institutions and less bureaucracy (Kyvik & Reymert, 2017, p. 952).

"Individual research collaborations depend on a diverse set of environmental conditions, and the research agenda can to a large extent be determined by disciplinary norms and traditions, the strategy of the research group, institutional strategies, and the priorities of funding agencies" (Kyvik & Reymert, 2017, p. 965).

Definitions:

Research group: an institutionally based research collaboration
Research network: collaborations crossing institutional boundaries. Group members can be connected to various networks.

*Most academics in Norway conduct research in an international network, which is a complementary research strategy to collaboration in groups.

Tags: definitions, international networks, research groups

Abstract: The purpose of this paper is to give a macro-picture of collaboration in research groups and networks across all academic fields in Norwegian research universities, and to examine the relative importance of membership in groups and networks for individual publication output. To our knowledge, this is a new approach, which may provide valuable information on collaborative patterns in a particular national system, but of clear relevance to other national university systems. At the system level, conducting research in groups and networks are equally important, but there are large differences between academic fields. The research group is clearly most important in the field of medicine and health, while undertaking research in an international network is most important in the natural sciences. Membership in a research group and active participation in international networks are likely to enhance publication productivity and the quality of research.

DOA: 6.6.2020
https://link-springer-com.er.lib.k-state.edu/content/pdf/10.1007/s11192-017-2497-5.pdf

Leite, D., & Pinho, I. (2016). ***Evaluating Collaboration Networks in Higher Education Research: Drivers of Excellence.*** **Springer.**

[See notes in “Measures and Indicators”]

Moock, J. L. (2016). ***Network Innovations: Building the Next Generation of Agricultural Scientists in Africa*** **(Chapter 10; 0 ed., Agricultural Research in Africa: Investing in Future Harvests). International Food Policy Research Institute. https://doi.org/10.2499/9780896292123**

[See notes in "Motivations"]

Wagner, C. S. (2018). ***The Collaborative Era in Science: Governing the Network*** **(C. S. Wagner, Ed.). Springer International Publishing. https://doi.org/10.1007/978-3-319-94986-4_9**

[See more notes in "Evidence"]

**image in Appendix- p. 160*

Definition:

The global network is the product of the decisions of thousands of scientists to reach beyond the borders of laboratories within their home countries to seek out collaborators who can enhance the knowledge-creating process. Collaborations overcome the limitations imposed by organizational specialties.

"The global network of science has emerged because scientists connect with each other on a peer-to-peer level, and a process of preferential attachment selects specific individuals into an increasingly elite circle. The process reduces free riders and greatly increases the visibility of parts of the system. The global network of science enhances the possibility that said research will be applied and cited or referenced by others. Joining the global network of science affords participants key benefits, as well as opportunities to passively exclude others who do not offer substantial contributions. It is the cream rising naturally to the top of the bottle. Policy is needed to reverse the natural tendency to have elites dominate the network" (Wagner, 2018, p. X).

"The global network of scientific collaboration has emerged in the 21st century. The network is one part of the innovation process and feeds other parts of the larger knowledge economy" (Wagner, 2018, p. v).

Despite predictions that scientific innovation would level off, new innovations, the rise of new parts of the world, and the growth of the scientific networks has defied all predictions.

Science network growth operates within a law of accelerating returns, so that as a barrier is reached, new inventions allow us to cross the barrier and proliferate under new conditions. Wagner tracks the history of mode one and two in science, and the rise of the globalized network in the last several decades. She analyzes the ways that communication functions within networks as they grow from system bounded, but relational, to hierarchical, to pollination hubs, to combined hierarchical and network interactions, where critical interactions cluster the network.

Tags: network communication, network growth

III. Evidence of increasing international collaboration

Adams, J. (2013). The fourth age of research. *Nature*, *497*(7451), 557–560. https://doi.org/10.1038/497557a

Analysis of three decades of domestic and international collaboration shows growth in research output in US and Western Europe due to increased international collaboration. In emerging economies, research output increases are due to domestic research output. For US and UK research, international articles are cited relatively more than domestic articles (Adams, 2013).

Tags: elite research groups, four ages of research, international collaboration

Abstract: Jonathan Adams analyses papers from the past three decades and finds that the best science comes from international collaboration.

DOA: 4.6.2020
https://www.nature.com/articles/497557a

Archambault, E. (2010). 30 Years in Science—Secular Movements in Knowledge Creation. *Science Metrix*, 16.

**images in Appendix- p. 138*

This paper explores the collapse of the Soviet Union, the Warsaw Pact, and the subsequent effect on scientific output of affected countries. It also tracks the changing landscape of the scientific network maps over a 30-year period in which Asia has grown and re-centered the scientific community (Archambault, 2010).

Tags: geopolitics of scientific networks, map of science

Abstract: This Discussion Paper examines the relationship between geopolitical factors and scientific activity based on publication data from a 30-year period (1980 to 2009). Using bibliometric methods, the analysis concentrates on large–scale, secular movements in the geopolitics of knowledge creation. First, the evolution of the scientific outputs of the countries of the former USSR and Eastern Bloc is examined followed by that of the Middle East. The paper then looks at how the global map of science has been reshaped in Asia's favour.

DOA: 5.18.2020
http://jazirehdanesh.com/files/site1/pages/30years_paper.pdf

Coccia, M., & Wang, L. (2016). Evolution and convergence of the patterns of international scientific collaboration. *Proceedings of the National Academy of Sciences*, *113*(8), 2057–2061. https://doi.org/10.1073/pnas.1510820113

Long-term trends from Science and Engineering (S&E) Indicators and bibliometrics on international collaboration in 11 countries, 7 fields and basic/applied research show that the volume of international collaboration increased over time in all fields. Internationally coauthored publications increased in all fields (highest astronomy/physics); while a converging pattern emerged between applied and basic sciences; and math and physics experienced a relative decline (Coccia & Wang, 2016).

Tags: applied sciences, basic sciences, convergence, evolution of science, international scientific collaboration

Abstract: International research collaboration plays an important role in the social construction and evolution of science. Studies of science increasingly analyze international collaboration across multiple organizations for its impetus in improving research quality, advancing efficiency of the scientific production, and fostering breakthroughs in a shorter time. However, long-run patterns of international research collaboration across scientific fields and their structural changes over time are hardly known. Here we show the convergence of international scientific collaboration across research fields over time. Our study uses a dataset by the National Science Foundation and computes the fraction of papers that have international institutional coauthorships for various fields of science. We compare our results with pioneering studies carried out in the 1970s and 1990s by applying a standardization method that transforms all fractions of internationally coauthored papers into a comparable framework. We find, over 1973–2012, that the evolution of collaboration patterns across scientific disciplines seems to generate a convergence between applied and basic sciences. We also show that the general architecture of international scientific collaboration, based on the ranking of fractions of international coauthorships for different scientific fields per year, has tended to be unchanged over time, at least until now. Overall, this study shows, to our knowledge for the first time, the evolution of the patterns of international scientific collaboration starting from initial results described by literature in the 1970s and 1990s. We find a convergence of these long-run collaboration patterns between the applied and basic sciences. This convergence might be one of contributing factors that supports the evolution of modern scientific fields.

DOA: 4.6.2020
https://www-pnas-org.er.lib.k-state.edu/content/pnas/113/8/2057.full.pdf

Cundill, G., Currie-Alder, B., & Leone, M. (2019). The future is collaborative. *Nature Climate Change*, 9(5), 343–345. https://doi.org/10.1038/s41558-019-0447-3

"In the past ten years alone, Canada, the United Kingdom and the Netherlands have invested at least 300 million dollars in a specific type of climate change research: large research collaborations that span countries, continents and disciplines" (G. Cundill et al., 2019, p. 344).

The authors suggest that the trajectory of large-scale collaboration threatens to undermine innovation and perpetuate patterns of inequality. They advocate for increasing support for research leaders in the global South, and improved efforts to include small institutions.

Tags: climate change research, network to network collaborations

Abstract: The way in which climate change research funds are managed is shifting dramatically toward investments in large collaborative research networks. This poses significant challenges for researchers and requires changes from the institutions and funders that support them.

DOA: 4.30.2020
https://www-nature-com.er.lib.k-state.edu/articles/s41558-019-0447-3

Graf, H., & Kalthaus, M. (2018). International research networks: Determinants of country embeddedness. *Research Policy*, 47(7), 1198–1214. https://doi.org/10.1016/j.respol.2018.04.001

[See notes in "Definitions"]

The InterAcademy Partnership. (2020). *InterAcademy Council*. IAP. https://interacademies.org/34864/InterAcademy-Council

The IAC consists of a governing board of the Presidents of 15 National Academies of Science, who represent 90 academies worldwide and act in an advisory capacity on international issues. It is an NGO that assembles project study panels to form a scientific consensus that can be used by policymakers at the UN and other international organizations (The InterAcademy Partnership, 2020).

Tags: development goals, networks of networks, scientific advisory

Abstract: Sound scientific knowledge is fundamental to addressing the critical issues - such as economic transformation and globalization; reduction of poverty, hunger, and disease; and the sustainable use of natural resources - facing the world today. The InterAcademy Council (IAC) was created by national science academies to mobilize the world's best scientists for providing expert knowledge and advice to international bodies, such as the United Nations and the World Bank, charged with addressing these issues. The IAC aims to complement, rather than duplicate, the advisory roles of other scientific institutions.

DOA: 4.16.2020
https://www.interacademies.org/34864/InterAcademy-Council

The InterAcademy Partnership. (2020). *The InterAcademy Partnership: Science, Heath, Policy*. IAP. Retrieved April 16, 2020, from http://interacademies.org/31840/About

The IAP operates within 3 pillars: Science, health, and policy. More than 140 member academies form the intellectual core in regional networks. Most recently they work on global issues relevant to food security and obtaining the UN's sustainable development goals.

Example: "The IAP Communiqué on the COVID-19 pandemic calls for collective action on the global scale to improve and accelerate the use of research and its outputs for the global public good. In addition to this international-level call, many IAP member academies around the world are playing their own part in national or regional initiatives – helping to ensure that trustworthy and credible information is reaching as many people as possible, much of it in local languages" (The Interacademy Partnership, 2020).

The IAP network of networks centralizes public health information from 140 national, regional and global academies and academy networks into a publicly available database and resource for policymakers.

Tags: network of network, global health, policy, scientific networks

Abstract: The InterAcademy Partnership (IAP) was formally launched in South Africa in March 2016, bringing together three established networks of academies of science, medicine and engineering, namely IAP, the global network of science academies, the InterAcademy Medical Panel (IAMP) and the InterAcademy Council (IAC).

Under the new InterAcademy Partnership, more than 140 national and regional member academies work together to support the special role of science and its efforts to seek solutions to address the world's most challenging problems. In particular, IAP harnesses the expertise of the world's scientific, medical and engineering leaders to advance sound policies, improve public health, promote excellence in science education, and achieve other critical development goals.

The work of the world’s academies of science, medicine and engineering has resulted in lives saved, better education, and more effective policy approaches to a range of issues. Academies are typically independent and highly committed institutions that recognize and promote excellence and achievement. By definition, they are merit-based, with members selected from among the leading scientific minds within a country or region. In addition to their honorific roles, academies are vital civil society institutions that have the credibility to inform the public and policymakers about problems and potential solutions. Their credibility comes not only from the scientific excellence of their members, but also from the fact that they are free of vested political and commercial interests. Indeed, although many academies were established by national governments and tasked with serving their countries by, among other things, bringing scientific perspectives to bear on national and international issues, they were also constituted as independent bodies.

Just as each IAP member academy represents an authoritative voice nationally, this unified voice of academies under IAP aims to have great impact at the international level. Now, as international attention has turned to the 2015 Sustainable Development Goals, IAP provides a collective mechanism and voice for science academies to further strengthen their crucial roles as providers of evidence-based policy and advice. IAP will also continue to produce evidence-based statements and reports examining major priorities for sustainable development and provide independent and authoritative advice to national governments and inter-governmental organizations, including the UN, on critical science-based issues.

DOA: 4.16.2020
http://www.interacademies.org/59576/How-are-academies-responding-to-COVID19

International Institute for Applied Systems Analysis. (2019). ***Annual Report*** **2018. https://iiasa.ac.at/**

**image in Appendix- p. 146*

As an independent network of member research organizations, the IIASA provides oversight, funding, a young scientists summer program, a postdoctoral program, and avenues for publication, strategic partnerships, and collaboration (International Institute for Applied Systems Analysis, 2019).

Tags: climate change, energy security, member networks, networks of networks, policy-oriented research, population aging, sustainable development

Abstract: IIASA is an international scientific institute that uses systems analysis to find solutions to global problems for the benefit of humankind.

Through its research programs and initiatives, the institute conducts policy-oriented research into issues that are too large or complex to be solved by a single country or academic discipline. This includes pressing concerns that affect the future of all of humanity, such as climate change, energy security, population aging, and sustainable development.

The results of IIASA research and the expertise of its researchers are made available to policymakers in countries around the world to help them produce effective, science-based policies that will enable them to face these challenges.

IIASA is governed by a Council that is made up of one representative of each of IIASA's member countries. Along with various external advisory bodies, the Council also regularly evaluates the institute's work.

DOA: 4.16.2020
https://iiasa.ac.at/web/home/about/whatisiiasa/informationkit/brief.html

Jacob, M., & Meek, V. L. (2013). Scientific mobility and international research networks: Trends and policy tools for promoting research excellence and capacity building. ***Studies in Higher Education*****,** ***38*****(3), 331–344. https://doi.org/10.1080/03075079.2013.773789**

Arguing that scientific mobility is a prerequisite for capacity building, the authors suggest that network infrastructure can help to overcome limited resources in developing economies (Jacob & Meek, 2013).

Tags: globalization, higher education, research networks, scientific mobility

Abstract: One of the ways in which globalization is manifesting itself in higher education and research is through the increasing importance and emphasis on scientific mobility. This article seeks to provide an overview and analysis of current trends and policy tools for promoting mobility. The article argues that the mobility of scientific labour is an indispensable prerequisite for building capacity and world-class excellence. Many of the newly emerging economies have been able to leverage themselves to advantageous positions in the global scientific economy through the skillful deployment of international research networks. Mobility is still a mixed blessing since scientific labour, like other scarce resources, has a tendency to cluster towards the centre. However, given advances in communication technology and the presence of good research infrastructure, a core group of networked researchers can go a long way towards helping a country with modest scientific resources achieve world-class excellence.

DOA: 6.6.2020
https://doi.org/10.1080/03075079.2013.773789

Jasanoff, S. (2004). ***States of Knowledge: The Co-Production of Science and the Social Order*. Routledge.**

Jasanoff examines the ways that the authority of science, strengthened by networks, conflicts with or warrants other forms of authority. Looking at climate change and conservation efforts spearheaded by networks, using CITES and African elephant conservation as an example, she examines the ways networks succeed and fail in affecting change within the social order (Jasanoff, 2004).

Tags: coproduction of science, political scientific networks, social order

DOA 5.7.2020
https://books.google.com/books?hl=en&lr=&id=1sRM9JT2iGUC&oi=fnd&pg=PP1&dq=jasanoff+states+of+knowledge&ots=FA4jaTKZMt&sig=lPxjLrQOv2-aZ79k_ZhrCYCnhXE#v=onepage&q=jasanoff%20states%20of%20knowledge&f=false

Kuhn, T. S. (2012). ***The Structure of Scientific Revolutions: 50th Anniversary Edition*. University of Chicago Press.**

Kuhn analyzes the structure of scientific revolutions and focuses on "incommensurability". He suggests that global scientific networks function to allow scientific knowledge to be incommensurable, comparable to species evolution. As Darwinian splits into sub-discipline communities (each represented by journals) and multi-disciplines, these fissures produce a constant evolution of the shape of trajectories over individual variants.

Tags: anomaly and emergence, normal science, scientific discoveries, scientific revolutions

Abstract: A good book may have the power to change the way we see the world, but a great book actually becomes part of our daily consciousness, pervading our thinking to the point that we take it for granted, and we forget how provocative and challenging its ideas once were—and still are. The Structure of Scientific Revolutions is that kind of book. When it was first published in 1962,

it was a landmark event in the history and philosophy of science. Fifty years later, it still has many lessons to teach. With The Structure of Scientific Revolutions, Kuhn challenged long-standing linear notions of scientific progress, arguing that transformative ideas don't arise from the day-to-day, gradual process of experimentation and data accumulation but that the revolutions in science, those breakthrough moments that disrupt accepted thinking and offer unanticipated ideas, occur outside of "normal science," as he called it. Though Kuhn was writing when physics ruled the sciences, his ideas on how scientific revolutions bring order to the anomalies that amass over time in research experiments are still instructive in our biotech age. This new edition of Kuhn's essential work in the history of science includes an insightful introduction by Ian Hacking, which clarifies terms popularized by Kuhn, including paradigm and incommensurability, and applies Kuhn's ideas to the science of today. Usefully keyed to the separate sections of the book, Hacking's introduction provides important background information as well as a contemporary context. Newly designed, with an expanded index, this edition will be eagerly welcomed by the next generation of readers seeking to understand the history of our perspectives on science.

DOA: 5.7.2020
https://books.google.com/books?hl=en&lr=&id=3eP5Y_OOuzwC&oi=fnd&pg=PR5&dq=kuhn+2012+scientific+revolutions&ots=xV3RG9pPsP&sig=bQjozVefrChxXTvxlew_Pab38Mc#v=onepage&q=kuhn%202012%20scientific%20revolutions&f=false

Kyvik, S., & Reymert, I. (2017). Research collaboration in groups and networks: Differences across academic fields. *Scientometrics*, *113*(2), 951–967. https://doi.org/10.1007/s11192-017-2497-5

[see notes in "Definitions"]

Mohrman, S., Galbraith, J., & Monge, P. (2006). Network Attributes Impacting the Generation and Flow of Knowledge within and from the Basic Science Community. In *Innovation, Science, and Institutional Change: A Research Handbook Edited by Jerald Hage and Marius Meeus*. OUP Oxford.

The authors argue that publicly funded science fails at benefiting society because it is not effectively organized to diffuse knowledge and stimulate technological innovation. They present a three-tiered approach to network analysis that can make knowledge communities more effective: (1) theoretical analysis of the network; (2) examination of the attributes of the nodes; (3) examination of the multiple relations in the network and their dynamics over time (Mohrman et al., 2006).

Tags: network analysis

Abstract: Innovation is central to the dynamics and success of organizations and society in the modern world, the process famously referred to by Schumpeter as 'gales of creative destruction'. This ambitious and wide-ranging book makes the case for a new approach to the study of innovation. It is the editors' conviction that this approach must accomplish several objectives: it must recognize that innovation encompasses changes in organizations and society, as well as

products and processes; it must be genuinely interdisciplinary and include contributes from economics, sociology, management and political science; It must be international, to reflect both different patterns or systems of innovation, and different research traditions; and it must reflect the fundamental changes taking place in science, research and knowledge creation at all levels. To this end they have gathered together a distinguished group of economists, sociologists, political scientists, and organization, innovation and institutional theorists to both assess current research on innovation, and to set out a new research agenda. This has been achieved through careful planning and development of the project, and also through the ensuing structure of the book which looks in turn at Product and Process Innovation (perhaps the best established focus of existing research on innovation), Scientific Research (assessing the changing character of basic research and science policy); Knowledge Dynamics in Context (encompassing organizational learning in all its aspects); and Institutional Change (an analysis of the institutional context that can shape, enable and constrain innovation). This carefully integrated and wide-ranging book will be an ideal reference point for academics and researchers across the Social Sciences interested in all dimensions of innovation - be they in the field of Management Studies, Economics, Organization Studies, Sociology, Political Science and Science and Technology Studies.

DOA: 5.20.2020
https://books.google.com/books?hl=en&lr=&id=H7gUDAAAQBAJ&oi=fnd&pg=PA196&dq=Mohrman,+S.,+Galbraith,+J.+R.,+%26+Monge,+P.+(2004).+Network+Attributes+Impacting+the+Generation+and+Flow+of+Knowledge+Within+and+from+the+Basic+Science+Community&ots=2xgqaitmRf&sig=HULk5ct9lu8i47sBhYFTBLksD7w#v=onepage&q&f=false

The National Academies. (2020). ***Science, Engineering, & Medicine: Working Toward a Better World- International activities of the U.S. National Academies*****. https://sites.nationalacademies.org/International/INTERNATIONAL_051878**

International networks: The U.S. NA works with counterpart academies and organizations around the world, such as the InterAcademy Panel, InterAcademy Council, InterAcademy Medical Panel, International Council on Science, and International Council of Academies of Engineering and Technological Sciences. The presidents and foreign secretaries of the NAS, NAE, and IOM serve as official representatives to these international organizations.

The National Academies respond to critical global challenges such as environmental change, malaria, safe drinking water, food, and international security. They build scientific networks in developing countries (i.e. telemedicine, conservation, symposia, and human rights committees. They advise the U.S. government of science, technology, security and health in foreign policy, execute fellowship programs, monitor and evaluate public health programs such as PEPFAR (The National Academies, 2020).

Tags: capacity building, global challenges, international partners, national advising, networks of networks, science of networks

Abstract: Operating under a congressional charter, the U.S. National Academy of Sciences (NAS), National Academy of Engineering (NAE), Institute of Medicine (IOM), and National

Research Council (NRC)—collectively the U.S. National Academies—are private, nonprofit institutions that advise the federal government and public on matters of science, technology, and health by establishing committees of experts to address critical technical and policy issues. The Academies promotes the use of science, engineering, and medicine to enhance the security and well-being of people throughout the world and to ease disparities in human welfare. To accomplish this, it cooperates with partner organizations and scientific communities internationally. It also works to increase the capacity of both individual national academies and regional and global networks of academies to provide evidence-based advice to their governments, policy makers, and the public, thus strengthening and shaping policy and programs worldwide.

DOA: 4.16.2020
https://sites.nationalacademies.org/International/INTERNATIONAL_051878

Newman, M. E. J. (2001). The structure of scientific collaboration networks. *Proceedings of the National Academy of Sciences*, *98*(2), 404–409. https://doi.org/10.1073/pnas.98.2.404

The author analyzes coauthor relationships to determine that scientific networks are "small worlds" with only about six steps between randomly chosen scientists. However, collaborators are highly clustered around labs and universities. High energy physics shows the largest collaboration networks. Biomedical research shows large networks, but less clustering than any other field (Newman, 2001).

Tags: network structure

Abstract: The structure of scientific collaboration networks is investigated. Two scientists are considered connected if they have authored a paper together and explicit networks of such connections are constructed by using data drawn from a number of databases, including MEDLINE (biomedical research), the Los Alamos e-Print Archive (physics), and NCSTRL (computer science). I show that these collaboration networks form “small worlds,” in which randomly chosen pairs of scientists are typically separated by only a short path of intermediate acquaintances. I further give results for mean and distribution of numbers of collaborators of authors, demonstrate the presence of clustering in the networks, and highlight a number of apparent differences in the patterns of collaboration between the fields studied.

DOA 5.20.2020
https://www-pnas-org.er.lib.k-state.edu/content/98/2/404/

Radosevic, S., & Yoruk, E. (2014). Are there global shifts in the world science base? Analysing the catching up and falling behind of world regions. Scientometrics, 101(3), 1897–1924. https://doi.org/10.1007/s11192-014-1344-1

**images in Appendix- p. 155*
By analyzing changes in RCAPAP (comparative advantage index that measures publication impact, specialization, and opportunity), the authors demonstrate that a shift in science is more

complex than can be demonstrated by bibliometrics alone. They document "a shift in absorptive capacity globally as the science base is a proxy not only for the world knowledge frontier but also for the capacity to absorb external knowledge" (Radosevic & Yoruk, 2014, p. 1907).

Global science is producing more papers (especially in Asia Pacific and other non-North Atlantic regions), but the relative impact remains stable. EU15 trends reveal that South EU is catching up both in terms of quantity and relative impact. After stagnating in the transition decade, the CEE region shows signs of catching up with the EU15 in relative impact but not yet in quantity (papers).

Science systems operate with high inertia and in areas of their historically inherited advantages and disadvantages. Within largely unchanged areas of regional advantages and disadvantages over the past 30 years, only the EU15 has gained RCA in papers in fundamental and applied sciences and CEE in applied sciences. Only the EU15 has gained RCA in citations in life and applied sciences. Other world regions have not gained advantages in new areas: this shows a very strong persistence of world science specialization patterns. De-specializations are more frequent than increased specializations. North America has lost advantages in applied sciences in both papers and citations; while the Middle East has lost advantages in fundamental (papers) and social sciences (both papers and citations), and Asia Pacific has lost advantages in life sciences (citations). CEE, South EU, Asia Pacific, Latin America, and the Middle East are proliferating in their dynamic specializations- Asia Pacific prioritizing applied science and South EU prioritizing fundamental science (Radosevic & Yoruk, 2014).

Tags: bibliometrics, regional advantage

Abstract: This paper explores the changing role of world regions (North America, EU15, South EU, Central and Eastern Europe (CEE), Former-USSR, Latin America, Asia Pacific and the Middle East) in science from 1981 to 2011. We use bibliometric data extracted from Thomson Reuter's National Science Indicators (2011) for 21 broad disciplines and aggregated the data into the four major science areas: life, fundamental, applied and social sciences. Comparing three sub-periods (1981–1989, 1990–2000 and 2001–2011), we investigate (i) over time changes in descriptive indicators such as publications, citations, and relative impact; (ii) static specialization measured by revealed comparative advantage (RCA) in citations and papers; and (iii) dynamic specialization measured by absolute growth in papers. Descriptive results show a global shift in science largely in quantity (papers) and much less in impact (citations). We argue this should be interpreted as a shift in science's absorptive capacity but not necessarily a shift of knowledge generation at the world science frontier, which reflects the nature of science systems operating with high inertia and path dependency in areas of their historically inherited advantages and disadvantages. In view of their common historical legacy in science we are particularly interested in the process of convergence/divergence of the catching-up/transition regions with the world frontier regions. We implement an interpretative framework to compare regions in terms of their static and dynamic specialization from 1981–1989 to 2001–2011. Again, our analysis shows that while science systems are mostly characterized by strong inertia and historically inherited (dis)advantages, Asia Pacific, Latin America and CEE show strong catching-up characteristics but largely in the absorptive capacity of science.

DOA: 6.20.2020
https://doi.org/10.1007/s11192-014-1344-1

Stokols, D., Misra, S., Moser, R. P., Hall, K. L., & Taylor, B. K. (2008). The Ecology of Team Science: Understanding Contextual Influences on Transdisciplinary Collaboration. *American Journal of Preventive Medicine*, *35*(2, Supplement), S96–S115. https://doi.org/10.1016/j.amepre.2008.05.003

The authors review the literature on team science in four domains. The last case study is most relevant to international networks and focuses on the processes and outcomes of scientific collaboration within transdisciplinary research centers.

The greatest barrier to effective transdisciplinary work is a misalignment of goals or priorities. The authors outline a series of common goals in Table 2 and suggest that initiatives should be strategic and explicit in tailoring training programs to match the complexity of the goal constellations. They also suggest project specific audits to realign the priorities of diverse organizations (Stokols et al., 2008).

Tags: team science

Abstract: Increased public and private investments in large-scale team science initiatives over the past two decades have underscored the need to better understand how contextual factors influence the effectiveness of transdisciplinary scientific collaboration. Toward that goal, the findings from four distinct areas of research on team performance and collaboration are reviewed: (1) social psychological and management research on the effectiveness of teams in organizational and institutional settings; (2) studies of cyber-infrastructures (i.e., computer-based infrastructures) designed to support transdisciplinary collaboration across remote research sites; (3) investigations of community-based coalitions for health promotion; and (4) studies focusing directly on the antecedents, processes, and outcomes of scientific collaboration within transdisciplinary research centers and training programs. The empirical literature within these four domains reveals several contextual circumstances that either facilitate or hinder team performance and collaboration. A typology of contextual influences on transdisciplinary collaboration is proposed as a basis for deriving practical guidelines for designing, managing, and evaluating successful team science initiatives.

DOA: 5.27.2020
https://www.ajpmonline.org/article/S0749-3797(08)00409-1/fulltext

Sugimoto, C. R., Robinson-Garcia, N., Murray, D. S., Yegros-Yegros, A., Costas, R., & Larivière, V. (2017). Scientists have most impact when they're free to move. *Nature*, *550*(7674), 29–31. https://doi.org/10.1038/550029a

International mobility is a major motivating factor of networked research. Scientists who move countries are on average more highly cited than those who do not. Countries with the strongest science systems train, keep, and attract outstanding researchers. Nations with less-established systems realize the greatest impact by recruiting established scholars or by nurturing those who go on to greatness elsewhere (Sugimoto et al., 2017).

Tags: bibliometrics, citations, research excellence, international research, scientific mobility

DOA: 6.6.2020
https://www.nature.com/news/polopoly_fs/1.22730!/menu/main/topColumns/topLeftColumn/pdf/550029a.pdf

UKRI. (2019). *Global Research Hubs tackle world's toughest challenges—UK Research and Innovation*. UK Research and Innovation. https://www.ukri.org/news/global-research-hubs/

"UK Research and Innovation (UKRI) is pioneering an ambitious new approach to tackle some of the world's most pressing challenges through a £200M investment across 12 global research Hubs. Over the next five years the Interdisciplinary Research Hubs will work across 85 countries with governments, international agencies, partners and NGOs on the ground in developing countries and around the globe, to develop creative and sustainable solutions which help make the world, and the UK, safer, healthier and more prosperous" (UKRI, 2019).

The 12 hubs support initiatives that align with the UN Sustainable Development Goals:

- UKRI GCRF Achievement for Africa's Adolescents Hub
- UKRI GCRF Accountability for Informal Urban Equity Hub
- UKRI GCRF Action Against Stunting Hub
- UKRI GCRF Gender, Justice and Security Hub
- UKRI GCRF Living Deltas Hub
- UKRI GCRF One Health Poultry Hub
- UKRI GCRF One Ocean Hub
- UKRI GCRF South Asian Nitrogen Hub
- UKRI GCRF South-South Migration, Inequality and Development Hub
- UKRI GCRF Trade, Development and the Environment Hub
- UKRI GCRF Urban Disaster Risk Hub
- UKRI GCRF Water Security and Sustainable Development Hub

Tags: development goals, research hubs

DOA: 4.30.2020
https://www.ukri.org/news/global-research-hubs/

UNESCO Science Report 2015. (2015). *UNESCO science report: Towards 2030*

The scientific network has changed so much since 2010, that the power balance between China and the West shifted. Then, the greater concern was the dominance of the global north over the global south. This trend seems to be changing as research and innovation are more intertwined than ever before.

The report outlines a growth strategy and highlights the need for balance between basic and applied science, more efficient network ties between the two, and the need for decreasing inequalities. It highlights the rise of new regions and public investment in R&D in low- and middle-income countries; and problematizes the R&D resources clustered around the business sectors of Singapore, Australia, the Philippines, and Malaysia. As innovation proliferates, policy regarding openness, opportunity, and effective communication is a challenge (UNESCO Science Report 2015, 2015).

Tags: assessment, innovation, science, sustainable development, technology

Abstract: In 2015, the United Nations General Assembly took a historic and visionary step with the adoption of the 2030 Agenda for Sustainable Development. For the first time at this level, the role of science, technology and innovation has been explicitly recognized as a vital driver of sustainability. Sustainability depends on the capacity of states to put science at the heart of their national strategies for development, strengthening their capacities and investment to tackle challenges, some of which are still unknown. This commitment resonates at the heart of UNESCO's mandate and I see this as a call for action, as we celebrate the 70th anniversary of the Organization. I see this edition of the UNESCO Science Report as a springboard to take the 2030 Agenda for Sustainable Development forward, providing precious insights into the concerns and priorities of member states and sharing critical information to harness the power of science for sustainability. The UNESCO Science Report draws a comprehensive picture of the many facets of science in an increasingly complex world – including trends in innovation and mobility, issues relating to big data and the contribution of indigenous and local knowledge to addressing global challenges. Since the UNESCO Science Report 2010, clear trends have emerged.

Firstly, despite the financial crisis, global expenditure on research and development has grown faster than the global economy, showing confidence that investment in science will bring future benefits. Much of this investment is in the applied sciences and is being spearheaded by the private sector. This points to an important shift in the landscape, with high-income countries cutting back public spending, while private sector funding has been maintained or increased, and with lower income countries increasing public investment in R&D. The debate between quick scientific gains and long-term public investment in basic and high-risk research to enlarge the scope of scientific discoveries has never been so relevant.

Secondly, the North–South divide in research and innovation is narrowing, as a large number of countries are incorporating science, technology and innovation in their national development agendas, in order to be less reliant on raw materials and move towards knowledge economies. Broad-based North–South and South–South collaboration is also increasing, in order to solve pressing sustainable developmental challenges, including climate change.

Thirdly, there are ever more scientists in the world, and they are becoming more mobile. The number of researchers and publications worldwide increased by over 20% during the period from 2007 and 2014. A growing number of countries are putting policies in place to increase the number of women researchers; at the same time, scientists are not only publishing more in international scientific journals but also co-authoring more with foreign partners, with more

articles becoming freely available through open access. At different income levels, countries across the world are striving to attract and retain scientific talent, upgrading their higher education and research infrastructure and developing new scholarships and scientific visas. Private firms are relocating research laboratories and some universities are setting up campuses abroad to tap into a bigger talent pool.

With all this, we face the challenge of mobilizing these accelerating trends of scientific enterprise, knowledge, mobility and international co-operation to inform policy and take the world on a more sustainable path. This calls for a stronger science–policy interface and for the relentless drive towards innovation. Achieving many of the Sustainable Development Goals will depend not only on the diffusion of technology but also on how well countries partner with one another in the pursuit of science. I see this as the key challenge of 'science diplomacy' in the years ahead and UNESCO will bring the full force of its scientific mandate to bear to support member states, strengthen capacities and share critical information ranging from sustainable water management to technology and innovation policies. This report is unique in providing such a clear vision of the global scientific landscape, reflecting the contributions of more than 50 experts from across the world. I am convinced that the analysis here will help clear the path towards more sustainable development, laying the foundations for more inclusive knowledge societies across the world.

DOA 4.7.2020
https://en.unesco.org/unescosciencereport

Wagner, C. S., & Leydesdorff, L. (2009). Network Structure, Self-Organization and the Growth of International Collaboration in Science. *ArXiv:0911.4299 [Physics]*. http://arxiv.org/abs/0911.4299

**image in Appendix- p. 161*

Preferential attachment is an important structuring factor for collaborative network dynamics within physics. "Over time, the number of nodes in a co-authorship network increase due to the arrival of new authors, and that the total number of links also increases through the connections made between existing authors. They also confirm that node selection is governed by preferential attachment, a feature of scale-free networks in which nodes link with a higher probability to those nodes that already have a larger number of links" (Wagner & Leydesdorff, 2009, p. 13).

International networks hold "small world" properties- they are highly clustered, efficient, and localized in how they share information. Continuants (scientists who have published established positions on a topic within recent years) play a preferential role as co-author links in establishing network preferential attachment.

Tags: continuants, physics, physics and society, preferential attachment, science policy, science collaboration, social network analysis, social systems

Abstract: Using data from co-authorships at the international level in all fields of science in 1990 and 2000, and within six case studies at the sub-field level in 2000, different explanations for the growth of international collaboration in science and technology are explored. We find that few of

the explanations within the literature can be supported by a detailed review of the data. To enable further exploration of the role of recognition and rewards as ordering mechanisms within the system, we apply new tools emerging from network science. These enquiries show that the growth of international co-authorships can be attributed to self-organizing phenomenon based on preferential attachment (searching for recognition and reward) within networks of co-authors. The co-authorship links can be considered as a complex network with sub-dynamics involving features of both competition and cooperation. The analysis suggests that the growth of international collaboration is more likely to emerge from dynamics at the sub-field level operating in all fields of science, albeit under institutional constraints. Implications for the management of global scientific collaborations are explored.

DOA: 4.20.2020
https://arxiv.org/pdf/0911.4299.pdf

Wagner, C. S. (2011). The Shifting Landscape of Science. *Issues in Science and Technology*, *28*(1), 77–81. JSTOR.

Wagner tracks the rise of international collaborations, a shift away from the U.S. at the center of scientific capacity in citations, university excellence, patents, and R&D funding- which opens new opportunities to fit into a global force for knowledge production.

One example is the collaborative international effort by governments, including the U.S. for an "Interdisciplinary Program on Application Software toward Exascale Computing for Global Scale Issues. After the 2008 Kyoto meeting of that identified 8 research directors, an agreement was reached to initiate a pilot collaboration in multilateral research. The participating agencies are the U.S. National Science Foundation, the Canadian National Sciences and Engineering Research Council, the French Agence Nationale de la Recherche, the German Deutsche Forschungsgemeinschaft, the Japan Society for the Promotion of Science, the Russian Foundation for Basic Research, and the United Kingdom Research Councils. These agencies will support competitive grants for collaborative research projects that are composed of researchers from at least three of the partner countries, a model similar to the one used by the European Commission. Proposals will be jointly reviewed by the participating funding organizations, and successful projects are required to demonstrate added value through multilateral collaboration. Support for U.S. -based researchers will be provided through awards made by the National Science Foundation. It would be useful to begin discussions about the metrics of success of these types of activities" (Wagner, 2011, p. 81).

Tags: global science, international collaboration, network to network

Abstract: The days of overwhelming U.S. science dominance are over, but the country can actually benefit by learning to tap and build on the expanding wellspring of knowledge being generated in many countries.

DOA: 5.18.2020
https://issues.org/wagner/

Wagner, C. S., Park, H. W., & Leydesdorff, L. (2015). The Continuing Growth of Global Cooperation Networks in Research: A Conundrum for National Governments. *PLoS ONE*, *10*(7). https://doi.org/10.1371/journal.pone.0131816

The percentage of internationally co-authored publications has doubled in last 20 years. In the internationally coauthored publications, the average number of co-authors increased from 2.9 in 1990 to 4.3 in 2011. Observing that international networks have become more dense, but not more clustered in the period from 1991- 2011, and that networks have become more efficient as excellence seeks out excellence, so that the macro behavior of the shape of relationships remains stable even as new connections are established and old ones dissolve, the authors recommend that national governments follow this model in funding and establishing policy based on these networks (Wagner et al., 2015).

Tags: co-authorships of peer-reviewed papers, global collaboration, network analysis

Abstract: Global collaboration continues to grow as a share of all scientific cooperation, measured as coauthorships of peer-reviewed, published papers. The percent of all scientific papers that are internationally coauthored has more than doubled in 20 years, and they account for all the growth in output among the scientifically advanced countries. Emerging countries, particularly China, have increased their participation in global science, in part by doubling their spending on R&D; they are increasingly likely to appear as partners on internationally coauthored scientific papers. Given the growth of connections at the international level, it is helpful to examine the phenomenon as a communications network and to consider the network as a new organization on the world stage that adds to and complements national systems. When examined as interconnections across the globe over two decades, a global network has grown denser but not more clustered, meaning there are many more connections, but they are not grouping into exclusive 'cliques'. This suggests that power relationships are not reproducing those of the political system. The network features an open system, attracting productive scientists to participate in international projects. National governments could gain efficiencies and influence by developing policies and strategies designed to maximize network benefits—a model different from those designed for national systems.

DOA: 4.6.2020
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4510583/

Wagner, C. S., Whetsell, T. A., & Leydesdorff, L. (2017). Growth of international collaboration in science: Revisiting six specialties. *Scientometrics*, 110(3), 1633–1652. https://doi.org/10.1007/s11192-016-2230-9

This study found that, in all six specialties measured, the global network is expanding to include more countries. Networks with greater geographical diversity held the greatest impact in scientific journals and citations. Eschewing individual cultural footprints for a global perspective is a key characteristic of effective networks. The authors argue that these dynamics create new fourth age norms at the global level, with feedback loops to regional networks in a complex, networked hierarchy (Wagner et al., 2017).

Tags: network characteristics, network size, scientific collaboration

Abstract: International collaboration in science continues to grow at a remarkable rate, but little agreement exists about dynamics of growth and organization at the discipline level. Some suggest that disciplines differ in their collaborative tendencies, reflecting their epistemic culture. This study examines collaborative patterns in six previously studied specialties to add new data and analyze patterns over time. Our findings show that a global network of collaboration continues to add new nations and new participants; since 1990, each specialty has added many new nations to lists of collaborating partners. We also find that the scope of international collaboration is positively related to impact. Network characteristics for the six specialties are notable in that instead of reflecting underlying culture, they tend towards convergence at the global level. This observation suggests that the global level may represent next-order dynamics that feed back to the national and local levels (as subsystems) in a complex, networked hierarchy.

DOA: 4.29.2020
https://link-springer-com.er.lib.k-state.edu/article/10.1007/s11192-016-2230-9

Wagner, C. S. (2018). ***The Collaborative Era in Science: Governing the Network*** **(C. S. Wagner, Ed.). Springer International Publishing. https://doi.org/10.1007/978-3-319-94986-4_9**

Wagner draws from a theoretical background of social network theory, and evolutionary ecology to explain how scientific networks become increasingly complex through mechanisms of specialization, expanding hierarchy, branch evolution, and reproduction of new links and nodes that emerge from adaptation in a "complex systems approach".

Science in the Age of Knowledge Abundance
Chapter Abstract: This book suggests that understanding science communication as a network is perhaps the best way to develop and interject governing principles; it builds an argument for viewing the global network as a new form of organization of science on top of national or institutional forms. This chapter details the many changes to science that have occurred within the knowledge-creating system since the 1980s.

The Scale and Scope of Global Science
Chapter Abstract: It is now widely accepted that science and technology underlie much of the economic growth that has been a highlight of human social development for over 300 years. Science has grown along with social welfare, economy, and the application of human imagination. This chapter describes the scale and scope of the current global system at this writing.

Levels and Patterns of Communication in the Global Network
Chapter Abstract: This chapter describes the communications dynamics within the global network by detailing the tenets of complexity theory to provide insights in the mechanisms driving the global system. Complex systems theory provides the framework within which to discuss the phase shift of scientific knowledge from an era of scarcity to one of abundance - a theme that will appear in the next several chapters.

It's Who You Know (or Could Know) That Counts
Chapter Abstract: Once complexity theory provides a foundation to a fuller understanding of mechanisms of change, this chapter applies network structures and principles to science. Networks are the actualization of complex systems, and we can use network analysis to begin a process of understanding the structure of the global network, exploring how networking changes the system. It also allows us to visualize and measure the global network at various levels.

The Global Network of Science Emerges
Chapter Abstract: This chapter presents the structure of the global network itself as well as the rules, norms, and practices associated with openness and abundance in the global knowledge-creating process. The creation of scientific knowledge includes not just tangible or codified output but also new practices and even new belief systems. The rules, norms, and practices are adapting to the changing system, but some aspects of knowledge remain the same and cannot or will not change. This includes the amount of time needed to master a body of scientific work. The rules for managing networked systems differ from those that applied under national, political systems and conditions of scarcity; we will unpack these rules in this chapter.

Openness in the Global Network
Chapter Abstract: This chapter presents the dynamics at the team level associated with collaboration and networked structures. Investment in science and technology is shifting. As it does, the structure of collaborative teaming is changing, too. This chapter describes the emerging landscape of collaboration for the individual and the team.

Nations Within the Global Network
Chapter Abstract: This chapter discusses the collaborative patterns at different geographical aggregations (local, national, regional, and global) over the most recent decade and explains why these patterns are the essence of the collaborative system and the clearest sign of a new era. Drawing upon data on global networks of collaboration, this chapter points to changes in the way scientific knowledge is created, protected, and shared at regional and national levels. The chapter also discusses networks within fields of science as well as global collaborative patterns.

Local Innovation and the Global Network
Chapter Abstract: The locations of knowledge centers—those geographic and institutional places where innovation is most likely to occur—are not evenly spread across the globe. There is no reason to think they should be, but as UNESCO (2011) reports, there is striking evidence of the persistence—expansion even—in the uneven distribution of research and innovation at the global level. This chapter focuses on challenges associated with making useful knowledge truly and universally accessible.

Governing Global Science
Chapter Abstract: The human condition is not improved by single facts of science. In their collection into a body of knowledge, joined to its careful application and validation, that we can stretch the boundaries of justice still larger. This chapter discusses the policy implications, governance rules, and measures applicable to the emerging global system of science (Wagner, 2018).

Tags: abundance, collaboration, collaborative era, complex systems theory, consumer - driven, global governance, globalization, innovation, peer review, policy, R&D, science, trans-disciplinary teams

Abstract: In recent years a global network of science has emerged as a result of thousands of individual scientists seeking to collaborate with colleagues around the world, creating a network which rises above national systems. The globalization of science is part of the underlying shift in knowledge creation generally: the collaborative era in science. Over the past decade, the growth in the amount of knowledge and the speed at which it is available has created a fundamental shift—where data, information, and knowledge were once scarce resources, they are now abundantly available. Collaboration, openness, customer- or problem-focused research and development, altruism, and reciprocity are notable features of abundance, and they create challenges that economists have not yet studied. This book defines the collaborative era, describes how it came to be, reveals its internal dynamics, and demonstrates how real-world practitioners are changing to take advantage of it. Most importantly, the book lays out a guide for policymakers and entrepreneurs as they shift perspectives to take advantage of the collaborative era in order to create social and economic welfare.

DOA: 4.30.2020

https://doi.org/10.1007/978-3-319-94986-4_9

Wagner, C. S., Whetsell, T. A., & Mukherjee, S. (2019). International research collaboration: Novelty, conventionality, and atypicality in knowledge recombination. *Research Policy*, *48*(5), 1260–1270. https://doi.org/10.1016/j.respol.2019.01.002

- Research suggests that international collaboration and atypical knowledge recombination tend to produce higher impact research.
- Research has yet to examine whether international collaboration produces atypical, novel, or conventional research.
- This article shows that international collaboration tends to produce conventional rather than novel or atypical research.
- Transaction costs and communication barriers may suppress novelty, while an audience effect may explain the higher impact of international work.
- The findings suggest nuanced support for international research collaboration, incentivizing creativity rather than reputation-seeking (Wagner et al., 2019).

Tags: bibliometrics, creativity, international collaboration, novelty, public policy

Abstract: Research articles produced through international collaboration are more highly cited than other work, but are they also more novel? Using measures developed by Uzzi et al. (2013), and replicated by Boyack and Klavans (2014), this article tests for novelty and conventionality in international research collaboration. Scholars have found that coauthored articles are more novel and have suggested that diverse groups have a greater chance of producing creative work. As such, we expected to find that international collaboration tends to produce more novel research. Using data from Web of Science and Scopus in 2005, we failed to show that international

collaboration tends to produce more novel articles. In fact, international collaboration appears to produce less novel and more conventional knowledge combinations. Transaction costs and communication barriers to international collaboration may suppress novelty. Higher citations to international work may be explained by an audience effect, where more authors from more countries results in greater access to a larger citing community. The findings are consistent with explanations of growth in international collaboration that posit a social dynamic of preferential attachment based upon reputation.

DOA: 4.28.2020
https://www.sciencedirect.com/science/article/abs/pii/S0048733319300046

Zhou, P., & Leydesdorff, L. (2006). The emergence of China as a leading nation in science. *Research Policy*, *35*(1), 83–104. https://doi.org/10.1016/j.respol.2005.08.006

This article documents the rise of EU networked science as its influence began to outpace the U.S., and then as Chinese scientific citations overtook both. The exponential growth of Chinese papers is attributed to government funding, proliferating networks, and cultural prioritization. The barrier to legitimacy that the Chinese language represents is also discussed (Zhou & Leydesdorff, 2006).

Tags: citations, highly cited papers, nanotechnology, publication, world share

Abstract: China has become the fifth leading nation in terms of its share of the world's scientific publications. The citation rate of papers with a Chinese address for the corresponding author also exhibits exponential growth. More specifically, China has become a major player in critical technologies like nanotechnology. Although it is difficult to delineate nanoscience and nanotechnology, we show that China has recently achieved a position second only to that of the USA. Funding for R&D has been growing exponentially, but since 1997 even more in terms of business expenditure than in terms of government expenditure. It seems that the Chinese government has effectively used the public-sector research potential to boost the knowledge-based economy of the country. Thus, China may be achieving the ("Lisbon") objectives of the transition to a knowledge-based economy more broadly and rapidly than its western counterparts. Because of the sustained increase in Chinese government funding and the virtually unlimited reservoir of highly skilled human resources, one may expect a continuation of this growth pattern in the near future.

DOA: 5.18.2020
https://www-sciencedirect-com.er.lib.k-state.edu/science/article/pii/S0048733305001794

IV. Motivations: What motivated large scale international research networks (higher impact science, faster discoveries, new ideas, reduced costs, etc.)? What evidence exists for these motivations?

Fischer, B. B., Queiroz, S., & Vonortas, N. S. (2018). On the location of knowledge-intensive entrepreneurship in developing countries: Lessons from São Paulo, Brazil. *Entrepreneurship & Regional Development*, *30*(5/6), 612–638. https://doi.org/10.1080/08985626.2018.1438523

Knowledge intensive entrepreneurship is driven by research networks and supported by local infrastructure that forms hubs around research universities. In Sao Carlos, Brazil, embeddedness in research networks allowed entrepreneurs to use more advanced technology, engage in consulting partnerships, and form an entrepreneurial ecosystem (Fischer et al., 2018).

Tags: developing countries, economies of agglomeration, entrepreneurial ecosystems, entrepreneurship, geography of innovation, income distribution, industrial concentration, industrial location, knowledge-intensive entrepreneurship

Abstract: This article empirically appraises the geographical distribution of knowledge-intensive entrepreneurship (KIE) in the settings of an emerging economy. We start from the typical agglomeration approach and then introduce a set of variables related to local market conditions, distance from the economic hub, and knowledge & innovation system to explain KIE location and density on the basis of city-level data in the State of São Paulo, Brazil. Findings indicate KIE concentration in and around a few urban areas, providing support to agglomeration economies concepts. There is strong evidence that the local presence of research-oriented universities, access to capital, and business concentration are correlated to KIE emergence and density. Results also indicate the moderating effect of agglomeration diseconomies mainly related to factors of rapid and anarchic expansion of urban centers and the consequences of extreme inequalities in income distribution. This challenges the usability of concepts of entrepreneurial ecosystems from advanced economies if not adapted to the realities of developing countries.

DOA: 4.21.2020
https://rsa.tandfonline.com/doi/abs/10.1080/08985626.2018.1438523#.Xp8BO9NKilM

Fortunato, S., Bergstrom, C. T., Börner, K., Evans, J. A., Helbing, D., Milojević, S., Petersen, A. M., Radicchi, F., Sinatra, R., Uzzi, B., Vespignani, A., Waltman, L., Wang, D., & Barabási, A.-L. (2018). Science of science. *Science*, *359*(6379). https://doi.org/10.1126/science.aao0185

The transdisciplinary field of science of science has been driven by increasing data availability and increasing collaborations based on big data-based capabilities.

Scientists' collective choices determine the direction of scientific discovery, while individual choices are driven more by the tension between productive tradition and risky innovation. As team science becomes more necessary to be effective, as the tools and data required to answer globalized questions must be pooled by multiple institutions and networks of scientists, the associated challenges of credit and status emerge.

"Despite the discovery of universals across science, substantial disciplinary differences in culture, habits, and preferences make some cross-domain insights difficult to appreciate within particular fields and associated policies challenging to implement" (Fortunato et al., 2018, p. 1097).

Overarching themes of science of science: (1) innovation and tradition must be balanced, where novel ideas are embedded in established knowledge, (2) persistence is key as scientists remain productive over their career trajectory, (3) collaboration is necessary in both small and large teams, which bring different strengths to the research paradigm, (4) credit will continually accrue to those with the most experience of success within the field, and (5) funding reviewers can promote this balance by focusing on assessing innovation, and taking on more risk, not just on whether or not projects are expected to succeed.

Tags: career dynamics, citation dynamics, conventionality and novelty, science of science, team science, team size

Abstract: The science of science (SciSci) is based on a transdisciplinary approach that uses large data sets to study the mechanisms underlying the doing of science—from the choice of a research problem to career trajectories and progress within a field. In a Review, Fortunato et al. explain that the underlying rationale is that with a deeper understanding of the precursors of impactful science, it will be possible to develop systems and policies that improve each scientist's ability to succeed and enhance the prospects of science as a whole.
The increasing availability of digital data on scholarly inputs and outputs—from research funding, productivity, and collaboration to paper citations and scientist mobility—offers unprecedented opportunities to explore the structure and evolution of science. The science of science (SciSci) offers a quantitative understanding of the interactions among scientific agents across diverse geographic and temporal scales: It provides insights into the conditions underlying creativity and the genesis of scientific discovery, with the ultimate goal of developing tools and policies that have the potential to accelerate science. In the past decade, SciSci has benefited from an influx of natural, computational, and social scientists who together have developed big data–based capabilities for empirical analysis and generative modeling that capture the unfolding of science, its institutions, and its workforce. The value proposition of SciSci is that with a deeper understanding of the factors that drive successful science, we can more effectively address environmental, societal, and technological problems.

Science can be described as a complex, self-organizing, and evolving network of scholars, projects, papers, and ideas. This representation has unveiled patterns characterizing the emergence of new scientific fields through the study of collaboration networks and the path of impactful discoveries through the study of citation networks. Microscopic models have traced the dynamics of citation accumulation, allowing us to predict the future impact of individual papers. SciSci has revealed choices and trade-offs that scientists face as they advance both their own careers and the scientific horizon. For example, measurements indicate that scholars are risk-averse, preferring to study topics related to their current expertise, which constrains the potential of future discoveries. Those willing to break this pattern engage in riskier careers but become

more likely to make major breakthroughs. Overall, the highest-impact science is grounded in conventional combinations of prior work but features unusual combinations. Last, as the locus of research is shifting into teams, SciSci is increasingly focused on the impact of team research, finding that small teams tend to disrupt science and technology with new ideas drawing on older and less prevalent ones. In contrast, large teams tend to develop recent, popular ideas, obtaining high, but often short-lived, impact.

SciSci offers a deep quantitative understanding of the relational structure between scientists, institutions, and ideas because it facilitates the identification of fundamental mechanisms responsible for scientific discovery. These interdisciplinary data-driven efforts complement contributions from related fields such as scientometrics and the economics and sociology of science. Although SciSci seeks long-standing universal laws and mechanisms that apply across various fields of science, a fundamental challenge going forward is accounting for undeniable differences in culture, habits, and preferences between different fields and countries. This variation makes some cross-domain insights difficult to appreciate and associated science policies difficult to implement. The differences among the questions, data, and skills specific to each discipline suggest that further insights can be gained from domain-specific SciSci studies, which model and identify opportunities adapted to the needs of individual research fields.
Summary Abstract: Identifying fundamental drivers of science and developing predictive models to capture its evolution are instrumental for the design of policies that can improve the scientific enterprise—for example, through enhanced career paths for scientists, better performance evaluation for organizations hosting research, discovery of novel effective funding vehicles, and even identification of promising regions along the scientific frontier. The science of science uses large-scale data on the production of science to search for universal and domain-specific patterns. Here, we review recent developments in this transdisciplinary field.

DOA: 4.7.2020
https://science.sciencemag.org/content/359/6379/eaao0185.abstract

Huang, J. S. (2014). Building Research Collaboration Networks—An Interpersonal Perspective for Research Capacity Building. The Journal of Research Administration, 45(2), 89–112.

Using a social network theory, Huan argues that research collaboration networks are a foundational aspect of capacity building at the interpersonal level. Propinquity, homophily, and heterophily are all discussed as mechanisms for building collaboration. In addition, several key challenges are addressed, including: (1) a nonlinear effect where greater collaboration does not necessarily lead to greater productivity or impact; (2) a double-edged sword of homophily, where diversity is necessary to new insights, but impedes the positive feedback loops created by homogenous collaborator communication; and (3) the oversight role taken by managers who would better serve their networks in a proactive role (Huang, 2014).

Tags: capacity building, research collaboration, social network theory

Abstract: While collaboration is increasingly recognized to be important for research, researchers' collaboration networks are still not adequately recognized as a form of research capacity in the literature. Research is a knowledge creation activity and interpersonal research collaboration networks are important for knowledge cross-fertilization and research productivity. By referring to social network theories, this paper argues that research collaboration networks are a form of research capacity at interpersonal level. It complements capacity building at individual, organizational and inter-organizational levels. However, building research collaborations can be challenging. Three key issues are raised for discussion. First, collaboration networks have nonlinear effect on research productivity. Second, fostering heterophilous communications and maintaining degrees of heterophily can be contradicting and thus challenging. Third, building research collaboration networks proactively requires shift of research management philosophy as well as invention of analytical tools for research management. Debates and solutions with regard to these issues may contribute to the advancement of theory and practice of research management.

DOA: 6.11.2020
https://eric.ed.gov/?id=EJ1157238

Jeong, S., Choi, J. Y., & Kim, J.-Y. (2014). On the drivers of international collaboration: The impact of informal communication, motivation, and research resources. *Science and Public Policy*, *41*(4), 520–531. https://doi.org/10.1093/scipol/sct079

This study provides an overview of the cost-benefit analysis that researchers and institutions conduct as they engage in international collaboration, which then forms the basis for networks. At the ground-level, "our empirical results suggest that substantial financial and attentional resources, academic excellence, individual motivation, and active informal communication play significant roles in encouraging international collaboration" (Jeong et al., 2014, p. 529).

Tags: evidence of international collaboration, network drivers, network motivations.

Abstract: International collaboration in research activities has been highlighted because it offers higher productivity and has a greater impact than non-international collaboration. Given the importance of international collaboration, researchers make strategic decisions on their collaboration modes in the light of their environments and the expected trade-offs, since long-distance research collaboration entails both costs and benefits. By using national data at the project level, this paper examines the possible factors in international collaboration in various research areas, mainly focusing on research activities by universities. Our empirical results suggest that substantial financial and attentional resources, academic excellence, individual motivation, and active informal communication play significant roles in accomplishing international collaboration. Additionally, this paper refines the understanding of the role of communication and policy in ensuring the most effective use of research resources, helping research managers to promote collaboration in an appropriate decision-making context.

DOA: 5.19.2020
https://academic-oup-com.er.lib.k-state.edu/spp/article/41/4/520/1612341

Leahey, E. (2016). From Sole Investigator to Team Scientist: Trends in the Practice and Study of Research Collaboration | Annual Review of Sociology. *Annual Review of Sociology*, *42*, 81–100.

[See notes in "team science"]

Moock, J. L. (2016). *Network Innovations: Building the Next Generation of Agricultural Scientists in Africa* (Chapter 10; 0 ed., Agricultural Research in Africa: Investing in Future Harvests). International Food Policy Research Institute. https://doi.org/10.2499/9780896292123

In developing countries, agricultural development for food security hinges on scientific and technological innovations that stem from networks. Research universities within Africa lack the human capital and infrastructure to support new PhD students and knowledge building in a way that international partnerships can.

Definitions:

Networks: postgraduate training and collaborations that strengthen institutions, unimpeded by geography—such as a collection of agricultural scientists capitalizing on greatly improved mobility and telecommunications to transcend institutional and national boundaries.

"In the agricultural sector, recent advances in biotechnology—such as breeding of higher-yielding and better-adapted crop varieties, along with market friendly policies and improved national research institutions—are helping to create a new platform for progress in Africa south of the Sahara (SSA). Strengthened commodity value chains that boost productivity, coupled with new forms of collective action and seismic change in farmer accessibility to low cost information technologies, offer exciting opportunities to use agriculture to promote development. In the face of this proliferation of new knowledge and scientific breakthroughs, the volume has been turned up on calls from African governments, the international funding community, and African scientists alike for a response to the challenges facing resource-poor institutions in building research and development (R&D) capacity. An abundance of essays and reports—perhaps best typified by the catalytic 2008 World Development Report1 and by Calestous Juma's book, The New Harvest: Agricultural Innovation in Africa (Juma, 2011)—argue that most needed is a transformation that will connect the mission and vision of advanced learning institutions with new local and global contexts. University-derived research is now commonly touted as essential to agricultural performance, from rapid appraisal of delivery services, marketing, and policy, to strategic research aimed at the creation and testing of new products appropriate for the African environment" (Moock, 2016, p. 254).

"The network concept offers great appeal as a vehicle for fostering advanced knowledge and knowledge applications, and for extending limited resources. It creates enduring institutional relationships based on a common mission and standard of effectiveness and relevance that can attract the attention of African governments, the private sector, and external funders" (Moock, 2016, p. 256).

Within Africa, cross-institutional networks are particularly important for fostering creativity and innovation for the following reasons:

1. They promote economies of scale for research universities that can band their resources together.
2. They build credibility and legitimacy in the research and economic community outside of Africa. This is important in securing donor and investor funding.
3. They utilize the strength that greater democracy and centralization bring to smaller universities- thus creating a better atmosphere for innovation.
4. They promote quality information through data sharing and peer review.
5. They strengthen links between research centers and private industry.
6. They create pipelines of female scientists who have been underrepresented in their fields, but necessary to scientific perspectives.
7. They reduce the cost of research and training, while developing opportunities for findings to be implemented into policy and practice immediately and locally.

Five examples of African research networks, and their key characteristics:

1. Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) Status: NGO Secretariat location: Makerere University Campus, Uganda Coverage: 55 universities in 22 East, Central, Southern, and West African countries Internet address: www.ruforum.org

2. Collaborative MSc Program in Agriculture and Applied Economics (CMAAE) Status: Program of the African Economic Research Consortium (AERC), an NGO Secretariat location: AERC, Kenya Coverage: 17 universities in 13 East and Southern African countries Internet address: www.aercafrica.org

3. Education for African Crop Improvement (EACI) Status: Program of the Alliance for a Green Revolution in Africa (AGRA) Central management location: AGRA, Kenya Coverage: 10 MSc universities and 2 PhD training centers at the University of Ghana (West African Center for Crop Improvement) and the University of Kwa-Zulu Natal (African Center for Crop Improvement) serving 16 countries Internet address: www.agra-alliance.org

4. Biosciences eastern and central Africa (BecA) Status: NEPAD-endorsed initiative hosted and managed by the International Livestock Research Institute (ILRI) Central management location: ILRI Campus, Kenya Coverage: One central hub and six institutional nodes serving 18 African countries Internet address: www.hub.africabiosciences.org

5. Partnership to Enhance Agriculture in Rwanda through Linkages (PEARL), 2000–2006/Sustaining Partnerships to Enhance Rural Enterprise and Agribusiness Development (SPREAD), 2006–201110 Status: Rwanda institutional partnership Secretariat location: National University of Rwanda Coverage: National University of Rwanda, Kigali Institute of Science and Technology, National Institute of Agriculture Research, NGOs that target agricultural cooperatives with more than 15,000 member farmers in Rwanda Former Internet address: www.spreadproject.org

Key Characteristics:

1. Comprehensive view of problems and solutions
2. Mechanisms for quality assurance
3. Skills for entrepreneurship, management, and leadership
4. Increased participation of women and the disadvantaged
5. Use of cost-effective information technology
6. Economies of scale: collaborative research/training

Sustainability through evaluation and risk management:

"As most networks are donor dependent, their longevity and potential scaling are linked with changing funder preferences. While this is difficult to alter under current African circumstances and probably into the foreseeable future, at least four constructive steps can be taken to lessen funding shocks: (1) gathering momentum and attracting funding by building a common "brand" of excellence and reliability that gains legitimacy and financial support; (2) developing an evaluation strategy codesigned by management and funders that, while not necessarily settling the sustainability issue, can reduce what may appear as random decisions by funders based on inadequate information (Prewitt 1997); (3) having in place a practical business plan to identify customer segments, a viable growth model, legitimate costs, potential funding streams, and risk-mitigation strategies; and (4) recognizing that scaling up, with reference to breadth of operations and financing, may present risks for individual funders, especially in the context of long-term commitment" (Moock, 2016, p. 277)

Tags: case study, development, evaluation, food security, network sustainability, definitions

DOA: 4.13.2020
https://www.researchgate.net/profile/Johannes_Roseboom/publication/327727828_Agricultural_Research_in_Africa_Investing_in_Future_Harvests/links/5ba0f15792851ca9ed12cfdd/Agricultural-Research-in-Africa-Investing-in-Future-Harvests.pdf#page=292

Petersen, A. M., Riccaboni, M., Stanley, H. E., & Pammolli, F. (2012). Persistence and uncertainty in the academic career. *Proceedings of the National Academy of Sciences*, *109*(14), 5213–5218. https://doi.org/10.1073/pnas.1121429109

Longitudinal career data for 200 leading physicists and 100 assistant physics professors suggests a model of proportional growth, where career longevity and achievement accrue to top individuals while "production shocks" intensify the effects of competition. The authors suggest working in teams- the size, shape, and effectiveness of these teams is a key factor in overcoming production shocks that disproportionately affect those who are early in their career or have not already experienced a great deal of success.
As teams inevitably get larger, and networks more complex, short term contracts may provide a solution, where collaborations can emerge more often and earlier for those who are left out of the institutional inertia. However, short term contracts can also disincentivize social capital accumulation that is central to scientific expertise and professionalism (Petersen et al., 2012).

Tags: career trajectory, computational sociology, labor market, science of science, tenure

Abstract: Understanding how institutional changes within academia may affect the overall potential of science requires a better quantitative representation of how careers evolve over time. Because knowledge spillovers, cumulative advantage, competition, and collaboration are distinctive features of the academic profession, both the employment relationship and the procedures for assigning recognition and allocating funding should be designed to account for these factors. We study the annual production of a given scientist by analyzing longitudinal career data for 200 leading scientists and 100 assistant professors from the physics community. Our empirical analysis of individual productivity dynamics shows that (i) there are increasing returns for the top individuals within the competitive cohort, and that (ii) the distribution of production growth is a leptokurtic "tent-shaped" distribution that is remarkably symmetric. Our methodology is general, and we speculate that similar features appear in other disciplines where academic publication is essential, and collaboration is a key feature. We introduce a model of proportional growth which reproduces these two observations, and additionally accounts for the significantly right-skewed distributions of career longevity and achievement in science. Using this theoretical model, we show that short-term contracts can amplify the effects of competition and uncertainty making careers more vulnerable to early termination, not necessarily due to lack of individual talent and persistence, but because of random negative production shocks. We show that fluctuations in scientific production are quantitatively related to a scientist's collaboration radius and team efficiency.

DOA: 6.7.2020
https://www-pnas-org.er.lib.k-state.edu/content/pnas/109/14/5213.full.pdf

Rosenfield, P. L. (1992). The potential of transdisciplinary research for sustaining and extending linkages between the health and social sciences. *Social Science & Medicine*, *35*(11), 1343–1357. https://doi.org/10.1016/0277-9536(92)90038-R

Increasingly, scientific questions that affect public health are not just medical- they intertwine with the environment, global inequalities, and the impacts of human industry. Therefore, the authors make the case for transdisciplinary networks as a social imperative. They analyze the Social and Economic Research Component of the UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases and the Applied Diarrheal Research Project as examples of how these collaborations can function (Rosenfield, 1992).

Tags: health and social sciences, interdisciplinary, multidisciplinary, public health, transdisciplinary

Abstract: The last decade of the twentieth century is witnessing a profusion of projects drawing together social and health scientists to study and recommend solutions for a wide range of health problems. The process—practices in both developed and developing countries—is usually called multidisciplinary or interdisciplinary research. Its historical precedents are briefly reviewed in this paper along with the types of problems addressed. From a review and discussion of a sample of projects selected from two major proponents of this approach to research, the Social and Economic Research Component of the UNDP/World Bank/WHO Special Programme for

Research and Training in Tropical Diseases and the Applied Diarrheal Disease Research Project, conclusions are drawn about the nature of contributions from such efforts—very useful for short-term problem solving, less so for longer-term programmatic changes, especially beyond the health sector, and even more limited in impact on theory building for coping with the changing human condition. The recognition of such limitations is now widespread in the social and natural sciences beyond the health sector, in population, ecology, and the humanities. Following these observations, I argue for a new approach to transcend the disciplinary bounds inherent in multi- and interdisciplinary research. A transdisciplinary approach can provide a systematic, comprehensive theoretical framework for the definition and analysis of the social, economic, political, environmental, and institutional factors influencing human health and well-being. The academic and career challenges for such researchers, while considerable, may be overcome since there is now flexibility in research-supporting organizations to encourage new ideas in international health, such as that of essential national health research.

DOA: 6.29.2020
https://www.sciencedirect.com/science/article/abs/pii/027795369290038R

Sugimoto, C. R., Robinson-Garcia, N., Murray, D. S., Yegros-Yegros, A., Costas, R., & Larivière, V. (2017). Scientists have most impact when they're free to move. *Nature*, *550*(7674), 29–31. https://doi.org/10.1038/550029a

[See notes in "Evidence"]

Syme, S. L. (2008). The Science of Team Science: Assessing the Value of Transdisciplinary Research. *American Journal of Preventive Medicine*, *35*(2), S94–S95. https://doi.org/10.1016/j.amepre.2008.05.017

A series of papers suggest different ways that public health issues can be addressed by networking with scientists in the disciplines that better understand drivers and determinants of disease. The purpose is to develop strategies for preventative medicine (Syme, 2008).

Tags: public health, team science

Abstract: Several years ago, I chaired a committee organized by the IOM to consider the success of our public health efforts to prevent disease. The resulting 493-page report concluded that we were not doing a very good job. The committee offered 18 recommendations intended to improve this situation. The first recommendation was that we needed to develop a better balance between clinical approaches to disease prevention (presently the dominant public health model for most risk factors) and work that recognizes the importance of generic social and behavioral determinants of disease, injury, and disability. The second recommendation was that we needed to develop interventions that took account of a wide range of health determinants that operated at the individual, interpersonal, institutional, community, and policy levels. The main message was that we needed somehow to transcend our disciplinary silos and consider a much broader set of determinants in a far more complex way than we have so far been able to do. Easier said than done. The papers in this supplement to the American Journal of Preventive Medicine therefore are a timely, important, and badly needed contribution to our work in preventing disease and promoting health.

DOA: 5.27.2020
https://www.ajpmonline.org/article/S0749-3797(08)00428-5/abstract

Uzzi, B., Mukherjee, S., Stringer, M., & Jones, B. (2013). Atypical Combinations and Scientific Impact. *Science*, *342*(6157), 468–472. JSTOR.

Balancing novel, creative ideas with conventional knowledge proves critical to the link between innovativeness and impact. Bibliometric analysis of 5 decades of research articles in Web of Science shows the highest-impact papers were those with a combination of novelty and conventional combinations of prior work, not papers with greatest novelty.

An analysis of 17.9 million papers demonstrated that high-impact science, which includes exceptional conventional work coupled with novel combinations are twice as likely to be highly cited, and that teams are 37.7% more likely to produce this type of science. "Teams can span scientific specialties, effectively combining knowledge that prompts scientific breakthrough" (Uzzi et al., 2013, p. 468).

"These patterns suggest that novelty and conventionality are not factors in opposition; rather, papers that mix high tail novelty with high median conventionality have nearly twice the propensity to be unusually highly cited" (Uzzi et al., 2013, p. 471).

Tags: combinations, conventionality and novelty, scientific impact, team science

Abstract: Novelty is an essential feature of creative ideas, yet the building blocks of new ideas are often embodied in existing knowledge. From this perspective, balancing atypical knowledge with conventional knowledge may be critical to the link between innovativeness and impact. Our analysis of 17.9 million papers spanning all scientific fields suggests that science follows a nearly universal pattern: The highest-impact science is primarily grounded in exceptionally conventional combinations of prior work yet simultaneously features an intrusion of unusual combinations. Papers of this type were twice as likely to be highly cited works. Novel combinations of prior work are rare, yet teams are 37.7% more likely than solo authors to insert novel combinations into familiar knowledge domains.

DOA: 6.7.2020
https://www-jstor-org.er.lib.k-state.edu/stable/42619958?seq=1#metadata_info_tab_contents

Wagner, C. S., & Jonkers, K. (2017). Open countries have strong science. *Nature News*, *550*(7674), 32. https://doi.org/10.1038/550032a

Nations that welcome international researchers and encourage international collaboration produce papers that are more highly cited. Openness index for countries is examined in relation to impact indices.

"In the longer term, countries could benefit more by funding the best science, wherever it is, and ensuring that domestically based scientists are linked with it. Restricting the movement of researchers — by limiting exchange opportunities or imposing visa restrictions, for example — could be counterproductive" (Wagner & Jonkers, 2017, p. 33).

Tags: bibliometrics, citations, impact index, international collaboration, openness index

Abstract: Caroline S. Wagner and Koen Jonkers find a clear correlation between a nation's scientific influence and the links it fosters with foreign researchers.

DOA: 6.9.2020
https://www.nature.com/news/open-countries-have-strong-science-1.22754

Wu, L., Wang, D., & Evans, J. A. (2017). Large Teams Have Developed Science and Technology; Small Teams Have Disrupted It (SSRN Scholarly Paper ID 3034125). Social Science Research Network. https://doi.org/10.2139/ssrn.3034125

Small teams disrupt science by developing new ideas; large teams develop existing ones.
"Small groups with more to gain and less to lose, tend to undertake new, untested opportunities, with potential for high growth and failure. ...Both small and large teams are essential to a flourishing ecology of science and technology. The increasing dominance of large teams, a flurry of scholarship on their perceived benefit" (Wu et al., 2017, p. 6).

Tags: citation networks, disruption, innovation, knowledge production, organization, science of science, team science

Abstract: Teams dominate the production of high-impact science and technology. Analyzing teamwork from more than 50 million papers, patents, and software products, 1954-2014, we demonstrate across this period that larger teams developed recent, popular ideas, while small teams disrupted the system by drawing on older and less prevalent ideas. Attention to work from large teams came immediately, while advances by small teams succeeded further into the future. Differences between small and large teams magnify with impact—small teams have become known for disruptive work and large teams for developing work. Differences in topic and research design account for part of the relationship between team size and disruption, but most of the effect occurs within people, controlling for detailed subject and article type. Our findings suggest the importance of supporting both small and large teams for the sustainable vitality of science and technology.

DOA: 6.7.2020
https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3034125

V. Impact: What is the impact for network participation for individuals?

Cruz-Castro, L., & Sanz-Menéndez, L. (2020). ***Grant Allocation Disparities from a Gender Perspective: Literature Review. Synthesis Report*** **(D.1.1.; GRANteD Project). CSIC Institute of Public Goods and Policies. https://digital.csic.es/handle/10261/200024**

Collaboration networks increased, especially for junior researchers, after they were awarded grant funding. Since the research environment was found to have a greater effect on perpetuating gender inequalities than grant funding, it is possible that networks created by grants could go a long ways toward correcting these disparities (Cruz-Castro & Sanz-Menéndez, 2020).

Tags: funding, GRANteD, impact, research networks

Abstract: The purpose of this review is to provide the GRANteD project with robust analytical approaches and methodological insights that take into account the state of the art, but it also acknowledges and aims to overcome the main shortcomings and point out the gaps of the existing literature; it is also our contention that knowledge could be used to improve and refine, and also to strengthen, gender equality policies and the management of diversity in teams and research institutions. The substantive focus of the literature review refers to the central event of the "allocation of grants by means of peer review evaluation, observed as a process and an outcome". We also consider "the impact of grants in career advancement in the context of hiring and promotion decisions". However, we can learn significantly from other areas in which gender research have made significant contributions, like occupation segregation, discrimination, stereotypes, etc.

DOA: 6.15.2020
https://digital.csic.es/bitstream/10261/200024/3/GRANteD_D1_CSIC_CruzySanz2019.pdf

Cundill, G., Currie-Alder, B., & Leone, M. (2019). The future is collaborative. ***Nature Climate Change*****, 9(5), 343–345. https://doi.org/10.1038/s41558-019-0447-3**

[see notes in "Evidence"]

Jeong, S., Choi, J. Y., & Kim, J.-Y. (2014). On the drivers of international collaboration: The impact of informal communication, motivation, and research resources. ***Science and Public Policy*****,** ***41*****(4), 520–531. https://doi.org/10.1093/scipol/sct079**

[See notes in "Motivations"]

Knecht, F., Spiesberger, M., & Carrieri, S. (2019). ***COST European Cooperation in Science & Technology: Impact assessment study*** **(No. 19003; p. 77). Erdyn- ZSI (Center for Social Innovation). https://www.cost.eu/wp-content/uploads/2019/09/Targeted-impact-assessment-on-career-development.pdf**

**image in Appendix- p. 147*

Involvement in research networks through COST positively impacted the careers of 88.5% of survey respondents, most of whom saw the benefits manifest in indirect ways by helping them start new connections or by enhancing their reputations in the scientific community. Interdisciplinary work was key to this success, especially for women, young scientists, and scientists from underrepresented countries (Knecht et al., 2019).

Tags: career advancement, networks, professional development

Abstract: The COST Association recently carried out a targeted impact assessment on career development through participation in COST Actions. Networking helps researchers and innovators make new contacts and establish collaborations, thereby creating opportunities for their professional growth. Professional development and career advancement are core elements of COST's impact philosophy.

The assessment involved a survey with more than 4500 former and current Action participants, and 30 in-depth interviews with participants holding a leadership position. The study paid particular attention to career development for younger researchers and researchers from Inclusiveness Target Countries (ITCs).

Main findings

- 88 % of survey respondents said COST has a strong or very strong impact on their careers
- COST Actions lead to new career opportunities, especially in 5-10 years' time
- Several Action leaders said that, thanks to their leadership position, they could get a permanent position or were able to build out a research group
- Impact on career is more often mentioned by researchers from ITCs, young and female researchers
- Younger researchers particularly mention opportunities to start new collaborations and projects
- One third of researchers said it was the first time they participated in a COST Action, and this led to substantially expand their network of contacts
- Five out of six countries with which most new networking links were created are ITCs: Serbia, Bulgaria, Portugal, Poland and Croatia

DOA: 4.20.2020
https://www.cost.eu/wp-content/uploads/2019/09/Targeted-impact-assessment-on-career-development.pdf

Kwiek, P. M. (2019). Internationalists and Locals: International Research Collaboration in Resource- Poor Systems. *Scientometrics*, *Preprint*, 44.

Internationalists and localists compete for funding, renown, and prestige within different and hierarchical reward systems. The author argues that international collaborations define a class of predominantly white and older researchers, that often coauthor six times more often than locals. Research networks give them the access and productivity to be infused with new ideas and networks of scientists who are already exploring similar ideas from different angles within their networks. Productivity and international collaboration thus reinforce each-other. Macro-level barriers such as geopolitics, history, language, cultural traditions, country size, country wealth; institutional factors such as reputation and resources; and individual factors such as attractiveness, predilections, risk-taking, cultural competencies, communication strategies, and gender contribute to the stratification (P. M. Kwiek, 2019).

Tags: internationalists, international collaboration, scientific productivity, stratification

Abstract: The principal distinction drawn in this study is between research "internationalists" and "locals," the former being scientists involved in international research collaboration while the latter are not. These two distinct types compete for academic prestige and professional recognition, research funding, and international recognition in science. As a clearly defined subgroup of Polish scientists (51.4%), internationalists are a different academic species. They are predominantly male and older; they have longer academic experience and higher academic degrees, and they occupy higher academic positions. Internationalists co-author internationally six times more often than locals. Across all academic clusters, internationalists consistently produce more than 90% of internationally co-authored publications: no international collaboration means no internationally co-authored publications. Internationalists are much more productive in terms of internationally co-authored publications: 2,320% of the productivity of locals for peer-reviewed articles and 1,600% for peer-reviewed article equivalents. For English language peer-reviewed articles, the figure is 290.9%, and for article equivalents, it is 276.5%. They are also about 70% more productive in terms of conference papers and about 50% more productive in terms of peer-reviewed articles, article equivalents, and books. Internationalists tend to spend less time than locals on teaching-related activities, more time on research, and more time on administrative duties. Finally, the multivariate analyses identified some new predictors of international research collaboration. Based on a large-scale academic survey (N = 3,704 returned questionnaires) of Poland's resource-poor higher education system, this study has global implications for academic career, productivity patterns, and internationalization policies.

DOA: 5.11.2020
http://cpp.amu.edu.pl/wp-content/uploads/2016/08/Kwiek_Internationalists_Locals_in_Research_2020.pdf

Kwiek, M., & Roszka, W. (2020). Gender Disparities in International Research Collaboration: A Large-scale Bibliometric Study of 25,000 University Professors. *ArXiv:2003.00537 [Cs]*. http://arxiv.org/abs/2003.00537

Gender disparity in international collaboration is pervasive. It is linked with age, academic position, institutional type, total productivity, and specific disciplines.

International collaboration also opens the door for more collaboration so that opportunities accrue to certain networks. "The likelihood for being internationally collaborative increases by half for full professors and by approximately one-fifth for associate professors, as it does for scientists working in comprehensive universities. The higher the individual total productivity, the greater the odds of being internationally collaborative (each article published increasing the odds by as much as 12.3%). Further, compared with arts and humanities, the likelihood also abruptly increases for scientists from the physics and astronomy fields (as much as 10 times) as well as from the biochemistry, genetics, molecular biology, and chemistry fields (7 times)" (M. Kwiek & Roszka, 2020, p. 31).

Tags: computer science, gender disparities, international collaboration

Abstract: In this research, we examine the hypothesis that gender disparities in international research collaboration differ by collaboration intensity, academic position, age, and academic discipline. The following are the major findings: (1) while female scientists exhibit a higher rate of general, national, and institutional collaboration, male scientists exhibit a higher rate of international collaboration, a finding critically important in explaining gender disparities in impact, productivity, and access to large grants. (2) An aggregated picture of gender disparities hides a more nuanced cross-disciplinary picture of them. (3) An analysis of international research collaboration at three separate intensity levels (low, medium, and high) reveals that male scientists dominate in international collaboration at each level. However, at each level, there are specific disciplines in which females collaborate more than males. Further (4), gender disparities are clearly linked with age. Until about the age of 40, they are marginal and then they begin to grow. Finally, we estimate the odds of being involved in international research collaboration using an analytical linear logistic model. The examined sample includes 25,463 internationally productive Polish university professors from 85 universities, grouped into 27 disciplines, who authored 159,943 Scopus-indexed articles.

DOA: 5.11.2020
https://arxiv.org/pdf/2003.00537.pdf

Liao, C. H. (2010). How to improve research quality? Examining the impacts of collaboration intensity and member diversity in collaboration networks. *Scientometrics*, *86*(3), 747–761. https://doi.org/10.1007/s11192-010-0309-2

The author analyzes embeddedness, using the Social Science Citation Index Database to confirm previous research that embeddedness in a collaboration network impacts research quality. Using multi-dimensional indicators to assess research quality, including the number of citations, the impact factor, and research award, the study captures a glimpse of the impact of collaboration on individual scientists, and suggests that there are differing benefits to collaboration with the same colleagues and with diverse groups (Liao, 2010).

Tags: embeddedness, collaboration network impact

Abstract: Better research quality not only inspires scholars to continue their research, but also increases the possibility of higher research budgets from sponsors. Given the importance of research quality, this study proposes that utilizing social capital (i.e., research collaboration) might be a promising avenue to achieve better research quality. In addition, as every scholar has his or her own expertise and knowledge, the diversity of collaborating members might be an extra resource for reinforcing research quality. The purpose of this study is to investigate the impact of research collaboration and member diversity on research quality, including the number of

citations, the impact factor, and the size of the research award. To explore unknown associations, the author adopts two data sources, that is, the Social Science Citation Index database and academic database of a university, to verify the hypotheses. The results show that a higher intensity at which scholars are embedded in a collaboration network, results in higher research quality. However, member diversity does not seem to be a major concern during the organization of a research group. Research quality is not affected, regardless of whether a scholar collaborates with different or the same co-authors.

DOA: 6.29.2020
https://akjournals.com/view/journals/11192/86/3/article-p747.xml

Newman, M. E. J. (2004). Coauthorship networks and patterns of scientific collaboration. *Proceedings of the National Academy of Sciences*, *101*(suppl 1), 5200–5205. https://doi.org/10.1073/pnas.0307545100

An analysis of bibliometric data constructs network structures and poses several motivating factors for individual researchers such as productivity and impact that vary by field. "Biological scientists tend to have significantly more coauthors than mathematicians or physicists, a result that reflects the labor-intensive, predominantly experimental direction of current biology" (Newman, 2004, p. 5204).

The authors suggest that further analysis could reveal new institutional structures in the form of "Invisible colleges" of collaboration networks.

Tags: collaboration networks

Abstract: By using data from three bibliographic databases in biology, physics, and mathematics, respectively, networks are constructed in which the nodes are scientists, and two scientists are connected if they have coauthored a paper. We use these networks to answer a broad variety of questions about collaboration patterns, such as the numbers of papers authors write, how many people they write them with, what the typical distance between scientists is through the network, and how patterns of collaboration vary between subjects and over time. We also summarize a number of recent results by other authors on coauthorship patterns.

DOA: 6.16.2020
https://www.pnas.org/content/101/suppl_1/5200

Pina, D. G., Barać, L., Buljan, I., Grimaldo, F., & Marušić, A. (2019). Effects of seniority, gender and geography on the bibliometric output and collaboration networks of European Research Council (ERC) grant recipients. *PLoS ONE*, *14*(2). https://doi.org/10.1371/journal.pone.0212286

Post-award, the collaboration network size and subcommunity membership ties increased for all grantees, although this trend was more pronounced for junior faculty. Pre and post grant performance were not found to be directly related to gender, although male junior awardees had more publications before and after the studied award period. Junior grantees located in lower research-performing countries published less and had less diverse collaboration networks than peers in higher research-performing countries within Europe (Pina et al., 2019).

Tags: publication volume, status, seniority, bibliometric output, collaboration networks, grant recipients

Abstract: Assessing the success and performance of researchers is a difficult task, as their grant output is influenced by a series of factors, including seniority, gender and geographical location of their host institution. In order to assess the effects of these factors, we analysed the publication and citation outputs, using Scopus and Web of Science, and the collaboration networks of European Research Council (ERC) starting (junior) and advanced (senior) grantees. For this study, we used a cohort of 355 grantees from the Life Sciences domain of years 2007–09. While senior grantees had overall greater publication output, junior grantees had a significantly greater pre-post grant award increase in their overall number of publications and in those on which they had last authorship. The collaboration networks size and the number of sub-communities increased for all grantees, although more pronounced for juniors, as they departed from smaller and more compact pre-award co-authorship networks. Both junior and senior grantees increased the size of the community within which they were collaborating in the post-award period. Pre-post grant award performance of grantees was not related to gender, although male junior grantees had more publications than female grantees before and after the grant award. Junior grantees located in lower research-performing countries published less and had less diverse collaboration networks than their peers located in higher research-performing countries. Our study suggests that research environment has greater influence on post-grant award publications than gender especially for junior grantees. Also, collaboration networks may be a useful complement to publication and citation outputs for assessing post-grant research performance, especially for grantees who already have a high publication output and who get highly competitive grants such as those from ERC.

DOA: 6.8.2020
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6375614/

Sugimoto, C. R., Robinson-Garcia, N., Murray, D. S., Yegros-Yegros, A., Costas, R., & Larivière, V. (2017). Scientists have most impact when they're free to move. *Nature*, *550*(7674), 29–31. https://doi.org/10.1038/550029a

[See notes in "Evidence"]

VI. Evaluation/description of funding programs

Currie-Alder, B., Cundill Kemp, G., Scodanibbio, L., Vincent, K., Prakash, A., & Nathe, N. (2019). ***Building climate resilience in Africa & Asia: Lessons on organisation, management & collaboration from research consortia*** **[Working Paper]. IDRC.** **https://idl-bnc-idrc.dspacedirect.org/handle/10625/57587**

**see images in Appendix- p. 144*

The authors evaluate the CARIAA research partnerships and offer three lessons for collaborative research:

1. Program and consortia design: "CARIAA was a partnership between two research funders, the United Kingdom's Department for International Development (DFID) and Canada's International Development Research Centre (IDRC). These funders initially agreed to award three consortia, one each for semi-arid lands, for river deltas, and for glacier-dependent basins. A call for proposals sought applications for potential consortia of five partner organisations. Each consortium would eventually receive in excess of CAD 13 million over five years. Given early gains in the exchange rates, and the high quality of proposals received, DFID and IDRC opted to fund an additional consortium addressing semi-arid lands, bringing the total to four: Adaptation at Scale in Semi-Arid Regions (ASSAR); Deltas, vulnerability and Climate Change: Migration and Adaptation (DECCMA); Himalayan Adaptation, Water and Resilience (HI-AWARE); and Pathways to Resilience In Semi-arid Economies (PRISE)" (Currie-Alder et al., 2019, p. 7)

   Beyond the finding structure, each consortium was required to organize around a lead institution and principle investigator. Each consortium adopted unique approaches to research design, geographical clustering, combinations of outputs, and clustering.

2. Partners, leadership, and relations: Effective structures involve diverse partners, strong leadership skills, investment in coordination, and team building

3. Teamwork: Effective collaboration requires transparency and fostering a sense of belonging to the research team and to the larger consortia.

Tags: adaptation, climate change, consortia, research organization, research teams

Abstract: During 2014–2018, the Collaborative Adaptation Research Initiative in Africa and Asia (CARIAA) supported four transdisciplinary research consortia involving more than 40 institutions across 15 countries. Drawing on participant surveys, technical reports and focus group discussions, this paper identifies three sets of lessons.

DOA: 4.15.2020
https://idl-bnc-idrc.dspacedirect.org/bitstream/handle/10625/57587/CARIAA%20Working%20Paper%2024_consortia%20model_final.pdf?sequence=5&isAllowed=y

D’Ippolito, B., & Ruling, C.-C. (2019). Research collaboration in Large Scale Research Infrastructures: Collaboration types and policy implications. *Research Policy*, *48*, 1282–1296.

This article addresses scientific collaboration in the context of Large-Scale Research Infrastructures (LSRIs), and focuses primarily on collaboration types, communication styles and management strategies. LSRIs are defined as “large scientific instrumentation, facility, and equipment clusters that require large investments and complex engineering and networking efforts; they are usually recipients of funding by national or supranational bodies and shared by communities of scientists shared research facilities, which integrate mechanisms for the professional development of individual scientists as well as offer an environment within which instrument scientists and visiting users can interact and engage in productive relationships, aiming for longer-term collaborations" (D’Ippolito & Ruling, 2019, p. 1283).

"Complementary collaboration" constitutes the most critical form of collaboration for LSRIs because it implies a balance between mutual commitment and specialisation of the parties; but this must be complemented by "full service" – to broaden and renew an LSRI's user base – and "instrument service" – to expose oneself to technically proficient and demanding users allowing to advance the quality of instruments and service provided" (D’Ippolito & Ruling, 2019, p. 1292).

Tags: collaboration types, research networks, research policy

Abstract: Over the past decades, Large Scale Research Infrastructures (LSRIs) have come to play a central role in providing scientist-users access to highly specialised scientific instrumentation and experimental conditions. Collaborations between (permanent) instrument scientists and users are at the core of these organisations, yet knowledge about the nature of such collaborations and their development over time is surprisingly scarce. In particular, we know very little about the interrelation between the individual and organisational drivers of collaboration. Based on a qualitative study of scientists and their collaborations at Institut Laue-Langevin, a world- leading neutron source, we identify four typical collaboration patterns, which reflect particular configurations of (dis)similarity between instrument scientists and users in terms of perceived expertise gap and co-development focus. Our findings suggest that the co-existence of multiple collaboration types within the same organisation plays an important role in the long-term success of LSRIs. In addition, we contend that dissimilarity can generate productive collaboration to the same extent as partner similarity; not only at the organisational level – co- existence of different types of collaborations across the LSRI, favouring the co-existence of a broad range of instrumentation – but also at the individual level – where instrument scientists benefit in terms of more productive collaborations over time despite the cost of learning involved.

DOA: 6.10.2020
https://www.sciencedirect.com/science/article/abs/pii/S0048733319300198

Falk-Krzesinski, H. J., Börner, K., Contractor, N., Fiore, S. M., Hall, K. L., Keyton, J., Spring, B., Stokols, D., Trochim, W., & Uzzi, B. (2010). Advancing the Science of Team Science. *Clinical and Translational Science*, *3*(5), 263–266. https://doi.org/10.1111/j.1752-8062.2010.00223.x

This panel presentation outlined a mapping project that defines and models team science. It also initiated a tool kit for facilitating team science, strategizing new directions, and promoting diversity (Falk-Krzesinski et al., 2010).

Tags: editorials, translational research, evaluation, team science

Abstract: 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. Such team-based research collaborations are also an essential feature of a robust translational research enterprise. 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. SciTS is concerned with understanding and managing circumstances that facilitate or hinder the effectiveness of collaborative cross-disciplinary science, and the evaluation of collaborative science outcomes. 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.

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, to engage funding agency program staff to provide guidance on developing and managing team science initiatives, and to afford data providers and analytics developers insight into team tracking and analysis needs. Because of the diverse participation, the conference served as an important conduit for translating empirical findings about team science into evidence-based

effective practices for scientific teams and funders of team science—a bridge between the praxis of team science and the science of team science.

More than 200 team science leaders/practitioners, research development officers, team science researchers, tool developers, and funding agency program officers attended this event, which included a keynote address, six panel discussions, and a research poster session. In addition, the agenda included a workshop on social network analysis (SNA) of teams. Each panel session was followed by a lively question and answer session, and the first 2 days of the conference concluded with an open discussion of the topics and ideas presented by the 24 panelists.

DOA: 6.9.2020
https://ascpt.onlinelibrary.wiley.com/doi/full/10.1111/j.1752-8062.2010.00223.x

Falk-Krzesinski, H. J., Contractor, N., 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*, *20*(2), 145–158. https://doi.org/10.3152/095820211X12941371876580

**images in Appendix- p. 145*

A concept-mapping approach provides a theoretical framework, that can then be used to identify various clusters, where funding can be targeted. This article aims at providing a foundation upon which a strategy for team science can be developed (Falk-Krzesinski et al., 2011).

Tags: concept mapping, team science

Abstract: An increase in cross-disciplinary, collaborative team science initiatives over the last few decades has spurred interest by multiple stakeholder groups in empirical research on scientific teams, giving rise to an emergent field referred to as the science of team science (SciTS). This study employed a collaborative team science concept-mapping evaluation methodology to develop a comprehensive research agenda for the SciTS field. Its integrative mixed-methods approach combined group process with statistical analysis to derive a conceptual framework that identifies research areas of team science and their relative importance to the emerging SciTS field. The findings from this concept-mapping project constitute a lever for moving SciTS forward at theoretical, empirical, and translational levels.

DOA: 6.9.2020
https://academic.oup.com/rev/article-abstract/20/2/145/1577613?redirectedFrom=fulltext

Goldstein, K. M., Vogt, D., Hamilton, A., Frayne, S. M., Gierisch, J., Blakeney, J., Sadler, A., Bean-Mayberry, B. M., Carney, D., DiLeone, B., Fox, A. B., Klap, R., Yee, E., Romodan, Y., Strehlow, H., Yosef, J., & Yano, E. M. (2018). Practice-based research networks add value to evidence-based quality improvement. *Healthcare*, *6*(2), 128–134. https://doi.org/10.1016/j.hjdsi.2017.06.008

Evidence-based Quality Improvement is an evaluation program targeted at improving networked research in clinical settings. "EBQI is an implementation strategy that uses a systematic, multilevel approach to incorporating scientific findings into clinical settings driven by the partnership of researchers and local healthcare leaders, managers and clinical staff. By enlisting clinical partners from organizational leadership and quality improvement (QI) teams using a top-down and bottom-up approach, EBQI infuses evidence into a structured process that is relevant and specific to local organizational needs and resources. EBQI makes use of behavior change theory, coupled with rigorous measurement strategies and formal feedback to local partners at all levels, to fuel the process of bringing objective evidence to the clinical setting" (Goldstein et al., 2018, p. 130).

Tags: evidence-based quality improvement, implementation, practice-based research networks

Abstract: Evidence-Based Quality Improvement (EBQI) is a systematic, multilevel approach to implementing research evidence into clinical settings. Little is known about EBQI effectiveness in the context of Practice-Based Research Networks (PBRNs), which are themselves designed to foster practice-based change. We evaluated EBQI implementation in a PBRN setting to determine the extent to which the PBRN infrastructure added value.

Methods: We conducted a four-site cluster randomized trial of an EBQI approach to tailoring an evidence-based gender awareness curriculum in the VA Women's Health PBRN (WH-PBRN). After curriculum implementation, site teams identified impacts of the WH-PBRN context on EBQI processes using qualitative methods, including a formal review of project call minutes, post-project debriefing calls, and structured site team input. WH-PBRN site feedback was mapped to the Replicating Effective Programs implementation phases: pre-condition, pre-implementation, implementation, and maintenance/evolution.

Results: The pre-condition phase benefited from the existing WH-PBRN research-clinician relationships to facilitate stakeholder engagement and build project buy-in at local sites. During pre-implementation, differences across WH-PBRN sites offered variations in local tailoring of EBQI elements. The WH-PBRN Coordinating Center helped resolve process complexities stemming from local resource differences and the sharing of mid-project adaptations during implementation. Local efforts were amplified in the maintenance phase by WH-PBRN dissemination of findings.

Conclusions: The PBRN strengthened multi-site EBQI activities across all implementation phases.

Implications: PBRNs contribute to the uptake of evidence into everyday practice and may serve as an important component of the future implementation of evidence-based initiatives.

DOA: 6.4.2020
https://www.sciencedirect.com/science/article/pii/S2213076416301014

Government of Canada, I. (2017). ***Evaluation of the Canadian Institute for Advanced Research – 2017—Audits and evaluations*** **(Innovation, Science, and Economic Development Canada, pp. 1–33) [Audit Reports]. Canadian Institute for Advanced Research. https://www.ic.gc.ca/eic/site/ae-ve.nsf/eng/h_03844.html**

The Canadian Institute for Advanced Research (CIFAR) is an independent nonprofit that supports networks of Canadian and International researchers in 14 program areas. CIFAR was established in 1982 as an independent Canadian institute of advanced study, forming unique partnerships between international researchers, research institutions, public funders, private donors and the broader community. ISED has funded CIFAR continuously since 1987; to date, the department has provided a total of $119 million in funding to the organization.

The CIFAR model is comprised of 3 pillars: research, a global academy that supports the next generation of scientists, and knowledge outreach.

The report concludes that public funding is vital to innovation and collaboration, both of which are necessary to solve this generation's scientific problems for the sake of the public good (food security, environmental resiliency, etc.) and for the sake of the longevity of Canada's contribution to global knowledge production. The performance of researchers and the CIFAR model is evaluated on the basis of achievements, novel approaches, products, social and economic benefit, and the ability to leverage additional funding and support.

The authors recommend a new performance measurement strategy that would include efficiency indicators that could be used as benchmarks for comparison (Government of Canada, 2017).

Tags: audit, evaluation, Canadian Institute for Advanced Research

Abstract: CIFAR is an independent not-for-profit corporation that supports networks of distinguished Canadian and international researchers. Its mission is to increase Canadian research capacity in areas of importance to Canada and strengthen the Canadian research environment through the promotion of excellence and engagement with the international research community at universities and research institutes worldwide. Since 1987, Innovation, Science and Economic Development Canada has invested a total of $119 million in funding to CIFAR. Budget 2017 committed an additional $35 million in funding over five years, starting in 2017-18. It also announced an investment of $125 million in CIFAR to support a Pan-Canadian Artificial Intelligence Strategy for Canada.

The purpose of this evaluation was to assess the relevance and performance of CIFAR. The evaluation covered the period from 2012-13 to 2015-16 and built upon the results of CIFAR's third-party evaluation completed in December 2015. The evaluation employed four primary data collection methods including a document and literature review, interviews and operational benchmarking.

There is a continued need for publicly funded fundamental research as a means to foster innovation and provide social, environmental and economic benefits to Canadians. CIFAR responds to this need by using global, interdisciplinary and collaborative research networks to

deliver large-scale research programs designed to achieve knowledge breakthroughs. CIFAR's objectives align with federal government priorities to invest in fundamental research and innovation. ISED's support for CIFAR is also consistent with the federal government's responsibility to foster science and technology. Further, the federal government has a role to play in funding fundamental research as a general contribution to societal need.

CIFAR has developed and broadened the research capabilities of Canadian and international researchers by providing them with the opportunity to explore novel research approaches and collaborate with the best researchers in the world in a face-to-face and interdisciplinary fashion. Further, early-career researchers have enhanced their capabilities through involvement in the institute.

The institute has been successful in facilitating interdisciplinary research and national and international collaboration. This approach has contributed to significant research achievements. CIFAR has produced high-caliber research that has contributed to social and economic benefits for Canadians. Further, researchers have produced and disseminated a significant amount of knowledge products. The program's outreach activities have increased in recent years and are highly regarded by participants.

The institute's virtual research model of serving as a facilitator of research collaborations suggests efficiencies compared to more traditional models used by other advanced research organizations. In addition, the program has been successful in leveraging external funding, exceeding federal leveraging requirements. Further conclusions could not be reached due to data limitations related to the organization's efficiency and economy.

The third-party evaluation led to six recommendations specific to CIFAR, which can be found in Appendix A. These recommendations were made in the context of CIFAR's Strategic Plan 2012-2017 (CIFAR 2.0) and are broader than the expected results stipulated in ISED's funding agreement.

The findings of this evaluation led to the following recommendation:

1. In order to draw more meaningful conclusions about the economy and efficiency of CIFAR's operations, SIS should work with CIFAR to update its "Performance Measurement Strategy" to include additional efficiency indicators. Consideration could be given to Identifying efficiency-related comparables (i.e. benchmarking) and targets to further assess CIFAR's operations.

DOA: 6.10.2020
https://www.ic.gc.ca/eic/site/ae-ve.nsf/vwapj/CIFAR-Final-Report-eng.pdf/$file/CIFAR-Final-Report-eng.pdf

Hall, K. L., Stokols, D., Moser, R. P., Taylor, B. K., Thornquist, M. D., Nebeling, L. C., Ehret, C. C., Barnett, M. J., McTiernan, A., Berger, N. A., Goran, M. I., & Jeffery, R. W. (2008). The Collaboration Readiness of Transdisciplinary Research Teams and Centers: Findings from the National Cancer Institute's TREC Year-One Evaluation Study. *American Journal of Preventive Medicine*, *35*(2, Supplement), S161–S172. https://doi.org/10.1016/j.amepre.2008.03.035

"During the fall of 2005, the National Cancer Institute (NCI) established the Transdisciplinary Research on Energetics and Cancer (TREC) initiative comprising four research centers and one coordination center. The TREC centers are intended to foster collaboration among transdisciplinary teams of scientists with the goal of accelerating progress toward reducing cancer incidence, morbidity, and mortality associated with energy imbalance, obesity, and low levels of physical activity. They also aim to conduct research to elucidate the mechanisms linking energetics and cancer and to provide training opportunities for new and established scientists who can carry out integrative research on energetics and energy balance (www.compass.fhcrc.org/trec). This $54-million initiative was created through a combination of funding mechanisms that enable four research centers to have the support of a centralized coordination center. NCI is partnering with the centers to support developmental projects both within and between centers as well as an initiative-wide evaluation process" (Hall et al., 2008, p. S162).

The first year of the National Cancer Institute's (NCI) Transdisciplinary Research on Energetics and Cancer (TREC) initiative contributes to the literature on team science by developing, testing, and suggesting evaluation tools for this type of collaboration. The TREC One-year survey reveals a great deal about researchers' attitudes and aptitudes toward interdisciplinary work.

They found (1) an inverse relationship between scores on the unidisciplinary and the multidisciplinary and interdisciplinary/transdisciplinary factors, suggesting that those who collaborate more at the start can benefit from the added infrastructure of interdisciplinary institutions and funding; (2) those who excelled at interdisciplinary collaboration and held a positive outlook on future collaboration felt that their institutions supported them with more resources; (3) the number of years researchers engaged in the initiative was inversely related to how effective they felt; and (4) the nature of the relationships within the center held direct bearing on how effective researchers felt the center was in its work.

Tags: case study, domestic partnerships, evaluation, researcher attitudes, team science, transdisciplinary health research

Abstract: Growing interest in promoting cross-disciplinary collaboration among health scientists has prompted several federal agencies, including the NIH, to establish large, multicenter initiatives intended to foster collaborative research and training. In order to assess whether these initiatives are effective in promoting scientific collaboration that ultimately results in public health improvements, it is necessary to develop new strategies for evaluating research processes and products as well as the longer-term societal outcomes associated with these programs. Ideally, evaluative measures should be administered over the entire course of large initiatives, including their near-term and later phases. The present study focuses on the development of new tools for assessing the readiness for collaboration among health scientists at the outset (during the first

year) of their participation in the National Cancer Institute's Transdisciplinary Research on Energetics and Cancer (TREC) initiative. Indexes of collaborative readiness, along with additional measures of near-term collaborative processes, were administered as part of the TREC Year-One evaluation survey. Additionally, early progress toward scientific collaboration and integration was assessed, using a protocol for evaluating written research products. Results from the Year-One survey and the ratings of written products provide evidence of cross-disciplinary collaboration among participants during the first year of the initiative, and also reveal opportunities for enhancing collaborative processes and outcomes during subsequent phases of the project. The implications of these findings for future evaluations of team science initiatives are discussed.

DOA: 4.3.2020
https://doi.org/10.1016/j.amepre.2008.03.035

Harris, J. K., Provan, K. G., Johnson, K. J., & Leischow, S. J. (2012). Drawbacks and benefits associated with inter-organizational collaboration along the discovery-development-delivery continuum: A cancer research network case study. *Implementation Science*, *7*(1), 69. https://doi.org/10.1186/1748-5908-7-69

Drawing from a social network perspective, the authors use network measures and statistical network modeling to examine the drawbacks and benefits associated with collaboration around discovery, development, and delivery in a network of organizations conducting cancer research. The role of the government and public health organizations makes centrality an important aspect, but also poses a barrier to transnational collaboration. A significant finding was a negative relationship between the perceived barrier of geographical differences and collaboration. Despite the fact that multi-site networks are complex, and experience fewer outcomes, and multiple communication barriers, once organizations are actually working together, geographical distance is no longer seen as a barrier.

"Although improved knowledge access is a likely outcome of collaboration, which is consistent with research in other fields, tangible outcomes of these collaborations including tools, methods, and funding are not being realized. These benefits may be more difficult to attain than others and may require more intensive collaboration over a longer period of time, possibly including the utilization of new approaches to communication to overcome barriers discussed above" (Harris et al., 2012, p. 69).

Tags: cancer research networks, evaluation, National Cancer Institute

Abstract: The scientific process around cancer research begins with scientific discovery, followed by development of interventions, and finally delivery of needed interventions to people with cancer. Numerous studies have identified substantial gaps between discovery and delivery in health research. Team science has been identified as a possible solution for closing the discovery to delivery gap; however, little is known about effective ways of collaborating within teams and across organizations. The purpose of this study was to determine benefits and drawbacks associated with organizational collaboration across the discovery-development-delivery research continuum.

Representatives of organizations working on cancer research across a state answered a survey about how they collaborated with other cancer research organizations in the state and what benefits and drawbacks they experienced while collaborating. We used exponential random graph modeling to determine the association between these benefits and drawbacks and the presence of a collaboration tie between any two network members.

Different drawbacks and benefits were associated with discovery, development, and delivery collaborations. The only consistent association across all three was with the drawback of difficulty due to geographic differences, which was negatively associated with collaboration, indicating that those organizations that had collaborated were less likely to perceive a barrier related to geography. The benefit, enhanced access to other knowledge, was positive and significant in the development and delivery networks, indicating that collaborating organizations viewed improved knowledge exchange as a benefit of collaboration. 'Acquisition of additional funding or other resources' and 'development of new tools and methods' were negatively significantly related to collaboration in these networks. So, although improved knowledge access was an outcome of collaboration, more tangible outcomes were not being realized. In the development network, those who collaborated were less likely to see 'enhanced influence on treatment and policy' and 'greater quality or frequency of publications' as benefits of collaboration.

With the exception of the positive association between knowledge transfer and collaboration and the negative association between geography and collaboration, the significant relationships identified in this study all reflected challenges associated with inter-organizational collaboration. Understanding network structures and the perceived drawbacks and benefits associated with collaboration will allow researchers to build and funders to support successful collaborative teams and perhaps aid in closing the discovery to delivery gap.

DOA: 6.10.2020
https://implementationscience.biomedcentral.com/articles/10.1186/1748-5908-7-69

Jasanoff, S. (2004). ***States of Knowledge: The Co-Production of Science and the Social Order*. Routledge.**

[See notes in "Evidence"]

Leite, D., & Pinho, I. (2016). Evaluating Collaboration Networks in Higher Education Research: Drivers of Excellence. Springer

**See images in Appendix- p. 148*

Definitions:

Research networks participatory evaluation: "a network approach to evaluate research in which researchers and other stakeholders actively engage in developing the evaluation and in all phases of its implementation in order to use results to improve learning, increase skills, and knowledge production. In this kind of evaluation, participants share knowledge and learn together to take corrective actions. This evaluation can develop leaders and build teams. We propose an RNPE process, divided into five main phases: (1) sensitization (discussion about evaluation needs' and criteria); (2) conducting the evaluation by quantitative indicators; (3) qualitative indicators facing quantitative results; (4) results (internal) and dissemination (if needed); and (5) deliberation and planning for excellence" (Moock, 2011).

Micro-level data: Researcher networks, project research, and group research.

Macro meta-level data: National research system, international and global research systems, and disciplines or scientific fields.

"This sequence is hierarchical but only on scale issue, that is, no level is more important than the other. For each context in the study, we should select and define the most appropriate level to address the research questions" (Leite & Pinho, 2016, p. 6).

Research performance framework: global science context informs international collaboration and research networks, which, in turn determine research performance.

"We need elaborate markers, qualitative and quantitative, indicators, for the evaluation of research networks" (Leite & Pinho, 2016, p. 8).

Measuring research performance across all levels (micro, meso, macro, institutional, individual, teams, networks, and countries) is key for improving knowledge production.

Tags: continuing education, higher education, education theory, social aspects of education, social science, developing countries, research collaborations, evaluation, research networks, research performance, definitions

Abstract: This book identifies key factors that drive the development and improvement of higher education research in emerging and advanced economies. In an increasingly interconnected world, knowledge production supported by strong research is a channel for the development of nations. The authors of this book argue that in order to drive knowledge production, leaders must strive to improve their understanding of how global research networks interact with one another, especially from the perspective of internationalization. This book is a useful resource for higher education researchers interested in knowledge production and dissemination as well as academic leaders and practitioners, students, and leaders interested in public administration policies and management.

1. Science geography and international research collaboration.

Chapter Abstract: In this introductory chapter, we start by discussing the main changes in knowledge production at some established and emerging economies. Next, we focus on research networks and international collaboration factors and excellence in knowledge production. There are changing roles of world regions in the science context. A science geography map of international collaboration is presented in four research major fields: life sciences, fundamental sciences, applied sciences, and social sciences. International collaboration is accepted as a source, a copious source, to scientific productivity. It is an important driver of science dynamics around the world. Following the focus of the book, we provide a conceptual research performance framework in order to address, evaluate, and monitor collaboration and international networks, a tool for excellence in scientific production.

High impact research should be international, read, understood, and replicated globally. Results should inform public policy and produce new researchers. Impactfulness is measured by bibliometric indicators (which fail to measure nonlinearity between size- number of publications, impact- number of citations). Evaluation should include: academic, government, and private sector network impacts: "The type of individual production includes bibliographic, cultural, and technical products, patents requested, patents that are commercially exploited, software, prototypes, and others" (Leite & Pinho, 2016, p. 2)

Definitions or measures:

Absorptive capacity: the ability to learn and implement knowledge or, in the context of science, the ability to recognize the value of new, external information, assimilate it, and apply it in another context.

World frontier knowledge activity: an analysis of historically rooted regional patterns.

Science operates along networks of inherited capacity. Data on four scientific areas (life, fundamental, applied, and social) is compared in eight regions (North America, EU15, South EU, Central and Easter Europe, former USSR, Latin America, Asia Pacific, and the Middle East).

2. Limits and frontiers to international collaboration

Chapter Abstract: This chapter discusses the difficulties, limits, and frontiers to international collaboration in emerging countries. The management of networks and research groups, and dealing with international collaborators are the functions that require new leadership skills. There seem to exist an international division of research labor, hard frontiers, tensions and limits marked for language expressions, publications of results, scarce resources to maintain international circulation, and hard access to the core journal in each area of knowledge. In addressing these issues, we do not intend to present an all-around theorization on the functioning of the knowledge disciplinary fields of research but to combine the critical considerations from contemporary educational theory with research-based evidence to elicit the discussion of alternatives for the improvement of strong research networks.

"In the fourth research age, collaboration networks mark the production of knowledge: (Leite & Pinho, 2016, p. 11).

On the one hand, networks work to toward inclusivity of the developing world, as diversity is one of the greatest assets to research innovation. On the other hand, they also work to reproduce patterns of inequality that accrue status to the collaborators of the global north, making diversity an exploitative pursuit for the sake of academic productivism.

Definitions:

Linguistic delimitation: This presents a disparity. International science speaks English (even though many leading scientists and data sources do not), but international education speaks many other languages.

"The English scientific communication is rather concentrated among the developed nations, a group easily identifiable as the member states of the Organization for Economic Cooperation and Development (OECD). In this scenario, Southern, developing countries lack visibility and prestige" (Leite & Pinho, 2016, p. 18)

3. Theoretical approaches to research collaboration networks

Chapter Abstract: This chapter presents a pertinent literature review about theoretical approaches to research collaboration networks. Research networks are the object of study in the new science of networks. In this science domain, research network can be conceptualized as a web of connections among scientists and collaborators whose relations on creating coauthorship inter-action produce knowledge circulation and innovation. Collaboration processes, during research networks' life cycle, converge to the acquisition of individual and collective scientific and social capital. We also introduce the notion of group theory and the importance of considering social and psychological relations inside a network research group. Searching for specific studies on the collaboration, we describe the learning component of collaboration, for example, the contribution of shared cognition to makeup a productive agency inside a research network.

Definitions:

Research network: "a web of connections among scientists and collaborators. RNs are made explicit in coauthorship intentional chains, resulting from relations among scientists, who may or may not be mediated by the Internet. The starting point is the idea that the publication of a coauthored paper produces a measurable link between scientists, resulting from the construction of relational and personal trust links. These are the connections that mark the fourth age of research" (Leite & Pinho, 2016, p. 27)

4. Research collaboration networks: what do the researchers say and what networks show?

Chapter Abstract: This chapter focuses on the researcher, the knowledge worker. Relevant information emerges from two approaches to the study of research networks: (1) in the context of consolidated research groups from leading universities and (2) within the context of a new university, geographically isolated, but connected both nationally and globally, a new network. Researchers from different disciplinary fields—Physics, Engineering, Social Sciences and Humanities, and Education—give their perceptions about networks issues, such as working in networks. We ask: what do researchers from two different countries say about networking? And, what does the analysis of their networks graphs show as an answer? The chapter ends by presenting a special case study, the biodiversity network.

Research network case study: Research Network on Biodiversity in the Biomes Cerrado, Amazonian Forest, and Pantanal of the State of Mato Grosso (RBBIO).

Moving from research group to network: The network connects a university campus located in a remote city in the Matogrossense Pantanal to researchers working in very distant institutions, in Brazil and abroad, in countries such as the Netherlands and Germany. These connections include universities, federal institutes, state secretaries, foundations, and firms. Knowledge/production reach. Research works involve researchers from institutions situated far from the investigated biomes, in Brazil and abroad. Research results are published in Brazilian journals both in Portuguese and English, as well as in foreign journals. Articles present multiple coauthorships, showing multiple collaborations both in the research and in the communication processes.

"Networks of international partners, with the national extra group and intragroup researchers plus international collaborators, are desirable outcomes of the networking process. Indeed, this is what configures a collaboration network beyond a research group. At the same time, they extend the scope of the search results and expand the range of new questions. No doubt, with the growth of the network also grows the spectrum of publications and journals in which they are conveyed" (Leite & Pinho, 2016, p. 52).

5. What do we measure by evaluating research?

Chapter Abstract: This chapter departs from the idea that collaborative processes must be diagnosed and monitored. Here is an introduction to evaluation tools, some of them very well known, such as rankings or bibliometric measures. We introduce the new metrics, the altmetrics. Here, we present answers to some questions: What do we measure when we intend to evaluate universities and higher education systems? Are we evaluating research collaboration networks? In an ultimate analysis, are we not measuring just researcher productivity? In this chapter, we question a critical view on the way indicators can even be a factor of system corruption. In another way, we assume the relevance of ethical principles to guide the selection of indicators and research work.

6. What is RNPE Evaluation? Does metrics mean the same?

Chapter Abstract: In this chapter, we directly approach the contemporaneous evaluation formula centered on the use of metrics to evaluate the research and researchers' productivity. We tell the reader a partial history of evaluation stating its role and importance in transmitting values and cultures and being nowadays a global imperative for higher education. In this context, we defend research networks participatory evaluation as a useful and necessary asset and being a competitive advantage to those organizations and institutions whose mission includes improving and valuing knowledge production. For networks research groups interested in micro-level evaluations, we suggest a protocol and qualitative and quantitative indicators to carry out a participatory evaluation. We also present some exogenous evaluation indicators for meso-and macro-level research networks evaluation. Finally, we conclude the chapter by reviewing the advantages of evaluating in a participatory manner with or without the most common metrics.

DOA: 6.8.2020

https://books.google.com/books?hl=en&lr=&id=j9CSDQAAQBAJ&oi=fnd&pg=PR4&dq=Leite,+D.+and+I.+Pinho.++2017.++Evaluating+collaborative+networks+in+higher+education+research.+&ots=0eE4unj18G&sig=89cV2MUgHoa2tlqvD59ALohBbC0#v=onepage&q=Leite%2C%20D.%20and%20I.%20Pinho.%20%202017.%20%20Evaluating%20collaborative%20networks%20in%20higher%20education%20research.&f=false

Mohrman, S., Galbraith, J., & Monge, P. (2006). Network Attributes Impacting the Generation and Flow of Knowledge within and from the Basic Science Community. In *Innovation, Science, and Institutional Change: A Research Handbook Edited by Jerald Hage and Marius Meeus*. OUP Oxford.

[See notes in “Evidence”]

Moock, J. L. (2011). Network Innovations: Building the Next Generation of Agricultural Scientists in Africa (Agricultural R&D: Investing in Africa’s Future). ASTI-IFPRI/FARA.

**images in file- p. 152*

Acronyms and Abbreviations
AERC: African Economic Research Consortium
APHRC: African Population and Health Research Center
AGRA: Alliance for a Green Revolution in Africa
ANAFE: African Network for Agriculture, Agroforestry and Natural Resources
AU: African Union
BASIC: Building African Scientific and Institutional Capacity
BecA: Biosciences Eastern and Central Africa
CAADP: Comprehensive Africa Agriculture Development Program
CARTA: Consortium for Advanced Research Training in Africa
CGIAR: Consultative Group on International Agricultural Research
CMAAE: Collaborative Master of Science in Agriculture and Applied Economics Education for African Crop Improvement
FARA: Forum for Agricultural Research in Africa
ICRAF: World Agroforestry Centre
NARS(s): national agricultural research system(s)
NEPAD: New Partnership for Africa’s Development
NGO(s) nongovernmental organization(s)
RUFORUM: Regional Universities Forum for Capacity Building in Agriculture

Definitions:
Networks: postgraduate training and collaborations that strengthen institutions, unimpeded by geography

Building on Juma's (2011) book and the World Development Report (2008), the authors argue that networks should exist to connect the missions and visions of academic institutions with global contexts and needs. Human capital and resource capacity can be gained by countries in Sub-Saharan Africa who need the innovations and who need to train up a new generation of agricultural scientists. They analyze five models of strategic networks, and present underlying principles and challenges.

Five models of strategic networks contain the following components:

1. Comprehensive view of problems and solutions
2. Mechanisms for quality assurance
3. Skills for entrepreneurship, management, and leadership
4. Increased participation of women
5. and the disadvantaged
6. Use of cost-effective information
7. technology
8. Economies of scale: collaborative
9. research/training
10. Horizontal Integration:
    links across local stakeholders
11. Vertical integration: linking global and local innovations
12. Regional platforms for policy advocacy and public education
13. Transition mechanisms between university and work
14. Embedded in university system or strategy with normal administration and faculty oversight
15. Nested in/or linked to broader research or action programs
16. Building on professional communities
17. Solid network leadership, management, and financial planning
18. Principal African ownership

"These networks are fortified by linkages to local stakeholders (for example, the private sector, nongovernmental organizations [NGOs], and government bodies) to continental alliances (for example, the African Union (AU), Forum for Agricultural Research in Africa (FARA), Comprehensive Africa Agriculture Development Program (CAADP) under the auspices of the New Partnership for Africa's Development (NEPAD)) and to global agricultural entities (for example, the CGIAR, world-class universities outside the region, international markets)" (Moock, 2011, p. 2).

Tags: agricultural systems, capacity building, evaluation of networks, research networks, science and entrepreneurship

Abstract: Despite several decades of crises in agricultural higher education, there has been major improvement. Many universities and research institutes in Africa are abandoning outmoded ways of doing things and devising new structures, behaviors, and incentives. Yet these advances are often inadequate to produce a new generation of scientists and leaders with the knowledge and skills to replace the large numbers in the agricultural sector now close to retirement, and spur the agricultural growth needed to reduce poverty. One increasingly popular way of building a strong human capital development infrastructure and harnessing gains from innovation in the research process is investment in networks. Networks, for the purposes of this discussion, refer to postgraduate training and collaborations that strengthen institutions, unimpeded by geography—such as a collection of agricultural scientists capitalizing on greatly improved mobility and

telecommunications to transcend institutional and national boundaries. This paper identifies five models of strategic networks making progress toward the stated goals of bolstering university-based training and research and enhancing the productivity of the agricultural sector. These models, while different in their composition, offer key principles and approaches of networks that are scalable and have the potential to be sustained. Of particular importance are those with the ability to produce "scientist entrepreneurs," create professional career structures, ensure gender equity, build economies of scale and serve as leverage points for translating knowledge into innovation and application.

Paolino, A. R., Lauf, S. L., Pieper, L. E., Rowe, J., Vargas, I. M., Goff, M. A., Daley, M. F., Tuzzio, L., & Steiner, J. F. (2014). Accelerating Regulatory Progress in Multi-Institutional Research. *EGEMS*, *2*(1). https://doi.org/10.13063/2327-9214.1076

The experience of the HMORN demonstrates how a network of researchers can partner with research administrators to create, continually evaluate, and improve its tools and systems to meet the needs of its member institutions and others. Evaluation tools should aim to increase trust and resiliency between networked institutions, while encouraging autonomy to opt in or out of sub-projects (Paolino et al., 2014).

Tags: administrative efficiency, data agreement, IRB, subaward, subcontract

Abstract: Multi-institutional collaborations are necessary in order to create large and robust data sets that are needed to answer important comparative effectiveness research (CER) questions. Before scientific work can begin, a complex maze of administrative and regulatory requirements must be efficiently navigated to avoid project delays. Staff from research, regulatory, and administrative teams involved in three HMO Research Network (HMORN) multi-institutional collaborations developed and employed novel approaches: to secure and maintain Institutional Review Board (IRB) approvals; to enable data sharing, and to expedite subawards for two data-only minimal risk studies. These novel approaches accelerated required processes and approvals while maintaining regulatory, human subjects, and institutional protections. Outcomes from the processes described here are compared with processes outlined in the research and regulatory literature and with processes that have been used in previous multisite research collaborations. Research, regulatory, and administrative staff are essential contributors to the success of multi-institutional collaborations. Their flexibility, creativity, and effective communication skills can lead to the development of efficient approaches to achieving the necessary oversight for these complex projects. Elements of these specific strategies can be adapted and used by other research networks. Other efforts in these areas should be evaluated and shared. The processes that help develop a "learning research system" play an important and complementary role in sustaining multi-institutional research collaborations.

DOA: 6.4.2020
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4371517/

Pomernacki, A., Carney, D. V., Kimerling, R., Nazarian, D., Blakeney, J., Martin, B. D., Strehlow, H., Yosef, J., Goldstein, K. M., Sadler, A. G., Bean-Mayberry, B. A., Bastian, L. A., Bucossi, M. M., McLean, C., Sonnicksen, S., Klap, R., Yano, E. M., & Frayne, S. M. (2015). Lessons from Initiating the First Veterans Health Administration (VA) Women's Health Practice-based Research Network (WH-PBRN) Study. *The Journal of the American Board of Family Medicine*, *28*(5), 649–657. https://doi.org/10.3122/jabfm.2015.05.150029

"While many complexities of conducting multisite, clinic-based research in an integrated health care system with a special population (women veterans) had to be addressed, our experience with the inaugural WH-PBRN study demonstrated the feasibility of establishing productive relationships with local clinicians and recruiting women veterans in diverse sites, and it illustrated strengths of a PBRN approach. We identified 7 critical study elements and described barriers to and facilitators of conducting multisite research within the newly formed WH-PBRN" (Pomernacki et al., 2015, p. 652).

Critical elements:

- Regulatory procedures: A centralized tracking system unique to the VA context included IRB (for the overall study and then for each site); local research & development (R&D) committee review at each site (with processes varying across sites); Office of Management and Budget waiver; and data access requests.
- Sampling frame: A centralized folder permission structure developed by the WH-PBRN coordinating center allowed each site to access their local sampling frame.
- Participant tracking systems
- Clinic based recruitment
- Participant enrollment: Site coordinators across all sites remarked on their perception that women were motivated to participate by a strong desire to help fellow women veterans.
- Effective clinic partnerships: A key characteristic of PBRNs is that investigators do not "helicopter" into clinics, recruit participants, and leave; instead, the local PBRN staff develop longstanding relationships with local clinicians and clinical leaders that support ongoing collaborative efforts. It is essential for the local PBRN team to acknowledge the added demands that research imposes on clinic staff, who are at the heart of any successful PBRN activity.

Tags: practice-based research, veterans' health, women's health

Abstract: The Veterans Health Administration (VA) Women's Health Practice-Based Research Network (WH-PBRN) was created to foster innovations for the health care of women veterans. The inaugural study by the WH-PBRN was designed to identify women veterans' own priorities and preferences for mental health services and to inform refinements to WH-PBRN operational procedures. Addressing the latter, this article reports lessons learned from the inaugural study.

Methods: WH-PBRN site coordinators at the 4 participating sites convened weekly with the study coordinator and the WH-PBRN program manager to address logistical issues and identify lessons learned. Findings were categorized into a matrix of challenges and facilitators related to key study elements.

Results: Challenges to the conduct of PBRN-based research included tracking of regulatory documents; cross-site variability in some regulatory processes; and troubleshooting logistics of clinic-based recruitment. Facilitators included a central institutional review board, strong relationships between WH-PBRN research teams and women's health clinic teams, and the perception that women want to help other women veterans.

Conclusion: Our experience with the inaugural WH-PBRN study demonstrated the feasibility of establishing productive relationships between local clinicians and researchers, and of recruiting a special population (women veterans) in diverse sites within an integrated health care system. This identified strengths of a PBRN approach.

DOA: 6.4.2020
https://www.jabfm.org/content/28/5/649.full

Qualls, L. G., Phillips, T. A., Hammill, B. G., Topping, J., Louzao, D. M., Brown, J. S., Curtis, L. H., & Marsolo, K. (2018). Evaluating Foundational Data Quality in the National Patient-Centered Clinical Research Network (PCORnet®). *EGEMs*, *6*(1). https://doi.org/10.5334/egems.199

A first attempt at incorporating electronic health data from multiple domains into a centralized database to be used by the National Patient-Centered Clinical Research Network revealed improvements in data compilation and an elimination of errors. This effort will provide feedback to better data standardization and efficiency as it is rolled out among the distributed research networks associated with PCOR (Qualls et al., 2018).

Tags: data quality, distributed research networks, electronic health records, quality improvement

Abstract: Distributed research networks (DRNs) are critical components of the strategic roadmaps for the National Institutes of Health and the Food and Drug Administration as they work to move toward large-scale systems of evidence generation. The National Patient-Centered Clinical Research Network (PCORnet®) is one of the first DRNs to incorporate electronic health record data from multiple domains on a national scale. Before conducting analyses in a DRN, it is important to assess the quality and characteristics of the data.

Methods: PCORnet's Coordinating Center is responsible for evaluating foundational data quality or assessing fitness-for-use across a broad research portfolio, through a process called data curation. Data curation involves a set of analytic and querying activities to assess data quality coupled with maintenance of detailed documentation and ongoing communication with network partners. The first cycle of PCORnet data curation focused on six domains in the PCORnet common data model: demographics, diagnoses, encounters, enrollment, procedures, and vitals.

Results: The data curation process led to improvements in foundational data quality. Notable improvements included the elimination of data model conformance errors; a decrease in implausible height, weight, and blood pressure values; an increase in the volume of diagnoses and procedures; and more complete data for key analytic variables. Based on the findings of the first cycle, we made modifications to the curation process to increase efficiencies and further reduce variation among data partners.

Discussion: The iterative nature of the data curation process allows PCORnet to gradually increase the foundational level of data quality and reduce variability across the network. These activities help increase the transparency and reproducibility of analyses within PCORnet and can serve as a model for other DRNs.

DOA: 6.3.2020
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5983028/

Rose, R. M. (n.d.). A Guide to Conceiving, Organizing, Implementing, and Monitoring Interdisciplinary Research Networks (Finding Answers to Big Questions: Overcoming Disciplinary Boundaries Through Research Networks, pp. 1–25). MacArthur Foundation. https://www.macfound.org/media/files/RoseNetworkMonograph.pdf

The author outlines a blueprint for the first several years of building a research network, from identifying members and securing funding to monitoring, evaluation, and annual review, and building linkages with practitioners for outlets to application. The evaluative blueprint builds on Kahn and Prager's (1994) argument that networks are needed to organize the complexity of interdisciplinary collaborations and team science into productive problem-solving mechanisms that draw on the expertise of the sum of their parts. "Collaborative networks serve to bring diverse perspectives, knowledge, expertise and strategies to illuminate complex problems associated with the health, well-being and behavior of individuals and societies in which they live. A key assumption is that network sponsored deliberations and research are structured to exploit the full range of talent represented by network members. Therefore, they are better able to address more complex and significant problems than can often be accomplished by individuals working by themselves" (Rose, n.d., p. 3).

MacArthur research networks provide examples for a formulaic structure of network preparation that involves (1) establishing foundation support, (2) following a pre-network development strategy using appreciative inquiry into existing networks, and (3) clear communication regarding the responsibilities of program staff.

Network formation should involve identifying potential members and a network chair who share values, communication strategies, etc.

- Criteria for evaluating members:
- Clear expertise in a given field
- Breadth of interests
- Curiosity
- Capacity to re-frame new information into one's own model system • Lack of disciplinary defensiveness
- Senior status in the profession
- Selection from a broad geographical base (not just a member in a few visible universities)

- Interest and potential capacity to commit the time and effort require.

These members should be encouraged to take on leadership roles within their networks, and to develop an ownership of new projects.

A guiding principle is to continually work to include members that will mitigate problems associated with disciplinary isolation and homogeneity.

Establishing, funding, a budget, clear roles of foundation staff, and network administrator are the next steps. After presentations of proposals, a subset should be asked to become the core group. Group consensus should lay the groundwork for designating a chair. It is recommended that this step should be informed by other staff and leaders in the foundation, outside consultants who have been particularly helpful in identifying potential scholars and those who have been invited to be core network members.

Solidifying the agenda as the more defined network core continues to meet and plan is the next step and takes about 18 months. It should have some degree of fluidity, but decisions need to be made as they move forward. Their work should be informed by peripheral members and shaped by the input of staff as they become responsible for writing the proposal for support as a more independent group

The discussions about this first proposal for funding serve to clarify:

- Areas they are most enthusiastic about and interested in collaborating on
- The strategies involved in designing the relevant research
- The most important gaps in their expertise that need to be filled by adding more network members in the future.

After this initial grant is reviewed and approved by the foundation, the network now assumes administrative responsibility for their work, organizing their own meetings, sponsoring appropriate reviews of the literature and beginning to solidify future research projects. This is greatly facilitated by the addition of a network administrator.

Tags: network guide, evaluation, network structure, network strategic plan, network timeline

Abstract: This monograph is a guide to enhance efforts in establishing and supporting interdisciplinary networks. Its primary audience is foundations, but other organizations may find this monograph valuable. Although these recommendations emerge from my experience in establishing and managing successful networks focused on interdisciplinary research in the health and behavioral sciences, the strategies that have proven useful are applicable to a broader range of collaborations, where it is important to integrate multiple, diverse perspectives. I was motivated to write the monograph for two reasons. The first grows out of the conviction that knowledge of real-world problems can rarely be grasped through the lens of a single discipline. If one accepts this perspective, the next question is how do we gather and carefully blend the range of perspectives necessary to truly understand complex social and natural phenomena if we are going to act effectively to solve that problem? I believe that a particularly effective strategy is to develop, and support appropriately constituted interdisciplinary research networks. My hope is

that this description in a step by step fashion will provide interested foundations and their staffs a blueprint that can lead to the successful initiation of new networks that will enable potentially powerful and exciting new contributions to a foundation's agenda.

DOA: 5.12.2020
https://www.macfound.org/media/files/RoseNetworkMonograph.pdf

Steiner, J. F., Paolino, A. R., Thompson, E. E., & Larson, E. B. (2014). Sustaining Research Networks: The Twenty-Year Experience of the HMO Research Network. *EGEMs*, *2*(2). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4371441/

A case study of the Health Maintenance Organization Research Network (HMORN), which operates18 clinical research centers in the United States and Israel, defines sustainability for a multi-institutional network and presents 10 essential elements that contribute to this. The HMORN provides important insight as epidemiological studies, and collaborations of clinical trials and health services research become increasingly pertinent to a globalized world.

Funding Institutions:
AHRQ = Agency for Healthcare Research & Quality
CDC = Centers for Disease Control and Prevention
FDA = U.S. Food and Drug Administration
NHGRI = National Human Genome Research Institute
NHLBI = National Health, Lung and Blood Institute
NIH = National Institutes of Health
NIMH = National Institute of Mental Health

Definition of sustainability for networks: "First, sustainability requires the development and enhancement of shared research assets to facilitate a sequence of research studies in a specific content area or multiple areas. Second, sustainability requires a community of researchers and other stakeholders who reuse and develop those assets" (Steiner et al., 2014, p. 2).

Ten essential elements for sustainability:

1. HMORN is overseen by a governing board that ensures shared research assets: oversight of data, tools, approaches to human subject review, etc.
2. Data sharing is standardized according to a model that defines processes for increasing the validity, quality, and governance of data openness/security.
3. Knowledge and research tools are shared through internal investigators, scientific interest groups, and external investigators. HMORN have been able to develop a standard practice for sharing tools such as recruitment materials, computer code, and surveys.
4. Administrative efficiency is attempted through increasingly centralized contracting, data sharing agreements, and financial closeout of studies. However, efficiency has, in several places, decreased, as it is no longer quickly done at an individual institution's level.
5. Physical infrastructure varies by location, but biorepositories may increase the ability to share infrastructure at some sites.

6. Funding is provided by a "relay race" of external funders, while individual activities like management of tumor registries and satisfying regulatory requirements are underwritten by host institutions.
7. A shared and explicit mission, vision, and values emphasize public domain research.
8. Protection of human subjects is achieved by a regular convention of IRB reviewers from individual sites. Differences in metrics and IRB software can hamper collaboration.
9. A culture of collaboration is difficult to achieve since culture cannot be explicitly defined or standardized. Nevertheless, longevity of programs helps "institutional memory" and consensus leadership over a loose federation of institutions linked only by dies allows individual cultures to thrive.
10. HMORN researchers often provide clinical services to their host institutions, but their relationships vary based on the individualized goals of each host.

This study recognizes a lack of information sharing and a lack of metrics to evaluating the efficiency of research as barriers to sustainable research networks.

Tags: clinical research, comparative effectiveness, data systems, health maintenance organization, network sustainability, organizational change, program sustainability

Abstract:
Purpose: As multi-institutional research networks assume a central role in clinical research, they must address the challenge of sustainability. Despite its importance, the concept of network sustainability has received little attention in the literature, and the sustainability strategies of durable scientific networks have not been described.

Innovation: The Health Maintenance Organization Research Network (HMORN) is a consortium of 18 research departments in integrated health care delivery systems with over 15 million members in the United States and Israel. The HMORN has coordinated federally funded scientific networks and studies since 1994. This case study describes the HMORN approach to sustainability, proposes an operational definition of network sustainability, and identifies 10 essential elements that can enhance sustainability.

Credibility: The sustainability framework proposed here is drawn from prior publications on organizational issues by HMORN investigators and from the experience of recent HMORN leaders and senior staff.

Conclusion and Discussion: Network sustainability can be defined as (1) the development and enhancement of shared research assets to facilitate a sequence of research studies in a specific content area or multiple areas, and (2) a community of researchers and other stakeholders who reuse and develop those assets. Essential elements needed to develop the shared assets of a network include: network governance; trustworthy data and processes for sharing data; shared knowledge about research tools; administrative efficiency; physical infrastructure; and infrastructure funding. The community of researchers within a network is enhanced by: a clearly defined mission, vision and values; protection of human subjects; a culture of collaboration; and strong relationships with host organizations. While the importance of these elements varies based

on the membership and goals of a network, this framework for sustainability can enhance strategic planning within the network and can guide relationships with external stakeholders.

DOA: 4.3.2020
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4371441/pdf/egems1067.pdf

Ulnicane, I. (2015). Why do international research collaborations last? Virtuous circle of feedback loops, continuity and renewal. *Science and Public Policy*, *42*(4), 433–447. https://doi.org/10.1093/scipol/scu060

A mid-range theory explains why and how long-term international collaborations lasting over 10 or 20 years evolve in the context of changing science policy; and examines the increased role of predominantly national fixed-term project funding. The theory suggests that long-term collaborations combine formal and informal interactions and operate as virtuous circles benefiting from positive feedback loops that work to establish thematic and organizational continuity and renewal.

The primary factors facilitating long-term international collaborations include the following realities:

- Emergence and renewal motivate trust: where close knowledge of research interests are aligned and mobilized. Complementary tasks are supported by institutional and social motives. Early results strengthen trust and motives. A mechanism is established for bringing in new people and ideas.
- Informal Collaboration: Resources for informal collaboration support riskier ideas, which enable innovation. Common ways of interacting informally facilitate productive formal projects.
- Formal collaboration: Formal mechanisms allow expansion and intensification of collaboration; diverse funding sources allow choices for follow-up projects. These are organized in such a way that the possibility exists of combining formal projects into diverse organizational continuity.

Results: Novel findings facilitate competitive application for follow-up projects. Training of the next generation facilitates change and expansion of the field with a renewal of the process (Ulnicane, 2015).

Tags: informal collaboration, international collaboration, long-term collaboration, project funding, science policy

Abstract: It is often argued that the unintended consequences of science policy transformation over the last 50 years—increased role of fixed-term project funding, evaluation and temporary contracts—are short-termism, fragmentation and limited freedom to choose research topics and collaborators. This paper focuses on a phenomenon that should be highly unlikely in this context: long-term international research collaborations lasting over 10 and 20 years which remain creative and productive. To shed light on the little studied topic of why and how long-term international

research collaborations evolve, the paper develops a mid-range theory from multiple longitudinal case studies. It suggests that long-term collaborations combining formal and informal interactions operate as virtuous circles whereas earlier results ensure feedback loops and thematic and organizational continuity, but renewal is crucial. The emergent theory is built from multiple data sources and methods analyzing international collaborations in the emerging field of nanoscience in Europe. DOA: 5.26.2020

Uwituze, S., Chindime, M. S., Osiru, M., & Adipala, E. (2016). ***Building capacity of African Universities to train proactive graduates through partnerships: The case of RUFORUM and Carnegie. Regional Universities Forum for Capacity Building in Agriculture (RUFORUM); RUFORUM Working Document Series*** **(ISSN 1607-9345) No. 14 (1): 185-196. https://repository.ruforum.org/**

Carnegie supported PhD students improved university relevance through revamped curricula, skills enhancement, and research grounded in local reality. Academic mobility improved through mentorship at partner institutions.

Additional networked projects emerged from networking events: ADECEA, AGRIBUSINESS, ARIS II, PhD Aquaculture, etc. (Uwituze et al., 2016).

Tags: academic mobility, capacity building, Carnegie, case study, doctoral training, funding, partnerships, RUFORUM

Abstract: Africa is currently last in all the knowledge economy indicators yet growth and development in a globalized world are driven by a knowledge economy. Although Africa demonstrated strong economic performance during the last decade, with at least 4.5% GDP growth, extreme poverty has grown with number of poor increasing dramatically over the past 15 years. With only 20% of academic staff having PhDs in public higher education institutions in Africa, universities face difficulties in serving local needs and responding to the market demand in order to reduce poverty. Accordingly, universities need to harness higher education partnerships so as to address the current inadequacy for higher education systems in Africa and help universities provide quality training, particularly at graduate (Masters and Doctoral) level and to harness regional, continental and global lessons and experiences. The Regional Universities Forum for Capacity Building in Agriculture (RUFORUM), a network of 60 universities in 25 African countries, has partnered with Carnegie Corporation of New York in a bid to strengthen the capacity for graduate training in African universities. Under this partnership Carnegie has provided two grants (the first $997,900 and the second $1,505,400) to support training of PhD students in selected regional PhD programmes in Africa. To date, 114 scholarships have been awarded, and already 29 students have completed their PhD training and returned to their home institutions. This paper highlights key achievements of this 5-year partnership, draws some lessons learned from implementation, and suggests possible future orientation for the partnership and other initiatives.

DOA: 4.22.2020
https://repository.ruforum.org/system/tdf/Uwituze.pdf?file=1&type=node&id=36155&force=

Wagner, C. S., Roessner, J. D., Bobb, K., Klein, J. T., Boyack, K. W., Keyton, J., Rafols, I., & Börner, K. (2011). Approaches to understanding and measuring interdisciplinary scientific research (IDR): A review of the literature. *Journal of Informetrics*, *5*(1), 14–26. https://doi.org/10.1016/j.joi.2010.06.004

The authors offer an overview of the literature on evaluating the interdisciplinary aspects of scientific research networks. They discuss bibliometric measures, network dynamics, and entropy- highlighting the strengths and gaps in each. Finally, they offer a roadmap for qualitative and quantitative measures, and call for more metrics to better measure knowledge integration as it appears organically in teams (Wagner et al., 2011).

Tags: bibliometrics, evaluation, indicators, interdisciplinary, research, science

Abstract: Interdisciplinary scientific research (IDR) extends and challenges the study of science on a number of fronts, including creating output science and engineering (S&E) indicators. This literature review began with a narrow search for quantitative measures of the output of IDR that could contribute to indicators, but the authors expanded the scope of the review as it became clear that differing definitions, assessment tools, evaluation processes, and measures all shed light on different aspects of IDR. Key among these broader aspects is (a) the importance of incorporating the concept of knowledge integration, and (b) recognizing that integration can occur within a single mind as well as among a team. Existing output measures alone cannot adequately capture this process. Among the quantitative measures considered, bibliometrics (co-authorships, co-inventors, collaborations, references, citations and co-citations) are the most developed, but leave considerable gaps in understanding of the social dynamics that lead to knowledge integration. Emerging measures in network dynamics (particularly betweenness centrality and diversity), and entropy are promising as indicators, but their use requires sophisticated interpretations. Combinations of quantitative measures and qualitative assessments being applied within evaluation studies appear to reveal IDR processes but carry burdens of expense, intrusion, and lack of reproducibility year-upon-year. This review is a first step toward providing a more holistic view of measuring IDR, although research and development is needed before metrics can adequately reflect the actual phenomenon of IDR.

DOA: 6.9.2020
https://www.sciencedirect.com/science/article/abs/pii/S1751157710000581

VII. Measures and Indicators

Barzel, B., & Barabási, A.-L. (2013). Universality in network dynamics. *Nature Physics*, *9*(10), 673–681. https://doi.org/10.1038/nphys2741

The authors propose a framework for understanding universality- especially how topology and dynamics relate to one another within and between networks (Barzel & Barabási, 2013).

Tags: network dynamics, universality

Abstract: Despite significant advances in characterizing the structural properties of complex networks, a mathematical framework that uncovers the universal properties of the interplay between the topology and the dynamics of complex systems continues to elude us. Here we develop a self-consistent theory of dynamical perturbations in complex systems, allowing us to systematically separate the contribution of the network topology and dynamics. The formalism covers a broad range of steady-state dynamical processes and offers testable predictions regarding the system's response to perturbations and the development of correlations. It predicts several distinct universality classes whose characteristics can be derived directly from the continuum equation governing the system's dynamics and which are validated on several canonical network-based dynamical systems, from biochemical dynamics to epidemic spreading. Finally, we collect experimental data pertaining to social and biological systems, demonstrating that we can accurately uncover their universality class even in the absence of an appropriate continuum theory that governs the system's dynamics.

DOA: 5.18.2020
https://www.nature.com/articles/nphys2741

Boyack, K. W., Klavans, R., & Börner, K. (2005). Mapping the backbone of science. *Scientometrics*, *64*(3), 351–374. https://doi.org/10.1007/s11192-005-0255-6

**images in Appendix- p. 143*

Eight different measures are calculated from the combined SCI/SSCI data to look at similarity across journal networks. These relationships are then mapped using a VxOrd method. These maps approximate disciplines, scientific collaboration networks, and can serve as foundations for policy-making (Boyack et al., 2005).

Tags: journal interconnectivity, mapping science, scientific networks

Abstract: This paper presents a new map representing the structure of all of science, based on journal articles, including both the natural and social sciences. Similar to cartographic maps of our world, the map of science provides a bird's eye view of today's scientific landscape. It can be used to visually identify major areas of science, their size, similarity, and interconnectedness. In order to be useful, the map needs to be accurate on a local and on a global scale. While our recent work has focused on the former aspect,1 this paper summarizes results on how to achieve structural accuracy. Eight alternative measures of journal similarity were applied to a data set of

7,121 journals covering over 1 million documents in the combined Science Citation and Social Science Citation Indexes. For each journal similarity measure we generated two-dimensional spatial layouts using the force-directed graph layout tool, VxOrd. Next, mutual information values were calculated for each graph at different clustering levels to give a measure of structural accuracy for each map. The best co-citation and inter-citation maps according to local and structural accuracy were selected and are presented and characterized. These two maps are compared to establish robustness. The inter-citation map is then used to examine linkages between disciplines. Biochemistry appears as the most interdisciplinary discipline in science.

DOA: 5.19.2020
https://link-springer-com.er.lib.k-state.edu/content/pdf/10.1007/s11192-005-0255-6.pdf

Chen, K., Zhang, Y., & Fu, X. (2019). International research collaboration: An emerging domain of innovation T studies? *Research Policy*, *48*, 149–168.

The authors suggest three phases of international research collaborations and indicators that signal the progress into a new phase: the emergence phase, fermentation phase, and "take off" phase. They analyze the historical roots of the IRC research field in bibliometric research, and they trace the trajectories through new methodologies that began to adopt International co-publication as the main indicator of IRC research collaboration across countries. They problematize the validity of this indicator alone and suggest that co-citation network analysis can be used in a more comprehensive framework for studying and evaluating networks. “The bibliographic coupling analysis shows that IRC studies can be categorized into five main research themes, namely, driving factors of IRC, IRC patterns, IRC effects, IRC networks and IRC measurement" (Chen et al., 2019, p. 165).

Tags: IRC, indicators, measurements, research collaboration

Abstract: International research collaboration (IRC) has been increasingly important as an emerging area of innovation studies. This study reviews the intellectual base, main research trajectories and intellectual communities of the IRC research domain over the period 1957–2015. It integrates qualitative review and three quantitative analyses including co-citation network analysis, main path analysis and bibliographic coupling analysis. The results show that the IRC research has gone through three phases, namely, “emergence” (1957–1991), “fermentation” (1992–2005) and “take-off” (2006–2015) phases. The co-citation network analysis confirms that the IRC re- search field has been developed under the influence of two pioneering studies related to bibliometrics research. The main research trajectories in IRC studies over the three development phases and over the whole period are identified based on the main path analysis, which shows that co-authorship analysis is the main research method in IRC studies. A bibliographic coupling analysis suggests that the whole IRC research domain can be classified into five distinct intellectual areas: drivers of IRC, IRC patterns, IRC effects, IRC networks and IRC measurement. Seven topics for future research are also identified.

DOA: 6.10.2020
https://www.sciencedirect.com/science/article/abs/pii/S0048733318301926

Clauset, A., Newman, M. E. J., & Moore, C. (2004). Finding community structure in very large networks. *Physical Review E*, *70*(6), 066111. https://doi.org/10.1103/PhysRevE.70.066111

An algorithm analyzes the density and structure of links (edges) and vertices (nodes) to determine meaningful communities. This is a modeling tool that could potentially be applied to research networks as well.

Definitions:

community structure: "the gathering of vertices into groups such that there is a higher density of edges within groups than between them" (Clauset et al., 2004, p. 1).

modularity: a network property in which the division contains many edges within communities and few between them.

dendrogram: a visual tool that represents the hierarchical decomposition of a network into communities.

Tags: community modeling, community structure, network algorithm, network analysis

Abstract: The discovery and analysis of community structure in networks is a topic of considerable recent interest within the physics community, but most methods proposed so far are unsuitable for very large networks because of their computational cost. Here we present a hierarchical agglomeration algorithm for detecting community structure which is faster than many competing algorithms: its running time on a network with n vertices and m edges is O(mdlogn) where d is the depth of the dendrogram describing the community structure. Many real-world networks are sparse and hierarchical, with m∼n and d∼logn, in which case our algorithm runs in essentially linear time, O(nlog2n). As an example of the application of this algorithm we use it to analyze a network of items for sale on the web site of a large on-line retailer, items in the network being linked if they are frequently purchased by the same buyer. The network has more than 400 000 vertices and 2×106 edges. We show that our algorithm can extract meaningful communities from this network, revealing large-scale patterns present in the purchasing habits of customers.

DOA: 4.20.2020
https://arxiv.org/pdf/cond-mat/0408187.pdf

Guimerà, R., Uzzi, B., Spiro, J., & Amaral, L. A. N. (2005). Team Assembly Mechanisms Determine Collaboration Network Structure and Team Performance. *Science*, *308*(5722), 697–702. https://doi.org/10.1126/science.1106340

An analysis of team size, diversity, and complex network (a measure of embeddedness in a larger network through previous external collaborations) in four fields (social psychology, economics, ecology, and astronomy) showed that the evolution of team science follows predictive patterns that depend on the intricacies of creative tasks and external pressures such as differentiation, specialization, and commercialization. While all four fields experienced similar growth in network size over time, the growth in social psychology and economics was linear, while ecology and astrology networks grew faster (Guimerà et al., 2005).

Tags: collaboration, network analysis, team science

Abstract: Agents in creative enterprises are embedded in networks that inspire, support, and evaluate their work. Here, we investigate how the mechanisms by which creative teams self-assemble determine the structure of these collaboration networks. We propose a model for the self-assembly of creative teams that has its basis in three parameters: team size, the fraction of newcomers in new productions, and the tendency of incumbents to repeat previous collaborations. The model suggests that the emergence of a large connected community of practitioners can be described as a phase transition. We find that team assembly mechanisms determine both the structure of the collaboration network and team performance for teams derived from both artistic and scientific fields.

Network analysis of successful entertainment productions and scientific projects reveals that the best performances result from newly formed, larger teams with both experienced and novice members.

DOA: 4.20.2020
https://science.sciencemag.org/content/308/5722/697

Leite, D., & Pinho, I. (2016). ***Evaluating Collaboration Networks in Higher Education Research: Drivers of Excellence*****. Springer.**

[See notes in "Evaluation"]

Leydesdorff, L., Wagner, C. S., & Bornmann, L. (2019). Interdisciplinarity as diversity in citation patterns among journals: Rao-Stirling diversity, relative variety, and the Gini coefficient. ***Journal of Informetrics*****,** ***13*****(1), 255–269. https://doi.org/10.1016/j.joi.2018.12.006**

The authors propose a measure of interdisciplinarity diversity DIV, that shows variety, balance, and disparity between disciplines in a more effective way than the RS Diversity indicator. This measure aligns with other measures of betweenness and centrality by measuring three components independently:

- "Balance" is operationalized by the gini coefficient;
- "Variety" is operationalized as "relative variety," that is, the number of classes in use divided by the number of classes available for use;
- "Disparity" can be operationalized using one distance measure or another as in the case of RS diversity (Leydesdorff et al., 2019).

Tags: diversity, Gini, interdisciplinary, Rao-Stirling, variety

Abstract: Questions of definition and measurement continue to constrain a consensus on the measurement of interdisciplinarity. Using Rao-Stirling (RS) Diversity sometimes produces anomalous results. We argue that these unexpected outcomes can be related to the use of "dual-concept diversity" which combines "variety" and "balance" in the definitions (ex-ante). We propose to modify RS Diversity into a new indicator (DIV) which operationalizes "variety," "balance," and "disparity" independently and then combines them ex post. "Balance" can be measured using the Gini coefficient. We apply DIV to the aggregated citation patterns of 11,487 journals covered by the Journal Citation Reports 2016 of the Science Citation Index and the Social Sciences Citation Index as an empirical domain and, in more detail, to the citation patterns of 85 journals assigned to the Web-of-Science category "information science & library science" in both the cited and citing directions. We compare the results of the indicators and show that DIV provides improved results in terms of distinguishing between interdisciplinary knowledge integration (citing references) versus knowledge diffusion (cited impact). The new diversity indicator and RS diversity measure different features. A routine for the measurement of the various operationalization of diversity (in any data matrix) is made available online.

DOA: 5.11.2020
https://www-sciencedirect-com.er.lib.k-state.edu/science/article/pii/S1751157718303535

Perianes-Rodriguez, A., & Ruiz-Castillo, J. (2018). The impact of classification systems in the evaluation of the research performance of the Leiden Ranking universities. *Journal of the Association for Information Science and Technology*, *69*(8), 1046–1053. https://doi.org/10.1002/asi.24017

The authors analyze the usefulness of ranking systems and advocate for publication level algorithms over journal-level. They cite high skewness and differences between each cluster using the top 1% and top 10% indicators for ranking research institutions (Perianes-Rodriguez & Ruiz-Castillo, 2018).

Tags: classification systems, publication impact, ranking algorithm, Leiden ranking, WoS, G8

Abstract: In this paper, we investigate the consequences of choosing different classification systems –namely, the way publications (or journals) are assigned to scientific fields– for the ranking of research units. We study the impact of this choice on the ranking of 500 universities in the 2013 edition of the Leiden Ranking in two cases. Firstly, we compare a Web of Science journal-level classification system, consisting of 236 subject categories, and a publication-level algorithmically constructed system, denoted G8, consisting of 5,119 clusters. The result is that the consequences of the move from the WoS to the G8 system using the Top 1% citation impact indicator are much greater than the consequences of this move using the Top 10% indicator. In the second place, we compare the G8 classification system and a publication-level alternative of the same family, the G6 system, consisting of 1,363 clusters. The result is that, although less important than in the previous case, the consequences of the move from the G6 to the G8 system under the Top 1% indicator are still of a large order of magnitude.

DOA: 6.21.2020

https://e-archivo.uc3m.es/bitstream/handle/10016/22147/we1603.pdf?sequence=3

Radosevic, S., & Yoruk, E. (2014). Are there global shifts in the world science base? Analysing the catching up and falling behind of world regions. Scientometrics, 101(3), 1897–1924. https://doi.org/10.1007/s11192-014-1344-1

[See notes in "Evidence"]

Stirling, A. (2007). A general framework for analysing diversity in science, technology and society. *Journal of The Royal Society Interface*, *4*(15), 707–719. https://doi.org/10.1098/rsif.2007.0213

A quantitative measure of diversity and interdisciplinarity is proposed based on a heuristic that accounts for 10 quality criteria that uniquely measure aspects of variety, balance, and disparity (Stirling, 2007).

Tags: diversity heuristic, diversity measure, interdisciplinarity

Abstract: This paper addresses the scope for more integrated general analysis of diversity in science, technology and society. It proposes a framework recognizing three, necessary but individually insufficient, properties of diversity. Based on 10 quality criteria, it suggests a general quantitative non-parametric diversity heuristic. This allows the systematic exploration of diversity under different perspectives, including divergent conceptions of relevant attributes and contrasting weightings on different diversity properties. It is shown how this heuristic may be used to explore different possible trade-offs between diversity and other aspects of interest, including portfolio interactions. The resulting approach offers a way to be more systematic and transparent in the treatment of scientific and technological diversity in a range of fields, including conservation management, research governance, energy policy and sustainable innovation.

DOA: 5.11.2020
https://royalsocietypublishing.org/doi/full/10.1098/rsif.2007.0213

Wagner, C. S., Whetsell, T. A., & Mukherjee, S. (2019). International research collaboration: Novelty, conventionality, and atypicality in knowledge recombination. *Research Policy*, *48*(5), 1260–1270. https://doi.org/10.1016/j.respol.2019.01.002

[See notes in "Evidence"]

Wagner, C. S., & Jonkers, K. (2017). Open countries have strong science. *Nature News*, *550*(7674), 32. https://doi.org/10.1038/550032a

[See notes in "Motivations"]

Waltman, L., van Eck, N. J., van Leeuwen, T. N., Visser, M. S., & van Raan, A. F. J. (2011). Towards a new crown indicator: Some theoretical considerations. *Journal of Informetrics*, *5*(1), 37–47. https://doi.org/10.1016/j.joi.2010.08.001

In order to address the differences between fields in bibliometric citation-based research evaluations, the authors evaluate two indicators: the CWTS "crown indicator" and the MNCS indicator. Both prove advantageous for measuring different aspects of collaboration such as weighting citations more heavily for fields that expect higher citation numbers, and for comparing consistent quality levels (Waltman et al., 2011).

Tags: bibliometric indicator, consistency, crown indicator, normalization, MNCS indicator

Abstract: The crown indicator is a well-known bibliometric indicator of research performance developed by our institute. The indicator aims to normalize citation counts for differences among fields. We critically examine the theoretical basis of the normalization mechanism applied in the crown indicator. We also make a comparison with an alternative normalization mechanism. The alternative mechanism turns out to have more satisfactory properties than the mechanism applied in the crown indicator. In particular, the alternative mechanism has a so-called consistency property. The mechanism applied in the crown indicator lacks this important property. As a consequence of our findings, we are currently moving towards a new crown indicator, which relies on the alternative normalization mechanism.

DOA: 5.18.2020
https://www-sciencedirect-com.er.lib.k-state.edu/science/article/pii/S1751157710000817

VIII. Case Studies

Almeida, P., & Kogut, B. (1999). The localization of knowledge and the mobility of engineers in regional networks. *Management Science*, 905–917.

This case study examines the diminished role of individual researchers, and heightened role of collaborative networks in securing new patents, by analyzing the network characteristics of engineering firms in Silicon Valley. Externalities, such as how corporate markets use knowledge and engineering innovations, are an important part of how scientific knowledge is diffused through regional centers of networked patent producers and inter-firm collaborations (Almeida & Kogut, 1999).

Tags: knowledge networks, knowledge spillovers, networks, regions

Abstract: Knowledge, once generated, spills only imperfectly among firms and nations. We posit that since institutions and labor networks vary by region, there should be regional variations in the localization of spillovers. We investigate the relationship between the mobility of major patent holders and the localization of technological knowledge through the analysis of patent citations of important semiconductor innovations. We find that knowledge localization is specific to only certain regions (particularly Silicon Valley) and that the degree of localization varies across regions. By analyzing data on the interfirm mobility of patent holders, we empirically show that the interfirm mobility of engineers influences the local transfer of knowledge. The flow of knowledge is embedded in regional labor networks.

DOA: 5.18.2020
http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.568.8647&rep=rep1&type=pdf

Aronova, E., Baker, K. S., & Oreskes, N. (2010). Big Science and Big Data in Biology: From the International Geophysical Year through the International Biological Program to the Long Term Ecological Research (LTER) Network, 1957—Present. *Historical Studies in the Natural Sciences*, *40*(2), 183–224. https://doi.org/10.1525/hsns.2010.40.2.183

Focusing on the historical conditions that prompted and mandated the rise of "Big Science" this article explains the origin of the current model used by the LTER networks- aspects that evolved from former attempts, and aspects that allowed it to thrive.

"Big Science became identified with the changes in the organization of scientific research that placed scientific production in line with postwar modernization and economic growth, appropriating the lessons of wartime mobilization of science" (Aronova et al., 2010, p. 184).

This period in the rise of Big Science was exemplified by the Manhattan Project and the National Space Program. Unlike the traditional physics model, the International Geophysical Year (IGY), established in 1957 attempted to harness data-driven research. It ultimately failed, because it lacked targeted theoretical drivers.

The International Biological Program (IBP, 1964–1974) tried to replicate this strategy with standardized methods and widely available datasets. A systems approach to biology, and the imperative brought by a new era in which humans played an outsized role in shaping natural processes and contributing to climate change, re-centered the need for ecology to operate as a big science. The IBP failed to keep pace with this need to center observational data for integrated long-term approaches.

The LTER was based on interdisciplinary teams of ecologists working in various research sites, at universities, and with various partners such as the U.S. Forest Service, Department of Energy, and the Park Service. "Officially started in 1980, LTER was at first part of the NSF ecosystems studies program. Eventually it was assigned its own program officer: James T. Callahan, the same person who had been the program officer for the IBP. So the IBP lived on as the new LTER program in the NSF. The IBP did not so much end as evolve—or perhaps transmute—from the original concept of a biological "year" to its virtual opposite—a program focused explicitly on the long term" (Aronova et al., 2010, p. 219).

Tags: big science, data-driven research, data management, ecology, International Biological Program (IBP), International Geophysical Year (IGY), LTER

Abstract: This paper discusses the historical connections between two large-scale undertakings that became exemplars for worldwide data-driven scientific initiatives after World War II: the International Geophysical Year (1957–1958) and the International Biological Program (1964–1974). The International Biological Program was seen by its planners as a means to promote Big Science in ecology. As the term Big Science gained currency in the 1960s, the Manhattan Project and the national space program became paradigmatic examples, but the International Geophysical Year provided scientists with an alternative model: a synoptic collection of observational data on a global scale. This new, potentially complementary model of Big Science encompassed the field practices of ecologists and suggested a model for the natural historical sciences to achieve the stature and reach of the experimental physical sciences. However, the program encountered difficulties when the institutional structures, research methodologies, and data management implied by the Big Science mode of research collided with the epistemic goals, practices, and assumptions of many ecologists. By 1974, when the program ended, many participants viewed it as a failure. However, this failed program transformed into the Long-Term Ecological Research program. Historical analysis suggests that many of the original incentives of the program (the emphasis on Big Data and the implementation of the organizational structure of Big Science in biological projects) were in fact realized by the program's visionaries and its immediate investigators. While the program failed to follow the exact model of the International Geophysical Year, it ultimately succeeded in providing a renewed legitimacy for synoptic data collection in biology. It also helped to create a new mode of contemporary science of the Long Term Ecological Research (LTER Network), used by ecologists today.

DOA: 6.2.2020
https://online.ucpress.edu/hsns/article/40/2/183/105628/Big-Science-and-Big-Data-in-Biology-From-the

Baatz, R., Sullivan, P., Li, L., Weintraub, S., Loescher, H., Mirtl, M., Groffman, P., Wall, D., Young, M., White, T., Wen, H., Zacharias, S., Kühn, I., Tang, J., Gaillardet, J., Braud, I., Flores, A., Kumar, P., Lin, H., … Looy, K. V. (2018). Steering Operational Synergies in Terrestrial Observation Networks: Opportunity for Advancing Earth System Dynamics Modelling. *Earth System Dynamics*, *9*(2), 593–609. http://dx.doi.org/10.5194/esd-9-593-2018

**image in Appendix- p. 141*

The authors analyze two case studies: the CZO and LTER networks. They explain the unique combination of geoscience and bioscience insight that the two networks contribute to climate change knowledge and suggest ways that they could improve feedback loops between observational data and network design.

First, they address the technological barrier and opportunity in expanding observational efforts across community methods and datasets (including ground-based instrumentation, remote sensing, computational power, and stakeholder participation) so that harmonized data could be available on the web.

Secondly, they highlight the need to better train the next generation of scientists to use the models in research and teaching across disciplines and platforms (Baatz et al., 2018).

A survey of data modeling of Earth Systems Dynamics- the Complex interactions between rock, soil, water, air, and living organisms that regulate the natural habitat, earth's processes, and climate change focuses on interconnections between the LTER and CZO networks. The authors argue that because these two networks span geosciences and biosciences, they are uniquely positioned to improve their modeling efforts through coordinated data sharing, availability of databases on the web, and more effective sharing of ground and unmanned data collection tools. Modeling efforts could potentially feedback to improve observation network design.

The two case studies: the CZO and LTER networks explain the unique combination of geoscience and bioscience insight that two networks contribute to climate change knowledge and suggest ways that they could improve feedback loops between observational data and network design.

Tags: critical zone observatories, ESD analysis, LTER network, monitoring and evaluation, operational synergies, terrestrial observation networks

Abstract: Advancing our understanding of Earth system dynamics (ESD) depends on the development of models and other analytical tools that apply physical, biological, and chemical data. This ambition to increase understanding and develop models of ESD based on site observations was the stimulus for creating the networks of Long-Term Ecological Research (LTER), Critical Zone Observatories (CZOs), and others. We organized a survey, the results of which identified pressing gaps in data availability from these networks, in particular for the future development and evaluation of models that represent ESD processes, and provide insights for improvement in both data collection and model integration.

From this survey overview of data applications in the context of LTER and CZO research, we identified three challenges: (1) widen application of terrestrial observation network data in Earth system modelling, (2) develop integrated Earth system models that incorporate process representation and data of multiple disciplines, and (3) identify complementarity in measured variables and spatial extent, and promoting synergies in the existing observational networks. These challenges lead to perspectives and recommendations for an improved dialogue between the observation networks and the ESD modelling community, including co-location of sites in the existing networks and further formalizing these recommendations among these communities. Developing these synergies will enable cross-site and cross-network comparison and synthesis studies, which will help produce insights around organizing principles, classifications, and general rules of coupling processes with environmental conditions.

DOA: 5.27.2020
https://scholarworks.boisestate.edu/cgi/viewcontent.cgi?article=1412&context=geo_facpubs

Baas, J., Schotten, M., Plume, A., Côté, G., & Karimi, R. (2020). Scopus as a curated, high-quality bibliometric data source for academic research in quantitative science studies. *Quantitative Science Studies*, *1*(1), 377–386. https://doi.org/10.1162/qss_a_00019

An overview of research based on bibliometric data from the Scopus database looks at mobility, social inequalities, algorithms for understanding network structure, funding, and collaboration networks. The authors suggest additional questions about research trajectories, the role of collaboration networks in career paths, evaluative structures, and research policy that can be answered through analysis of this database.

Additionally, an initial evaluation of the 2019 launch of the ICSR (International Center for the Study of Research) is included (Baas et al., 2020).

Tags: database, ICSR, research networks, Scopus

Abstract: Scopus is among the largest curated abstract and citation databases, with a wide global and regional coverage of scientific journals, conference proceedings, and books, while ensuring only the highest quality data are indexed through rigorous content selection and re-evaluation by an independent Content Selection and Advisory Board. Additionally, extensive quality assurance processes continuously monitor and improve all data elements in Scopus. Besides enriched metadata records of scientific articles, Scopus offers comprehensive author and institution profiles, obtained from advanced profiling algorithms and manual curation, ensuring high precision and recall. The trustworthiness of Scopus has led to its use as bibliometric data source for large-scale analyses in research assessments, research landscape studies, science policy evaluations, and university rankings. Scopus data have been offered for free for selected studies by the academic research community, such as through application programming interfaces, which have led to many publications employing Scopus data to investigate topics such as researcher mobility, network visualizations, and spatial bibliometrics. In June 2019, the International Center for the Study of Research was launched, with an advisory board consisting of bibliometricians,

aiming to work with the scientometric research community and offering a virtual laboratory where researchers will be able to utilize Scopus data.

DOA: 6.15.2020
https://www.mitpressjournals.org/doi/full/10.1162/qss_a_00019

Barnard, H., Cowan, R., & Müller, M. (2012). Global excellence at the expense of local diffusion, or a bridge between two worlds? Research in science and technology in the developing world. *Research Policy*, *41*(4), 756–769. https://doi.org/10.1016/j.respol.2011.12.002

The South African National Research Foundation serves as a case study for examining whether local scientific leaders forgo local impact in order to compete in global scientific networks. The authors find that these key individuals play a "gatekeeping" role in establishing local networks, new graduate programs, and institutional research networks for a new generation of local and regional scientists (Barnard et al., 2012).

Tags: collaboration, case study, developing country, research, science and technology

Abstract: Do world-leading researchers from developing countries contribute to upgrading locally, or do they disengage from the local context? The paper investigates the scientific collaborations of university-based science and technology researchers in the database of the South African National Research Foundation (NRF) and analyses the co-authorships of researchers who were ranked by the NRF during the 2001–2007 period. To establish the extent to which a researcher can access knowledge outside the South African academic science and technology research community, and share it inside that community, we develop a measure of 'gatekeeping'. The evidence suggests that there is not a local/global trade-off in knowledge creation in academia in the developing world, and that the world-leading researchers in developing countries may play an especially important role as conduits of new knowledge in their country.

DOA: 5.18.2020
https://www.sciencedirect.com/science/article/abs/pii/S0048733311002241

Brantley, S. L., McDowell, W. H., Dietrich, W. E., White, T. S., Kumar, P., Anderson, S. P., Chorover, J., Lohse, K. A., Bales, R. C., Richter, D. D., Grant, G., & Gaillardet, J. (2017). Designing a network of critical zone observatories to explore the living skin of the terrestrial Earth. *Earth Surface Dynamics*, *5*(4), 841. https://doi.org/10.5194/esurf-5-841-2017

This case study explores the strengths and weaknesses of the network of critical zone observatories (CZO) in the United States. The networked observatories laid the groundwork for a new frontier of science.

Strengths include the development of convergent expertise and an integrated approach to the study of a field that centers global understanding of climate change issues. "The current CZO network as constituted in the United States and abroad has many strengths. Students are trained to cross disciplines within their work, and they graduate with convergent expertise in the new field of CZ science. CZ science harmonizes vocabulary and conceptual understanding across disciplines and sets a research agenda and an integrated approach. Postdoctoral scholars learn from observatory personnel that derive from many disciplines" (Brantley et al., 2017, p. 853).

Weaknesses include first, the need for better data management and better integrity of data in a centralized database. Secondly, the CZO network excluded social science in the beginning, and therefore new hypotheses that highlight human-environment interaction are lacking. Finally, the CZO networks needs a more fair and equitable mechanism for sharing resources. "Since each observatory is individually funded based on the merits of its targeted science, there is competition for allocation of resources to address common measurements versus site-specific activities. This results in a less-than-optimal identification of emergent network-scale outcomes. Of course, individual site-specific outcomes can have implications and impacts that are just as important as network-scale outcomes. Thus, we need to find mechanisms to foster all such approaches while acknowledging limitations in resources."

Future recommendations include redesigning the network around a hub and spoke model of satellite centers, which would allow distributed long-term observatories and focused campaign-style investigations. This direction would help model the interconnectivity of the processes that the centers observe.

"We now recognize the critical zone as an entity composed of co-evolving systems that create the structured dynamic skin of the Earth. We are seeing the first maps of this structure as they emerge and we are discovering how the structure influences water resources and hydrologic processes, vegetation, ecosystems, erosion, biogeochemical processes, and even regional climate. Surface and deep processes are connected" (Brantley et al., 2017, p. 856).

Tags: critical zone, networked observatories, research centers

Abstract: The critical zone (CZ), the dynamic living skin of the Earth, extends from the top of the vegetative canopy through the soil and down to fresh bedrock and the bottom of the groundwater. All humans live in and depend on the CZ. This zone has three co-evolving surfaces: the top of the vegetative canopy, the ground surface, and a deep subsurface below which Earth's materials are unweathered. The network of nine CZ observatories supported by the US National Science Foundation has made advances in three broad areas of CZ research relating to the co-evolving surfaces. First, monitoring has revealed how natural and anthropogenic inputs at the vegetation canopy and ground surface cause subsurface responses in water, regolith structure, minerals, and biotic activity to considerable depths. This response, in turn, impacts aboveground biota and climate. Second, drilling and geophysical imaging now reveal how the deep subsurface of the CZ varies across landscapes, which in turn influences aboveground ecosystems. Third, several new mechanistic models now provide quantitative predictions of the spatial structure of the subsurface of the CZ. Many countries fund critical zone observatories (CZOs) to measure the fluxes of solutes, water, energy, gases, and sediments in the CZ and some relate these observations to the histories of those fluxes recorded in landforms, biota, soils, sediments, and rocks. Each US observatory has succeeded in (i) synthesizing research across disciplines into convergent

approaches; (ii) providing long-term measurements to compare across sites; (iii) testing and developing models; (iv) collecting and measuring baseline data for comparison to catastrophic events; (v) stimulating new process-based hypotheses; (vi) catalyzing development of new techniques and instrumentation; (vii) informing the public about the CZ; (viii) mentoring students and teaching about emerging multidisciplinary CZ science; and (ix) discovering new insights about the CZ. Many of these activities can only be accomplished with observatories. Here we review the CZO enterprise in the United States and identify how such observatories could operate in the future as a network designed to generate critical scientific insights. Specifically, we recognize the need for the network to study network-level questions, expand the environments under investigation, accommodate both hypothesis testing and monitoring, and involve more stakeholders. We propose a driving question for future CZ science and a hubs-and-campaigns model to address that question and target the CZ as one unit. Only with such integrative efforts will we learn to steward the life-sustaining critical zone now and into the future.

DOA: 5.27.2020
https://repository.arizona.edu/handle/10150/626604

Cochrane, L., Cundill, G., Ludi, E., New, M., Nicholls, R. J., Wester, P., Cantin, B., Murali, K. S., Leone, M., Kituyi, E., & Landry, M. (2017). A reflection on collaborative adaptation research in Africa and Asia. *Regional Environmental Change; Dordrecht*, 17(5), 1553–1561. http://dx.doi.org.er.lib.k-state.edu/10.1007/s10113-017-1140-6

"The Sustainable Development Goals of the 2030 Agenda for Sustainable Development recognize the central challenge of adapting to climate change and have therefore integrated targets related to climate adaptation and resilience throughout the goals. It is increasingly apparent, therefore, that supporting people experiencing poverty in their efforts to respond to climate change impacts will be a defining social challenge in the coming decades" (Cochrane et al., 2017, p. 1554).

The authors examine several approaches for regional climate change adaptation research that can support people's livelihoods while networking scientific advances and expertise.

- The "hotspot" approach targets certain geographies where biodiversity loss is pivotal. (UN Environmental Program, Fourth IPCC Assessment Report (2007)
- "Collaboration" approaches build networks of regional research networks, practitioners, policymakers, and stakeholders from the public and private sector (CARIAA)

Emphasis is on "third spaces"- where practitioners know the research process and researchers are continually challenged by practitioners.

Tags: adaptation, climate change, collaborative research, hotspots

Abstract: The reality of global climate change demands novel approaches to science that are reflective of the scales at which changes are likely to occur, and of the new forms of knowledge required to positively influence policy to support vulnerable populations. We examine some of the opportunities and challenges presented by a collaborative, transdisciplinary research project on climate change adaptation in Africa and Asia that utilized a hotspot approach. A large-scale effort to develop appropriate baselines was a key challenge at the outset of the program, as was

the need to develop innovative methodologies to enable researchers to work at appropriate spatial scales. Efforts to match research to the biophysical scales at which change occurs need to be aware of the mismatch that can develop between these regional scales and the governance scales at which decisions are made.

DOA: 4.28.2020
https://search-proquest-com.er.lib.k-state.edu/docview/1902403954?accountid=11789

Coddington, J. A., Barker, K., Droege, G., Astrin, J. J., Bartels, P., Butler, C., Cantrill, D., Forest, F., Gemeinholzer, B., Hobern, D., Mackenzie-Dodds, J., Tuama, É. Ó., Petersen, G., Sanjur, O. I., Schindel, D. E., & Seberg, O. (2014). GGBN: Making Genomic Collections Discoverable for Research through a Networked Community of Biodiversity Repositories. In *DNA Banking for the 21st Century, edited by Applequist, W. A. and Campbell, L. M.*

Banks of high-quality samples and professionally managed data regarding biodiversity genomics hold the potential to influence taxonomy, phylogeny, conservation, ecological monitoring, wildlife management, agriculture, drug development, zoonotic disease forecasting, and many other fields if they are networked well and available to all for collaboration. Projects such as the Ten Thousand Vertebrate Genomes Project and Global Invertebrate Genomics Alliance are working toward this goal individually, while the Global Genome Biodiversity Network (GGBN) seeks to bridge access and workflow between such projects.

"GGBN is an open network of currently 24 biodiversity repositories from across all continents that came together with the aim to endorse biodiversity biobank stewardship, information sharing and ethical use of collections in compliance with national and international conventions and regulations" (Coddington et al., 2014, p. 166).

As a networking organization, their model involves providing samples for research and training, providing free access to a global data portal for primary specimens, developing standards for sharing tissue information, developing best practices for stewardships, developing a standardized process for sample deposition, developing targeted collections, providing a platform for knowledge exchange, and recruiting partners with different regional sets of expertise.

The network is comprised of core members that are institutional biorepositories at the highest level of contribution and standards, associate members who are working toward this status, and observer institutions that collect, contribute, and benefit from repositories but do not curate biorepositories individually.

Tags: genomic collections, GGBN, networked biodiversity repositories

Abstract: Advances in DNA extraction techniques, combined with next generation sequencing technologies, provide new tools for the study of non-human genetics and evolution. However, the accelerating loss of biodiversity and the demand to support and improve conservation efforts in a time of increasing sensibilities worldwide regarding collecting activities, increasing sensitivity regarding national biodiversity patrimony and unsolicited commercialization has increased the

demand for accessible information on non-human genomic collections world- wide. It is increasingly urgent for biodiversity collection-holding institutions to set a standard of collaboration towards excellence in collections stewardship, information access and sharing, and responsible and ethical use of collections. The Global Genome Biodiversity Network (GGBN) seeks to meet this need by making genomic col- lections discoverable for research through a networked community of biorepositories and providing trusted and transparent access to genomic samples for users and contributors through an access and benefit sharing framework.

DOA: 5.12.2020
https://repository.si.edu/handle/10088/30885

Cundill, G., Harvey, B., Tebboth, M., Cochrane, L., Currie-Alder, B., Vincent, K., Lawn, J., Nicholls, R. J., Scodanibbio, L., Prakash, A., New, M., Wester, P., Leone, M., Morchain, D., Ludi, E., DeMaria-Kinney, J., Khan, A., & Landry, M.-E. (2019). Large-Scale Transdisciplinary Collaboration for Adaptation Research: Challenges and Insights. *Global Challenges*, *3*(4), 1700132. https://doi.org/10.1002/gch2.201700132

Four consortia, representing 450 researchers in 17 countries are examined as an example of a large-scale, longitudinal (7 year) set of partnerships focusing on climate change adaptation. The Collaborative Adaptation Research Initiative in Africa and Asia (CARIAA) provides insight into the key elements of successful collaboration. Other examples include: Future Climate for Africa, and Ecosystem Services for Poverty Alleviation.

Climate change research represents one of the most urgent areas for collaboration as the scale and complexity are truly global and the stakes for finding solutions are profoundly high.

"The CARIAA experience suggests that it is critical to pay attention to three key dimensions of transdisciplinary collaboration in large-scale research programs. These are design, or how programs are structured to support collaboration and impact; relational features, or how interpersonal and interinstitutional dynamics evolve and are mediated; and systemic features, which refer to pre-existing norms and biases that affect how the other two dimensions take shape. Our experience also highlights the importance of built-in flexibility in the availability of funds to enable emergent collaboration beyond initial expectations" (Cundill et al., 2019, p. 1).

Design: The design were each unique- based on pre-existing partnerships, so that results and conclusions could inform learning frameworks: "The aim was to create collaborative spaces embedded in ongoing mutual learning processes" (Cundill et al., 2019, Figure 1, p. 2). Common ground could consist of regional similarities or proximity, discipline, or standardized methods.

Relational features: These included trust, respect, and effective leadership.

Systemic features: These included legal agreements, power asymmetries (inter-disciplinary, and inter-state), institutional values and cultures.

Built-in flexibility: Shared funding and resources that could be re-allocated as new avenues emerged provided a key foundation for flexibility.

Example: A new migration question emerged for two groups of researchers. Using the momentum and familiarity of a research team that worked well together, knew each other's strengths and weaknesses, and communicated well enough to identify the same problem as a tangent to previous findings, they were able to utilize flexible funding, under the guidance of a "champion" to pursue further questions.

Tags: climate change, collaboration, team science, transdisciplinary research

Abstract: An increasing number of research programs seek to support adaptation to climate change through the engagement of large-scale transdisciplinary networks that span countries and continents. While transdisciplinary research processes have been a topic of reflection, practice, and refinement for some time, these trends now mean that the global change research community needs to reflect and learn how to pursue collaborative research on a large scale. This paper shares insights from a seven-year climate change adaptation research program that supports collaboration between more than 450 researchers and practitioners across four consortia and 17 countries. The experience confirms the importance of attention to careful design for transdisciplinary collaboration, but also highlights that this alone is not enough. The success of well-designed transdisciplinary research processes is also strongly influenced by relational and systemic features of collaborative relationships. Relational features include interpersonal trust, mutual respect, and leadership styles, while systemic features include legal partnership agreements, power asymmetries between partners, and institutional values and cultures. In the new arena of large-scale collaborative science efforts, enablers of transdisciplinary collaboration include dedicated project coordinators, leaders at multiple levels, and the availability of small amounts of flexible funds to enable nimble responses to opportunities and unexpected collaborations.

DOA: 4.3.2020
https://doi.org/10.1002/gch2.201700132

Currie-Alder, B., Arvanitis, R., & Hanafi, S. (2018). Research in Arabic-speaking countries: Funding competitions, international collaboration, and career incentives. *Science and Public Policy*, 45(1), 74–82. https://doi.org/10.1093/scipol/scx048

Examining six Arabic-speaking countries that created or expanded public research funds (Morocco, Tunisia, Egypt, Lebanon, Jordan, and Qatar), this study reveals how the design of funding opportunities shape the national research system. While all connections to outside sources of funding and outside scientific networks aimed to reach sustainable development goals, funders were generally prescriptive in their demands. Local scientific networks benefited through proximity to status, but they lost sovereignty over structure and scalability (Currie-Alder et al., 2018).

Tags: external funding, research collaboration, research networks

Abstract: Morocco, Tunisia, Egypt, Lebanon, Jordan, and Qatar expanded research funds over the past two decades. The use of competitive calls required researchers to prepare and submit proposals for team-based projects or time-limited research units. Identification of national priorities and societal challenges sought to rally research toward real-world problems, while larger grants encouraged a wider range of research activities and greater levels of ambition. Yet, the incentives within hiring organizations still determine how researchers allocate their time and effort, including whether they even seek external funding or collaboration. Selection and evaluation criteria privileged collaboration with distant, scientifically proficient partners abroad, in order to connect with global networks and rise in international rankings of academic quality. Moving forward, countries need to consider how funding opportunities shape the size and organization of distinct research efforts, and which arrangements are best suited to making meaningful progress on different problems of societal and scientific interest.

DOA: 4.29.2020
https://academic.oup.com/spp/article/45/1/74/4107903

EFSA (European Food Safety Authority). (2015). *Annual report of the Scientific Network on Microbiological Risk Assessment 2015* (No. 2015:EN-914; EFSA Supporting Publication, p. 14).

Purpose: To implement European Food Safety Authority regulations through scientific coordination. This report focuses on filling data gaps and setting priorities for data collections, including: (i) the exchange of scientific data and information, (ii) sharing of risk assessment practices, (iii) harmonization of risk assessment methodologies, and (iv) cooperation and coherence in communication. Scientific Network on Microbiological Risk Assessment (MRA) is the network arm of the EFSA (EFSA (European Food Safety Authority), 2015).

Tags: communication exchange, data exchange, data gaps, risk assessment

DOA: 4.3.2020
https://doi.org/10.2903/sp.efsa.2015.EN-914

Franco, M., & Pinho, C. (2019). A case study about cooperation between University Research Centres: Knowledge transfer perspective. *Journal of Innovation & Knowledge*, *4*(1), 62–69. https://doi.org/10.1016/j.jik.2018.03.003

The SiNGULAR project (Smart and Sustainable Insular Electricity Grids Under Large-Scale Renewable Integration) provides a case study of cooperation between research centers which already contain collaboration within themselves.

Dimensions of knowledge transfer, choice of partners, institutional culture, and financial incentives were all considered in an analysis of the benefits and obstacles to cooperation. A key finding is that, despite the potential for communication barriers, cultural diversity was an asset to research centre partnerships in terms of the incentives it garners and the innovation it inspires.

"In the case of UBI it was possible to have numerous researchers from different countries. Namely, Spain, Ethiopia, Greece, Moldova, Turkey, Venezuela, and of course, Portugal. The cultural exchange was a bonus, since it was possible to create new bonds, expand our horizons of knowledge, in both the academic and industrial world, and it was also possible to show a bit of our country to the researchers of other nationalities" (Franco & Pinho, 2019, p. E1).

Tags: cooperation, culture, financing, knowledge transfer, partnerships, SiNGULAIR project, University Research Centres

Abstract: The aim of this study is to provide a wide-ranging view of the benefits and obstacles of cooperation between University Research Centres. To do so, the four dimensions associated with knowledge transfer, choice of partners, culture and financing were considered. A qualitative approach was adopted, and within this the case study method: The SiNGULAR project. Data were obtained from various in-depth interviews, documentary analysis and the official site of the project. Based on the results obtained, it is concluded that knowledge transfer, choice of partners and finance stimulate this type of cooperation, and that cultural differences between researchers and research centres are a bonus for this cooperation. Several implications for theory and practice are also presented.

DOA: 5.26.2020
https://www.sciencedirect.com/science/article/pii/S2444569X18300313

Franzoni, C., & Sauermann, H. (2014). Crowd science: The organization of scientific research in open collaborative projects. *Research Policy*, 43(1), 1–20. https://doi.org/10.1016/j.respol.2013.07.005

**image in Appendix- p. 157*

Also known as citizen science, networked science, or massively collaborative science, crowd science builds upon existing knowledge of system science. It is characterized by two features: (1) participation is wide and open to a wide base of potential contributors, and (2) inputs such as data and problem solving tools and algorithms are free and openly available.

Case Study Example: Foldit- a computer game designed to mimic an algorithm for permutations of protein shapes. Players lend computational space on their computers and configuration ideas as The Baker lab at the University of Washington (funded by the Howard Hughes Medical Institute) use players data to strengthen the tools they use for modeling.

Key features of crowdsourced science: "openness in project participation and openness with respect to the disclosure of intermediate inputs such as data or problem-solving approaches" (Franzoni & Sauermann, 2014, p. 7).

Tags: case study, crowd science, networked science, open collaboration

Abstract: A growing amount of scientific research is done in an open collaborative fashion, in projects sometimes referred to as “crowd science”, “citizen science”, or “networked science”.

This paper seeks to gain a more systematic understanding of crowd science and to provide scholars with a conceptual framework and an agenda for future research. First, we briefly present three case examples that span different fields of science and illustrate the heterogeneity concerning what crowd science projects do and how they are organized. Second, we identify two fundamental elements that characterize crowd science projects – open participation and open sharing of intermediate inputs – and distinguish crowd science from other knowledge production regimes such as innovation contests or traditional "Mertonian" science. Third, we explore potential knowledge-related and motivational benefits that crowd science offers over alternative organizational modes, and potential challenges it is likely to face. Drawing on prior research on the organization of problem solving, we also consider for what kinds of tasks particular benefits or challenges are likely to be most pronounced. We conclude by outlining an agenda for future research and by discussing implications for funding agencies and policy makers.

DOA 4.23.2020
https://www-sciencedirect-com.er.lib.k-state.edu/journal/research-policy/vol/43/issue/1

Fu, B., Li, S., Yu, X., Yang, P., Yu, G., Feng, R., & Zhuang, X. (2010). Chinese ecosystem research network: Progress and perspectives. *Ecological Complexity*, *7*(2), 225–233. https://doi.org/10.1016/j.ecocom.2010.02.007

The Chinese Ecosystem Research Network (CERN) exemplified the way that site-specific research works best when networked with other ecosystems measuring similar aspects of desertification, erosion, evapotranspiration, etc. These networked sites have been a part of the ILTER network since 1993.

"The CERN sites cover almost all typical ecosystems in China: cropland, forest, grassland, desert, marshes, lakes, bays and urban ecosystem, etc. Its unique features are the emphasis on understanding long-term patterns and processes of ecological systems, combination of the cross-site or comparison research and the voluntary site-based exploration, and data sharing both with domestic institutions and international networks at different levels" (Fu et al., 2010, p. 230).

Tags: Chinese ecosystem, long-term ecological research, planning, progress

Abstract: As a national innovative scientific and technological facility that integrates monitoring, research and demonstrations, the Chinese Ecosystem Research Network (CERN) has become one of the largest networks in the world that consists of 40 field stations, 5 sub-centers and 1 synthesis center, covering almost all typical ecosystems in China: cropland, forest, grassland, desert, marshes, lakes, bays and urban ecosystem. Its unique features are the emphasis on understanding long-term structure and function, patterns and processes of ecosystems, combination of the inter-site comprehensive research or cross-site comparison research and the voluntary site-based exploration, and the data sharing both for domestic institutions and international networks at different levels. This paper provides a brief review of CERN by introducing its developing history, objectives and missions, summarizing its progress with the long-term ecological research in China including monitoring, scientific accomplishments in carbon cycle, ecosystem structure and functions, ecosystem restoration and data management. The paper also describes CERN's strategic plan to 2020 and its development perspectives in the future with focus on six core thematic areas.

DOA: 6.2.2020
https://www.sciencedirect.com/science/article/abs/pii/S1476945X10000097

Gaillardet, J., Braud, I., Hankard, F., Anquetin, S., Bour, O., Dorfliger, N., Dreuzy, J. R. de, Galle, S., Galy, C., Gogo, S., Gourcy, L., Habets, F., Laggoun, F., Longuevergne, L., Borgne, T. L., Naaim-Bouvet, F., Nord, G., Simonneaux, V., Six, D., … Zitouna, R. (2018). OZCAR: The French Network of Critical Zone Observatories.

Focused on the Anthropocene (the current period of time, where human activities suddenly exert a substantial geological force), the French observatories of the critical zone work toward a single goal of monitoring, understanding, and predicting the dynamics of water and matter in the Earth's near surface, and of predicting how they will change in response to the "new climatic regime". This work is done disparately by diverse research groups, with diverse methodologies, in diverse disciplines, and across disciplines.

However, the OZCAR infrastructure allows networking and building open infrastructure within France and in the international CZ community towards common research questions, better quality shared instruments, and more accurate data to support time and spatial models.

This network example flows out of the U.S. Critical Zone Exploration Network initiative proposed by the National Science Foundation in 2003. OZCAR was launched in 2015, supported by the French Ministry of Higher Education, Research, and Innovation. It organized 21 pre-existing observatories, some of which had been gathering data for site-specific research questions for 40 years.

"All these observatories share the same characteristic of being highly instrumented areas, however, designed to address a particular scientific and societal question of local importance, generating continuous standardized series of observations on water quality, discharge, ice and snow, soil erosion, piezometric levels, soil moisture, gas and energy exchange between ground and atmosphere, and ecosystem parameters (Supplemental Table S1). They cover different compartments of the CZ " (Gaillardet et al., 2018, p. 2).

These observatories were then linked according to seven thematic networks, making it a true network of networks. Each contains its own affiliation to networks in other geographical areas and ecosystem constellations that align with their research questions and cooperate in the education of future network members.

1. The Réseau des Bassins Versants network (RBV) comprises catchments ranging from zero-order basins to the whole Amazon River system.

2. The H+ observation service (hplus.ore.fr), created in 2002, is a network of hydrogeological sites located in France and India, aimed at characterizing and modeling flows, transport and reactivity in heterogeneous aquifers.

3. The CRYOBS-CLIM (The Cryopshere: a Climate Observatory) Observatory focuses on the cryosphere.

4. The Tourbières (Peatland) Observatory is a network of four French instrumented sites and one Siberian mire aimed at studying the effect of global change on the C sink function and the hydrological budget of temperate and sub boreal peatlands, which are ecosystems containing a third of the global surface C stock in an area accounting for only 3 to 5% of the land surface.

5. The Regional Spatial Observatory (OSR) is documenting the long-term effects of climate change and increasing anthropogenic pressures on the hydrologic and agro-ecologic evolution of agricultural regions, at various spatial and temporal scales, in a perspective for sustainable management of water and soil resources.

6. The ROSES (observatory network for groundwater systems at the French national level) was initially set up to answer water management issues and was strengthened in the framework of the implementation of the European Water Directive.

7. The Long-lasting Observatory of the Environment (OPE) focuses on a landscape in the eastern part of the Paris Basin (a few hundred square kilometers) around the preselected site as the French deep geological repository of high-level and intermediate-level long-lived radioactive wastes (Gaillardet et al., 2018, p. 6).

Tags: critical zone observatories, network of networks

Abstract: Core Ideas OZCAR is a network of sites studying the critical zone. OZCAR covers various disciplines. OZCAR will help disciplines to work together for a better representation and modeling of the critical zone. The French critical zone initiative, called OZCAR (Observatoires de la Zone Critique–Application et Recherche or Critical Zone Observatories–Application and Research) is a National Research Infrastructure (RI). OZCAR-RI is a network of instrumented sites, bringing together 21 pre-existing research observatories monitoring different compartments of the zone situated between “the rock and the sky,” the Earth's skin or critical zone (CZ), over the long term. These observatories are regionally based and have specific initial scientific questions, monitoring strategies, databases, and modeling activities. The diversity of OZCAR-RI observatories and sites is well representative of the heterogeneity of the CZ and of the scientific communities studying it. Despite this diversity, all OZCAR-RI sites share a main overarching mandate, which is to monitor, understand, and predict (“earthcast”) the fluxes of water and matter of the Earth's near surface and how they will change in response to the “new climatic regime.” The vision for OZCAR strategic development aims at designing an open infrastructure, building a national CZ community able to share a systemic representation of the CZ, and educating a new generation of scientists more apt to tackle the wicked problem of the Anthropocene. OZCAR articulates around: (i) a set of common scientific questions and cross-cutting scientific activities using the wealth of OZCAR-RI observatories, (ii) an ambitious instrumental development program, and (iii) a better interaction between data and models to integrate the different time and spatial scales. Internationally, OZCAR-RI aims at strengthening the CZ community by providing a model of organization for pre-existing observatories and by offering CZ instrumented sites.

OZCAR is one of two French mirrors of the European Strategy Forum on Research Infrastructure (eLTER-ESFRI) project.

DOA: 6.1.2020
https://acsess.onlinelibrary.wiley.com/doi/full/10.2136/vzj2018.04.0067

Global Land Programme. (2020). ***The Evolution of the Global Land Program*****.**
https://glp.earth/who-we-are/our-history

The Global Land Programme was co-founded by the Swiss Academies and the Swiss National Science Foundation. It is an interdisciplinary community of science and practice fostering the study of land systems and the co-design of solutions for global sustainability. It developed from loosely connected research projects in monitoring and modelling the ecological impacts of land cover changes to a large-scale network that uses remote sensing and global datasets to achieve a synthesis in case studies and identify driving factors and patterns of climate change on land use patterns.

The LUCC project and Global Change and Terrestrial Ecosystems projects are too such terrestrial research coordinated efforts that are linked in IGBP research.

The network to network connections are coordinated by a program office in Switzerland hosted by the Centre for Development and Environment of the University of Bern, Switzerland. These projects are facilitated by a steering committee of scientists that represent institutions in Switzerland, the USA, Canada, China, Argentina, Belgium, Australia, India, Spain, Germany, Ethiopia, and the UK.

Each nodal office seeks additional funding and forms the context and structure for the training of new scientists in the GLP fellows program. GLP is a global research project of Futurereach research for global sustainability and is funded by both the University of Bern Center for Development and Environment and the Swiss Agency for Development and Cooperation (Global Land Programme, 2020).

Tags: interdisciplinary science, global sustainability, land use, climate change

Abstract: Land system science has developed over the past twenty years. The study of land use and land cover change [coordinated through the former Land Use Cover Change (LUCC) project] was initially dominated by monitoring and modelling of the ecological impacts of major land cover changes such as deforestation and desertification on the natural system (Turner II et al., 1993; Lambin et al., 2000; Lambin and Geist, 2006). Achievements were made in terms of observing land cover changes by remote sensing for single case studies as well as in global datasets (Walsh and Crews-Meyer, 2002). As part of LUCC activities, Belward (1996) developed definitions of land cover classes. The legend employed was developed to meet the needs of IGBP projects, providing for a consistent and objective representation of significant landforms for all projects. One of the main achievements of the early LUCC work was the synthesis of case studies to identify common driving factors of change and causation patterns (Geist and Lambin, 2002,

2004). At the same time, land use models were developed that allowed the exploration of future scenarios of land use change (Verburg et al., 1999; Pontius et al., 2001).

Besides the LUCC project the Global Change and Terrestrial Ecosystems (GCTE) project contributed by the research on terrestrial ecosystem changes under local, regional and global environmental changes such as increasing concentrations of greenhouse gases, changes in global and regional climate, habitat destruction, and increases in number and impacts of exotic invasive species (Pitelka et al., 2007). The overarching goal of the GCTE project was to predict the effect of changes in climate, atmospheric composition, and land use on terrestrial ecosystem and to determine how these effects lead to feedback to the atmosphere and physical climate system. GCTE took the lead in analyzing the nature of nonlinear change in Earth System functioning. This work played a central role in the emergence of abrupt change, surprises and extreme events as unifying themes in the second phase of IGBP research.

Gradually, the research field of land use and land cover change matured and became more integrative, focusing on both the drivers and impacts of land change and including a wider range of interacting processes of land use change. The growing group of researchers engaged in this field led to the emergence of 'Land Change Science' as a separate, interdisciplinary, research field engaging scientists across the social, economic, geographical and natural sciences (Rindfuss et al., 2004; Turner et al., 2007). The increasing attention to feedbacks between drivers and impacts including adaptive behavior (Verburg, 2006), the interactions between social and ecological systems and teleconnections between world regions (Lambin and Meyfroidt, 2011; Liu et al., 2013) and between cities and their rural hinterlands (Seto et al., 2012b) have motivated an integrated socio-ecological systems perspective. In this integrated concept, land systems are conceptualized as the result of dynamic interactions within the socio-ecological system. This perspective has also moved land system science from a focus on the most dramatic land cover changes to greater attention for subtle changes of human interactions with the natural surroundings, including land management (Erb et al., 2013; Kuemmerle et al., 2013) and the provisioning of a wide range of ecosystem services (Crossman et al., 2013).

Over the past decade the Land System Science community has been organized through the Global Land Project, now renamed into the Global Land Programme (GLP). The orientation of land system science at the interface of social, physical and ecological systems was reflected in GLP being a core project of both the International Geosphere Biosphere Programme (IGBP) and the International Human Dimensions Programme on Global Environmental Change (IHDP) commissioned by the International Council for Science (ICSU) and the International Social Science Council (ISSC). The Global Land Project started in 2006 for a 10-year period after publishing its science plan in 2005 (GLP, 2005). GLP is a successor of the previous Land Use and Land Cover Change project (LUCC; 1994-2005) and the Global Change and Terrestrial Ecosystems project (GCTE; 1992-2003). GLP aims at synthesis and integration of insights, knowledge and methodologies in research across the land system science community. A core task of GLP is the identification of scientific priorities and agenda setting through synthesis of existing knowledge, meta-analysis of land-based research and targeted workshops. In addition, GLP provides a platform for the land system science community through networking activities, such as the organization of workshops and conferences.

In the final years of first phase of GLP several synthesis activities have been conducted to summarize the state-of-the-art of scientific achievements of GLP and define science priorities for the research community. A survey amongst the participants of the GLP Open Science Meeting in 2014 and an internal evaluation process by the GLP Scientific Steering Committee have identified the future needs for coordination of the GLP community and its priorities.

A major conclusion of this evaluation is that Land System Science is more important than ever: many of the important global change challenges are related to the use of land resources and many of the Societal Grand Challenges are related to the sustainable use of land. Increasingly, research is being done on land systems from different disciplinary perspectives as well as from an interdisciplinary perspective. Land system science is evolving as a discipline with strong connections between scientific understanding and the communities of practice and policy that govern and manage the use of land. In this context the scientific and practice communities still require synthesis and agenda setting activities, as well as a platform for exchange, collaboration and innovation.

To fulfill this role, GLP now operates more as a Programme or Network rather than as a traditional research project, bounded to specific research questions and hypotheses to be answered in the middle term. Hence, this current second phase of GLP uses 'the Global Land Programme' as its full name to reflects its networking, synthesis, and agenda-setting functions.

DOA: 7.6.2020
www.glp.earth

Harvey, B., Cochrane, L., & Epp, M. V. (2019). Charting knowledge co-production pathways in climate and development. *Environmental Policy and Governance*, 29(2), 107–117. https://doi.org/10.1002/eet.1834

This paper reviews the literature related to six self-identified "success stories" of knowledge co-production in international collaborations related to climate change research.

Cases: CKB Manifesto, RCCC Writeships, CDKN Exchange, FSN Dialogue, CCSL Sandbox, IPC Potato Park

Defining Features: These case studies were identified for their similarities in funding and time-bound programming.

Legitimacy and innovation were presented in the case studies in opposition to one another. The cases that were more bounded in their co-production activities were perceived as more successful and translated into policy outcomes.

Knowledge production processes were characterized into two broad categories: "brokered"- in which engagement with stakeholders is mediated and disciplinary boundaries are maintained, and "agora"- in which interactions disrupt these traditional bounds and new perspectives emerge (Harvey et al., 2019).

Tags: climate change, knowledge co-production, program design

Abstract: Climate change poses significant global challenges. Solutions require new ways of working, thinking, and acting. Knowledge co-production is often cited as one of the innovations needed for navigating the complexity of climate change challenges, yet how to best approach co-production processes remains unclear. In this article, we explore the ways in which climate and development researchers are approaching the co-production of knowledge and grapple with the extent to which the modalities used are reaching their stated potential. Using a multiple case analysis of six examples of successful co-production, we outline a spectrum of co-production approaches and outcomes and examine the drivers and challenges to co-production in practice. Drawing on the case evidence and literature, we propose a heuristic that maps out this spectrum of aims and approaches to co-production and that could inform reflections on how those planning co-production processes envision them in practice.

DOA: 4.28.2020
https://onlinelibrary-wiley-com.er.lib.k-state.edu/doi/full/10.1002/eet.1834

Kahn, R. (1994). Interdisciplinary Collaborations Are A Scientific And Social Imperative. *The Scientist Magazine*. https://www.the-scientist.com/opinion-old/interdisciplinary-collaborations-are-a-scientific-and-social-imperative-59085

Kahn examines the rise of scientific networks established by the MacArthur foundation and dismantles the idea of science as individual while arguing for the imperative of multi-disciplinary, sustained collaboration for science to progress. He outlines four stages of network development: listening across the gulf, conceptual translation, the onset of collaboration, and joint projects (Kahn, 1994).

Tags: collaborative science

Abstract: We are well past the point at which the knowledge required to enhance the health and well-being of individuals and communities can come solely from lone investigators trying to unlock nature's secrets, or from the offerings of any single discipline. The myth of the solitary scientist in search of truth is a romantic notion whose continued existence serves as a major barrier to progress in bringing the collective weight of the sciences to bear on the problems of humankind. And the idea that all scientific progress takes place within the boundaries of current disciplines is historically invalid and currently counterproductive.

DOA: 5.12.2020
https://www.the-scientist.com/opinion-old/interdisciplinary-collaborations-are-a-scientific-and-social-imperative-59085

Lendemer, J., Thiers, B., Monfils, A. K., Zaspel, J., Ellwood, E. R., Bentley, A., LeVan, K., Bates, J., Jennings, D., Contreras, D., Lagomarsino, L., Mabee, P., Ford, L. S., Guralnick, R., Gropp, R. E., Revelez, M., Cobb, N., Seltmann, K., & Aime, M. C. (2020). The Extended Specimen Network: A Strategy to Enhance US Biodiversity

Collections, Promote Research and Education. *BioScience*, *70*(1), 23–30. https://doi.org/10.1093/biosci/biz140

"Science, industry, and society rely on physical specimens housed in US biodiversity collections (e.g., Bradley et al. 2014, Tewksbury et al. 2014, Trejo- Salazar et al. 2016, DuBay and Fuldner 2017). Ongoing advances in data generation and analysis have transformed biodiversity collections from physical specimens to dynamic suites of interconnected resources enriched through study over time (Page et al. 2015, Soltis 2017, Nelson and Ellis 2018). The concept of an extended specimen (Webster 2017) conveys the current perspective of the biodiversity specimen as extending beyond the singular physical object to potentially limitless additional physical preparations and digital resources (figure 1; Schindel and Cook 2018)" (Lendemer et al., 2020, p. 24).

An extended specimen network combines object-based learning with a digital gateway into infinite cross-referenced materials. The goals of an extended specimen network are to:

- promote discovery
- enable data integration, attribution, and use tracking
- sustain the extended specimen network
- index biodiversity holdings
- improve digitized data
- build and strengthen strategic partnerships
- identity and fill gaps in biodiversity data
- build links with data aggregators
- facilitate data integration across international biodiversity organizations
- advance the NSFs 10 big ideas, especially:
    - understanding the rules of life;
    - harnessing data for science and engineering;
    - develop a space for midscale infrastructure;
    - navigating the new arctic;
    - growing convergent research;
    - human technology frontier; and
    - enhancing diversity.

DOA: 5.12.2020
https://academic-oup-com.er.lib.k-state.edu/bioscience/article/70/1/23/5637849

Leung, R. C. (2013). Networks as sponges: International collaboration for developing nanomedicine in China. *Research Policy*, *42*(1), 211–219. https://doi.org/10.1016/j.respol.2012.05.001

A case study of networked Chinese scientists and engineers developing nanotechnology for medical use highlights the barriers to international collaborative networks. A sponge metaphor explains a benefit, where Chinese scientists access a "learning by doing" community. A pipe metaphor explains a barrier to networks, where Chinese infrastructure for information sharing, and a traditional research orientation resembling a "closed door" policy make it difficult for them to compete. A clogged pipe occurs when the quantity of publications reaches a saturation point, making quality publications difficult to highlight and overwhelming incoming researchers. Finally, networks work as prisms, where researchers reflect and benefit from the reputation of others, but if that reputation is not fully known, it can create trust issues (Leung, 2013).

Tags: China, collaboration, emerging technology, networks

Abstract: Previous research tended to emphasize the benefits of international collaboration. This emphasis has led to a common belief that international collaboration will necessarily enhance productivity in science, innovativeness, and even societal impact. Yet, benefits and costs are relative. Economic actors and scientists do not perceive benefits in the same way in all contexts, and there are situational barriers to overcome for materializing the benefits of collaboration. This study examines the case of Chinese science actors who develop medical applications with nanotechnology and highlights the "barriers to networks" when scientists attempt to collaborate overseas for an emerging technology. I present my findings with the metaphors of "pipes", "prisms", and "sponges", and propose a framework for evaluating the utility of international collaborative networks.

DOA: 5.20.2020
https://www.sciencedirect.com/science/article/abs/pii/S0048733312001382

Li, Y., Li, H., Liu, N., & Liu, X. (2018). Important institutions of interinstitutional scientific collaboration networks in materials science. *Scientometrics*, 117(1), 85–103. https://doi.org/10.1007/s11192-018-2837-0

The Chinese Academy of Science and MIT operate with similar intermediary roles in their collaboration networks. The Chinese Academy of Science mediates between domestic institutions and foreign institutions with high betweenness centrality and a low clustering coefficient, while MIT collaborates with similar networks that mirror their own collaboration types and growth rates. These case studies explain network characteristic preferences for high-performing networks, and the policy institutions that rely on them (Li et al., 2018).

Tags: intermediary roles, network preferences, network characteristics

Abstract: Interinstitutional scientific collaboration plays an important role in knowledge production and scientific development. Together with the increasing scale of scientific collaboration, a few institutions that positively participate in interinstitutional scientific collaboration are important in collaboration networks. However, whether becoming an important institution in collaboration networks could be a contributing factor to research success and how these important institutions collaborate are still indistinct. In this paper, we identified the scientific institutions that possess the highest degree centrality as important institutions of an interinstitutional scientific collaboration network in materials science and examined their collaboration preferences utilizing several network measures. We first visualized the appearance of these important institutions that had the most positive collaborations in the interinstitutional scientific collaboration networks during the period of 2005–2015 and found an obvious scale-free feature in interinstitutional scientific collaboration networks. Then, we measured the advantages of being important in collaboration networks to research performance and found that positive

interinstitutional collaborations can always bring both publication advantages and citation advantages. Finally, we identified two collaboration preferences of these important institutions in collaboration networks—one type of important institution represented by the Chinese Academy of Science plays an intermediary role between domestic institutions and foreign institutions with high betweenness centrality and a low clustering coefficient. This type of important institution has better performance in the number of publications. The other type of important institution represented by MIT tends to collaborate with similar institutions that have positive collaborations and possess a larger citation growth rate. Our finding can provide a better understanding of important institutions' collaboration preferences and have significant reference for government policy and institutional collaboration strategies.

DOA: 4. 29.2020
https://link-springer-com.er.lib.k-state.edu/article/10.1007/s11192-018-2837-0

Marino, A. H., Suda-Blake, K. A., & Fulton, K. R. (2019). Innovative Collaboration Formation: The National Academies Keck Futures Initiative. In K. L. Hall, A. L. Vogel, & R. T. Croyle (Eds.), *Strategies for Team Science Success: Handbook of Evidence-Based Principles for Cross-Disciplinary Science and Practical Lessons Learned from Health Researchers* (pp. 241–250). Springer International Publishing. https://doi.org/10.1007/978-3-030-20992-6_18

[See Notes in "Team Science"]

Moock, J. L. (2016). *Network Innovations: Building the Next Generation of Agricultural Scientists in Africa* (Chapter 10; 0 ed., Agricultural Research in Africa: Investing in Future Harvests). International Food Policy Research Institute. https://doi.org/10.2499/9780896292123

[See notes in "Motivations"]

National Institute of Food and Agriculture. (2016). *AFRI Annual Review: Agriculture and Food Research Initiative (AFRI) | National Institute of Food and Agriculture*. National Institute of Food and Agriculture. https://nifa.usda.gov/program/agriculture-and-food-research-initiative-afri

"The Agriculture and Food Research Initiative (AFRI) is the nation's leading competitive grants program for agricultural sciences. The National Institute of Food and Agriculture (NIFA) awards AFRI research, education, and extension grants to improve rural economies, increase food production, stimulate the bioeconomy, mitigate impacts of climate variability, address water availability issues, ensure food safety and security, enhance human nutrition, and train the next generation of the agricultural workforce" (National Institute of Food and Agriculture, 2016).

NIFA provides AFRI grants to support research, education and extension activities in six Farm Bill priority areas:

- Plant Health and Production and Plant Products;
- Animal Health and Production and Animal Products;

- Food Safety, Nutrition, and Health;
- Bioenergy, Natural resources, and Environment;
- Agriculture Systems and Technology;
- and Agriculture Economics and Rural Communities.

AFRI-funded science is vital to meeting food, fiber, and fuel demands as the world's population races toward a projected 9 billion by 2050 concomitant with diminishing land and water resources and increasingly variable climatic conditions. In addition, AFRI programs help develop new technologies and a workforce that will advance our national security, our energy self-sufficiency, and the health of Americans.

NIFA's AFRI funding portfolio includes both single- and multi-function research, education, and extension grants that address key problems of national, regional, and multi-state importance. AFRI-funded projects sustain all components of agriculture, including farm efficiency and profitability, ranching, renewable energy, forestry (both urban and agroforestry), aquaculture, rural communities and entrepreneurship, human nutrition, food safety, biotechnology, and conventional breeding. These projects also create jobs and help develop the next generation of agriculture and food scientists.

The AFRI portfolio includes Coordinated Agricultural Projects (CAP) and Food and Agricultural Science Enhancement (FASE) grants. CAP grants are large, multi-million-dollar projects that often involve multiple institutions. FASE grants help institutions become more competitive and attract new scientists and educators to careers in high-priority areas of agriculture.

Examples of NIFA programs include the (1) "Dual Purpose with Dual Benefit Project: Research in Biomedicine and Agriculture using Agriculturally Important Domestic Animal Species" which partners with the NIH; (2) The "National Robotics Initiative" which partners with the NSF, DOE, DOD, and National Aeronautics and Space Agency; and (3) "Ecology and Evolution of Infectious Diseases" which partners with the NSF, NIH, U.K. BBSRC, and the U.S.- Israel Binational Science Foundation

The impacts of NIFA grants are documented in continuously updated articles on their webpage. These impacts generally focus on the effect of researcher-stakeholder collaborations in producing social and environmental change. For example, one study at Michigan State University examines how monarch butterflies interact with milkweed and monarch predators and suggests strategically timed milkweed trimming to maximize monarch reproduction and minimize predation (National Institute of Food and Agriculture, 2016).

Tags: AFRI, grant funding, scientific collaboration, science communities, food security, water, bioenergy, climate change

Abstract: Established by the 2008 Farm Bill and re-authorized in the 2018 Farm Bill, the Agriculture and Food Research Initiative (AFRI) is the nation's leading competitive grants program for agriculture. It is the flagship funding program the National Institute of Food and Agriculture (NIFA) uses to combat major agriculture-related societal challenges through research,

education, and extension. AFRI is one of NIFA's major programs through which to address the six Farm Bill priority areas.

AFRI, with its broad funding portfolio, addresses every facet of agriculture, including food production, farming and ranching, renewable energy, aquaculture, nutrition, forestry, food safety, rural communities, farm efficiency and profitability, and traditional and innovative breeding techniques. AFRI advances fundamental sciences as well as translational research and development in support of agriculture and coordinates research opportunities to build on these new discoveries. In addition, AFRI-awarded programs deliver this science to communities through extension programs, which allows the public to make informed decisions that impact their daily lives.

With the world's population expected to exceed nine billion by 2050, NIFA works to solve the challenges of meeting the food, clothing, fuel, and shelter needs of all people. In order for NIFA to address these critical issues, we partnered with food and agricultural scientists and educators with expertise in: plant health and production and plant products; animal health and production and animal products; food safety, nutrition, and health; bioenergy, natural resources, and environment; agricultural systems and technology; and agricultural economics and rural communities. NIFA partners with the scientific community to provide federal financial assistance grants to address critical issues in United States agriculture in the areas of global food security, water for agriculture, childhood obesity prevention, food safety, sustainable bioenergy, and climate change.

DOA: 7.7.2020
https://nifa.usda.gov/program/agriculture-and-food-research-initiative-afri

Nielsen, M. (2020). *Reinventing Discovery: The New Era of Networked Science*. Princeton University Press.

Online tools like polymath allow laypeople to be involved in scientific discovery. The author suggests that this type of openness recreates the democracy and inclusiveness around science that existed 400 years ago.

"Change is important. Improving the way science is done means speeding up things such as curing cancer, solving the climate change problem..." (Nielsen, 2020, p. 11).

Example: ASSET, a nonprofit technology training institute for girls in India used InnoCentive, an online marketplace for scientific problems that offered prizes for solutions. Using a $20,000 grant from the Rockefeller Foundation, their wireless router/solar panel configuration that needed to be made with low cost, easily available hardware and software problem was downloaded 400 times. They were presented with 27 solutions. An engineer from Texas won the prize, and a prototype was built by engineering students at the University of Arizona (Nielsen, 2020).

Tags: crowd science, technology and engineering, science and communication

Abstract: How the internet and powerful online tools are democratizing and accelerating scientific discovery. Reinventing Discovery argues that we are living at the dawn of the most dramatic change in science in more than three hundred years. This change is being driven by powerful cognitive tools, enabled by the internet, which are greatly accelerating scientific discovery. There are many books about how the internet is changing business, the workplace, or government. But this is the first book about something much more fundamental: how the internet is transforming our collective intelligence and our understanding of the world. From the collaborative mathematicians of the Polymath Project to the amateur astronomers of Galaxy Zoo, Reinventing Discovery tells the exciting story of the unprecedented new era in networked science. It will interest anyone who wants to learn about how the online world is revolutionizing scientific discovery—and why the revolution is just beginning.

Pohl, C., Rist, S., Zimmermann, A., Fry, P., Gurung, G. S., Schneider, F., Speranza, C. I., Kiteme, B., Boillat, S., Serrano, E., Hadorn, G. H., & Wiesmann, U. (2010). Researchers' roles in knowledge co-production: Experience from sustainability research in Kenya, Switzerland, Bolivia and Nepal. *Science & Public Policy (SPP)*, *37*(4), 267–281. https://doi.org/10.3152/030234210X496628

**image in Appendix- p. 154*

Four case studies of thought collectives or knowledge co-production schemes are analyzed, identifying problems of power, integration, and sustainability (Pohl et al., 2010).

- Drought management in the Makueni District, Kenya is approached through a collaborative network of agropastoral households, government and NGO workers, researchers in the area, and the Centre for Integrated Training and Research for Arid and Semi-Arid Lands Development (CETRAD).
- Soil protection in Switzerland is monitored and governed by a network of scientists, data collectors, farmers, extension, and government.
- Governance of biodiversity in Tunari National Park is collectively managed by the Bolivia central government, the indigenous Quechua communities and a network of regional researchers.

Tags: Switzerland, Bolivia, Kenya, Nepal, co-production of knowledge, knowledge management, research, sustainable development

Abstract: Co-production of knowledge between academic and non-academic communities is a prerequisite for research aiming at more sustainable development paths. Sustainability researchers face three challenges in such co-production: (a) addressing power relations; (b) interrelating different perspectives on the issues at stake; and (c) promoting a previously negotiated orientation towards sustainable development. A systematic comparison of four sustainability research projects in Kenya (vulnerability to drought), Switzerland (soil protection), Bolivia and Nepal (conservation vs. development) shows how the researchers intuitively adopted three different roles to face these challenges: the roles of reflective scientist, intermediary, and facilitator of a joint learning process. From this systematized and iterative self-reflection on the roles that a

researcher can assume in the indeterminate social space where knowledge is co-produced, we draw conclusions regarding training.

DOA: 4.28.2020
http://web.b.ebscohost.com.er.lib.k-state.edu/ehost/pdfviewer/pdfviewer?vid=2&sid=97936528-55d3-4e0a-8e33-404a0f4f7acd%40pdc-v-sessmgr04

Rahm, A. K., Ladd, I., Burnett-Hartman, A. N., Epstein, M. M., Lowery, J. T., Lu, C. Y., Pawloski, P. A., Sharaf, R. N., Liang, S.-Y., & Hunter, J. E. (2019). The Healthcare Systems Research Network (HCSRN) as an Environment for Dissemination and Implementation Research: A Case Study of Developing a Multi-Site Research Study in Precision Medicine. *EGEMs*, *7*(1). https://doi.org/10.5334/egems.283

The Healthcare Systems Research Network (HCSRN) is a care-based network of 28 million people in 13 states. The interconnected systems each have researchers networked into their sites, as well as a standardized electronic health record system for better data sharing. Each opts in to adopting a shared data model, administrative procedures, and similar types of collaborations with external research organizations. One area for improvement involves the use of shared templates for best practices for data use agreements and IRB. If these could be centralized, better multi-site research could be facilitated (Rahm et al., 2019).

Tags: healthcare networks, HCSRN

Abstract:

Context: In existence for nearly 25 years, the Healthcare Systems Research Network (HCSRN) is an established and sustainable network of health care systems that serves as a "real world" laboratory to enable the integration of research findings into practice. The objective of this paper is to demonstrate how the HCSRN serves as an ideal environment for studying dissemination and implementation of evidence-based practices into health care systems through the example of developing a multi-site study on the implementation of evidence-based precision medicine practices.

Case description: The "Implementing Universal Lynch Syndrome Screening (IMPULSS)" study (NIH R01CA211723) involves seven HCSRN health care systems and two external health care systems. The IMPULSS study will describe and explain organizational variability around Lynch syndrome (LS) screening to identify which factors in different organizational contexts are important for successful implementation of LS screening programs and will create a toolkit to facilitate organizational decision making around implementation and improvement of precision medicine programs in health care systems.

Major Themes: The strengths of the HCSRN that facilitate D&I research include: 1) a culture of collaboration, 2) standardization of data and processes across systems, and 3) researchers embedded in diverse health care systems. We describe how these strengths contributed to developing the IMPULSS study.

Conclusion: Given the importance of conducting research in real world settings to improve patient outcomes, the unique strengths of the HCSRN are of vital importance. The IMPULSS study is one case example of how the strengths of the HCSRN make it an excellent environment for research on implementing evidence-based precision medicine practices in health care systems.

DOA: 6.4.2020
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6460496/

Rose, R., & Prager, D. (2009). The Value of Interdisciplinary Research Networks. *Views Form the Field*, 2.

Two successful MacArthur networks, The Mental Health and the Law Network and the Network on Adolescent Development and Juvenile Justice, exemplify some of the challenges in establishing successful networks, such as the tendency of disciplines to separate into silos, and some of the strategies for success, such as close collaboration between foundation staff and developing networks. Growth is maintained by developing in the context of the problems of greatest concern to the foundation and then applying those questions to future grantmaking. An iterative process must occur between staff and the network. Staff must not be overly prescriptive, yet maintain concert with the central questions, and maintain communication about new angles as they evolve (R. Rose & Prager, 2009).

Tags: case studies, interdisciplinary networks, MacArthur Foundation

DOA: 5.12.2020
https://www.gih.org/files/usrdoc/Research_Networks_February_2009.pdf

Subklew, G., Ulrich, J., Fürst, L., & Höltkemeier, A. (2010). Environmental impacts of the Yangtze Three Gorges project: An overview of the Chinese-German research cooperation. *Journal of Earth Science; Dordrecht*, *21*(6), 817–823. http://dx.doi.org.er.lib.k-state.edu/10.1007/s12583-010-0133-x

An Engineering Hydrological project that spanned the Yangtze River required the cooperation of multiple scientific networks, in multiple disciplines, and in multiple countries to form an accurate, holistic representation of environmental impacts. This article provides an overview of the network dynamics, in which 30 Chinese and German partners collaborated. The German network included universities, Helmholtz Centers, and private companies, whereas the Chinese network included universities, CAS institutions, and government establishments. While the environmental impact is clearly established, the impact on individual researchers and the impact on the shape of scientific networks is not discussed (Subklew et al., 2010).

Tags: dams, earth sciences, environmental impact

Abstract: The construction of the Three Gorges Dam on the Yangtze River in China has a great influence on the ecosystems involved. In order to investigate these environmental effects in the Yangtze catchment area as well as downstream of the dam, Forschungszentrum Jülich has organized a research network for the Chinese and German partners. In the research fields of (1)

interaction water/sediment/contaminants, (2) vegetation/biodiversity, (3) changing land use/erosion/mass movements, and (4) atmosphere, the partners have accumulated a great deal of expertise in handling major issues and also in developing models and recommendations for action. The following provides an overview of the research network and the research tasks. On the German side, five projects in research field (3) have been in operation since 2008. The results are reported in contributions by Ehret et al., Jaehnig and Cai, Schönbrodt et al., and Seeber et al.. Another five projects in research field (1) have started by September 2010. The research tasks undertaken in these five projects are presented below.

DOA: 6.29.2020

https://link.springer.com/article/10.1007/s12583-010-0133-x

Vanderbilt, K., & Gaiser, E. (2017). The International Long-Term Ecological Research Network: A platform for collaboration. *Ecosphere*, *8*(2), e01697. https://doi.org/10.1002/ecs2.1697

The ILTER is a true network of networks as it expanded out of the U.S., primarily NSF funded LTER sites in the 1990s, to a global federation of sites that draw funding from a variety of local and international sources. It is unlike other networks in that members engage in long-term, site-based ecological research. "ILTER researchers can extend the scope of their research to sites that are located in many more ecosystems than are represented in one country's LTER Network alone" (Vanderbilt & Gaiser, 2017, p. 3).

The model operates on a platform of free and open data sharing operated by DataONE, a distributed network of data centers that disseminate and curate content for its users, while mandating a structural metadata language (EML), and training scientists to document their data in accordance, so that the data can be collected into repositories such as the Knowledge Network for Biodiversity. LTER case studies examine how LTER sites are uniquely equipped to connect researchers who study similar phenomena in comparable, but different ecosystems.
The structure of ILTER promotes bottom-up, self-organized, and collectively funded, grassroots approaches that strive towards inclusivity and resource sharing.

Tags: collaboration, everglades, information management, international collaboration, international long-term ecological research, long-term ecological research, National Science Foundation, network, LTER

Abstract: Many scientists around the world became interested in the U.S. Long Term Ecological Research (U.S. LTER) Network's research model during the 1990s and began to develop LTER and Long Term Socio-ecological Research networks in their own countries. These local networks, including the U.S. LTER Network, were loosely federated in 1993 to form the International Long Term Ecological Research (ILTER) Network, a "network of networks." Although the first 10 years of ILTER Network activities were largely supported by funds from the U.S. National Science Foundation, the ILTER Network had transformed into a robust, self-sustaining entity by 2006 following a two-year strategic planning process. The goal of the ILTER Network is to improve understanding of how pressures such as climate change and land use affect global

ecosystems in order to inform solutions to current and future environmental problems. To fulfill this mission, the ILTER Network fosters collaborations among member scientists to extend the scope of their research across disciplinary boundaries and across more of the ILTER's 600+ research sites. The ILTER Network also has many long-term data sets that are freely available for use by students, scientists, and policymakers all over the world. In this collection of papers, we consider how the ILTER Network has been, and will be, leveraged by U.S. researchers to advance understanding of ecological and socio-ecological systems around the globe.

DOA: 5.12.2020
https://esajournals.onlinelibrary.wiley.com/doi/full/10.1002/ecs2.1697

Vanderlinden, J.-P., Baztan, J., Chouinard, O., Cordier, M., Da Cunha, C., Huctin, J.-M., Kane, A., Kennedy, G., Nikulkina, I., Shadrin, V., Surette, C., Thiaw, D., & Thomson, K. T. (2020). Meaning in the face of changing climate risks: Connecting agency, sensemaking and narratives of change through transdisciplinary research. *Climate Risk Management*, 29, 100224. https://doi.org/10.1016/j.crm.2020.100224

Five case studies exemplify agency-community interactions, where outcomes that force inaction or misguided agency emerge. Using an artistic approach, the intermediate agencies between researchers and the public rely on storytelling to stimulate behavioral or management changes. However, stories make the science behind them ambiguous. Whether narratives are adopted or not depends on their plausibility and whether they resonate with local political economies (Vanderlinden et al., 2020).

Tags: agency, coastal adaptation, narratives, sensemaking, transdisciplinary science

Abstract: This paper contributes to the body of knowledge associated with the analysis of transdisciplinary research. We use a narrative centered approach, focusing on hybridity, sensemaking and the potential for transdisciplinary research to foster agency. When confronted with changes, people – as individuals – and local communities – as groups – make sense of them in the light of their own knowledge, beliefs and experiences. The process by which communities make sense of changing institutional and natural environments can be defined as the interaction between their own frame of reference and the perception of the situational demands inherent to changes, together with their interpretation of these changes. Such a dynamic process of sensemaking constantly redefines the boundaries of the narratives that community members can call on to give meaning to their past, present and future. In this paper we use five case studies to analyze how this sensemaking plays out in situations of changing climate risk and changing frames of reference associated with the presence of transdisciplinary scientists. We identify the central challenge of ambiguity. We define ambiguity as situations where narratives of change assign different meanings to the changes observed. In such situations, we observe three potential outcomes in our case studies: (1) communities appear to be forced into inaction – as a consequence of agency-depriving senselessness; (2) communities appear to be cornered into maladaptation – as a consequence of a misguided sense of agency; and (3) communities try to resolve ambiguity and effectively move forward – as knowledge-based agency-fostering exercise. In light of these results, we argue that by contributing to the clarification of such ambiguities, climate science may contribute to increases in local agency, thus enhancing adaptive capacities.

We conclude by proposing that climate science be place-based and community–centered. The purpose of such a shift would be aimed at building the agency-enhancing sensemaking of local communities.

DOA: 4.28.2020
https://www-sciencedirect-com.er.lib.k-state.edu/science/article/pii/S2212096320300140

Young, J. R. (2010, May 28). Crowd Science Reaches New Heights. *The Chronicle of Higher Education*. https://www.chronicle.com/article/The-Rise-of-Crowd-Science/65707

Galaxy Zoo provides an example of a crowdsourced data collection project in which amateur astronomers, schoolteachers, classrooms etc., can record their observations and contribute to scientific discovery.

"Astronomy is just one of many disciplines being reshaped by a data explosion. Bio scientists have found that decoding entire genomes also meant cultural shifts for their profession" (Young, 2010). Cultural shifts include professors taking time to share data and potentially credit.

Other examples: Gene Wikis (GenMAPP) and potential oceanography projects that allow networks of sensors to replace human expedition.

Tags: crowd science

DOA: 4.23.2020
https://www.chronicle.com/article/The-Rise-of-Crowd-Science/65707/

Youtie, J., Shapira, P., Reinsborough, M., & Fisher, E. (2019). Research network emergence: Societal issues in nanotechnology and the center for nanotechnology in society. *Science and Public Policy*, *46*(1), 126–135. https://doi.org/10.1093/scipol/scy043

Using the Center for Nanotechnology in Society at Arizona State University (CNS-ASU), as an example of a single node within a research network of social issues in nanotechnology researchers, the authors use geographical citation mapping and network analysis of coauthors to examine the extent to which a network has emerged around this center.

The analysis revealed that the center demonstrates a geographical network of coauthors and citations. Center senior members are the hub of the co-author network of researchers in the nano-social issues co-authorship domain. From a subject matter viewpoint, the center's own publications integrate works from other social science as well as physical and biological science domains (Youtie et al., 2019).

Tags: geographic networks, interdisciplinary networks, nanotechnology, network analysis, social issues

Abstract: This article looks at the creation of a network of researchers of social issues in nanotechnology and the role of the Center for Nanotechnology in Society at Arizona State University (CNS-ASU) in the creation of this network. The extent to which CNS-ASU is associated with the development of a research network around the study of social issues in nanotechnology is examined through geographic mapping of co-authors and citations of center publications, network analysis of co-authors of papers on social issues in nanotechnology, and a disciplinary analysis of these papers. The results indicate that there is an extensive network of co-authorships among researchers studying social issues in nanotechnology with CNS-ASU at the center of this network. In addition, papers written by center members and affiliates integrate a diverse range of disciplines. Qualitative data are used to interpret some of the ways that citation occurs.

DOA: 5.12.2020
https://academic.oup.com/spp/article/46/1/126/5039639

IX. Team Science and the Science of Team Science: What are "best practices" for the organization, management, and coordination of large-scale collaborations? Do findings from the team science literature scale up to networks of networks?

Aarons, G. A., Reeder, K., Miller, C. J., & Stadnick, N. A. (2019). Identifying strategies to promote team science in dissemination and implementation research. *Journal of Clinical and Translational Science*, 1–8. https://doi.org/10.1017/cts.2019.413

The authors use survey and focus group data to identify communication strategies for effective team science. They find that clear goals and expectations are foundational, but must be achieved through communication that is inclusive and adaptable, best done in smaller, nominal groups (Aarons et al., 2019).

Tags: cross-disciplinary, dissemination, implementation, nominal group technique, team science

Abstract: Scientific endeavors are increasingly carried out by teams of scientists. While there is growing literature on factors associated with effective science teams, little is known about processes that facilitate the success of dissemination and implementation (D&I) teams studying the uptake of healthcare innovations. This study aimed to identify strategies used by D&I scientists to promote team science.

Using a nominal group technique, a sample of 27 D&I scholars responded to the question, "What strategies have you or others used to promote team science?" Participants were asked to individually respond and then discuss within a small group to determine the group's top three strategies. Through a facilitated consensus discussion with the full sample, a rank-ordered list of three strategies was determined.

A total of 126 individual responses (M = 9; SD = 4.88) were submitted. Through small group discussion, six groups ranked their top three strategies to promote team science. The final ranked list of strategies determined by the full sample included: (1) developing and maintaining clear expectations, (2) promoting and modeling effective communication, and (3) establishing shared goals and a mission of the work to be accomplished.

Because of its goal of translating knowledge to practice, D&I research necessitates the use of team science. The top strategies are in line with those found to be effective for teams in other fields and hold promise for improving D&I team cohesion and innovation, which may ultimately accelerate the translation of health innovations and the improvement of care quality and outcomes.

DOA: 6.29.2020
https://www.cambridge.org/core/journals/journal-of-clinical-and-translational-science/article/identifying-strategies-to-promote-team-science-in-dissemination-and-implementation-research/4BE9B50EB15FA3AC37162CB120E27FF0

Asencio, R., Carter, D. R., DeChurch, L. A., Zaccaro, S. J., & Fiore, S. M. (2012). Charting a course for collaboration: A multiteam perspective. *Translational Behavioral Medicine*, *2*(4), 487–494. https://doi.org/10.1007/s13142-012-0170-3

The Memorial Sloan-Kettering Cancer Center provides an example of multiple interdependent teams. In this case, "research teams work interdependently with physician teams in the cancer care unit to apply empirical findings to improve patient care and to refine their future research based on clinical observations" (Asencio et al., 2012, p. 487).

Multiteam charters can be designed with specific leadership and communication protocols between researcher teams, clinician teams, and practitioner teams.

Necessary elements of these charters: the (1) identification of between-team communication norms, (2) shared leadership among members from different component teams, and (3) the identification of members from different component teams to gather information and enable communication across boundaries to facilitate achievement of system-level goals.

Tags: behavioral norms, communication, multiteam charter, multiteam systems, shared leadership, team charter

Abstract: The translation of medical research from bench-to-bedside often requires integrated input from multiple expert teams. These collectives can best be understood through the lens of multiteam systems theory. Team charters are a practical tool thought to facilitate team performance through the creation of explicit shared norms for behavior. We extend the current literature on team charters to the multiteam context and make three practical recommendations for multiteam charter content that could facilitate effective communication and leadership processes between teams.

DOA: 4.20.2020
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3717938/

Börner, K., Contractor, N., Falk-Krzesinski, H. J., Fiore, S. M., Hall, K. L., Keyton, J., Spring, B., Stokols, D., Trochim, W., & Uzzi, B. (2010). A Multi-Level Systems Perspective for the Science of Team Science. *Science Translational Medicine*, *2*(49), 49cm24-49cm24. https://doi.org/10.1126/scitranslmed.3001399

The National Institutes of Health (NIH) funds several inter and transdisciplinary research centers on cancer, health disparities, and other topics. The NIH's National Center for Research Resources funds the Clinical and Translational Science Awards (CTSAs) with the goal of implementing new discoveries into patient treatments. Similarly, the National Science Foundation invites projects on Cyber-Enabled Discovery and Innovation with the goal of "paradigm-changing research findings" through innovation in collaboration. The National Academies KECK Futures initiative supports a similar drive toward interdisciplinary team science. The MacArthur, Robert Wood Johnson, and W.T. Grant Foundations all support interdisciplinary research networks.

The authors use these examples to offer ten insights from micro and meso level research that embed into these seven insights from macro level research:

1. Space/geography matters in research impacts.
2. Although teamwork spans Universities, the hierarchical nature of multi-institutional collaborations concentrate productivity in key clustered areas.
3. Traditions of scientific independence pose a barrier to effective collaboration.
4. Team characteristics can be used to identify teams that will benefit from cyberinfrastructures.
5. Structural elements of collaboration are interrelated to external sectors, organization, and funding structures.
6. Science as a whole is now driven by co-authorship teams.
7. Seven principles guide a framework for evaluation (Klein) (Börner et al., 2010).

Tags: mixed methods, multi-level approaches, SCITS (Science of Team Science)

Abstract: 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. Understanding how teams function is vital because they are increasingly dominating the production of high-impact science.

DOA: 6.9.2020
https://stm.sciencemag.org/content/2/49/49cm24/tab-pdf

De Dreu, C. K. W., & West, M. A. (2001). Minority dissent and team innovation: The importance of participation in decision making. *Journal of Applied Psychology*, *86*(6), 1191–1201. https://doi.org/10.1037/0021-9010.86.6.1191

This study highlights the value of diversity in teams. Although the study participants are not all scientific research teams, it provides insight on the ways that differing viewpoints stimulate creativity, and in turn, innovation. However, the authors warn that communication power structures play a role in inclusivity and decision-making, which can work to undermine the voices of minorities when they are not being purposefully elevated (De Dreu & West, 2001).

Tags: creativity, group decision-making, group dynamics, group structure, innovation, self-managing work teams

Abstract: This study integrates research on minority dissent and individual creativity, as well as team diversity and the quality of group decision making, with research on team participation in decision making. From these lines of research, it was proposed that minority dissent would predict innovation in teams but only when teams have high levels of participation in decision making.

This hypothesis was tested in 2 studies, 1 involving a homogeneous sample of self-managed teams and 1 involving a heterogeneous sample of cross-functional teams. Study 1 suggested that a newly developed scale to measure minority dissent has discriminant validity. Both Study 1 and Study 2 showed more innovations under high rather than low levels of minority dissent but only when there was a high degree of participation in team decision making. It is concluded that minority dissent stimulates creativity and divergent thought, which, through participation, manifest as innovation.

DOA: 6.29.2020
https://psycnet.apa.org/record/2001-05650-012?doi=1

Falk-Krzesinski, H. J., Börner, K., Contractor, N., Fiore, S. M., Hall, K. L., Keyton, J., Spring, B., Stokols, D., Trochim, W., & Uzzi, B. (2010). Advancing the Science of Team Science. *Clinical and Translational Science*, *3*(5), 263–266. https://doi.org/10.1111/j.1752-8062.2010.00223.x

[See notes in “Evaluation”]

Falk-Krzesinski, H. J., Contractor, N., 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*, *20*(2), 145–158. https://doi.org/10.3152/095820211X12941371876580

[See notes in “Evaluation”]

Fortunato, S., Bergstrom, C. T., Börner, K., Evans, J. A., Helbing, D., Milojević, S., Petersen, A. M., Radicchi, F., Sinatra, R., Uzzi, B., Vespignani, A., Waltman, L., Wang, D., & Barabási, A.-L. (2018). Science of science. *Science*, *359*(6379). https://doi.org/10.1126/science.aao0185

[See notes in “Motivations”]

Guise, J.-M., Winter, S., Fiore, S. M., Regensteiner, J. G., & Nagel, J. (2017). Organizational and training factors that promote team science: A qualitative analysis and application of theory to the National Institutes of Health’s BIRCWH career development program. *Journal of Clinical and Translational Science*, *1*(2), 101–107. https://doi.org/10.1017/cts.2016.17

Seven key design elements support team science: (1) semiformal meta-organizational structure, (2) shared context and goals, (3) formal evaluation processes, (4) meetings to promote communication, (5) role clarity in mentoring, (6) building interpersonal competencies among faculty and trainees, and (7) designing promotion and tenure and other organizational processes to support interdisciplinary team science (Guise et al., 2017).

Tags: interdisciplinary communication, models, organizational models, research, translational medical research, team science

Abstract: Research organizations face challenges in creating infrastructures that cultivates and sustains interdisciplinary team science. The objective of this paper is to identify structural elements of organizations and training that promote team science. We qualitatively analyzed the National Institutes of Health's Building Interdisciplinary Research Careers in Women's Health, K12 using organizational psychology and team science theories to identify organizational design factors for successful team science and training. This application of theory to a long-standing and successful program provides important foundational elements for programs and institutions to consider in promoting team science.

DOA: 4.20.2020
https://www.cambridge.org/core/services/aop-cambridge-core/content/view/ED1E4A42A0C379E00DC1BB95BB269706/S2059866116000170a.pdf/organizational_and_training_factors_that_promote_team_science_a_qualitative_analysis_and_application_of_theory_to_the_national_institutes_of_healths_bircwh_career_development_program.pdf

Hall, K. L., Stokols, D., Moser, R. P., Taylor, B. K., Thornquist, M. D., Nebeling, L. C., Ehret, C. C., Barnett, M. J., McTiernan, A., Berger, N. A., Goran, M. I., & Jeffery, R. W. (2008). The Collaboration Readiness of Transdisciplinary Research Teams and Centers: Findings from the National Cancer Institute's TREC Year-One Evaluation Study. *American Journal of Preventive Medicine*, *35*(2, Supplement), S161–S172. https://doi.org/10.1016/j.amepre.2008.03.035

"During the fall of 2005, the National Cancer Institute (NCI) established the Transdisciplinary Research on Energetics and Cancer (TREC) initiative comprising four research centers and one coordination center.8 The TREC centers are intended to foster collaboration among transdisciplinary teams of scientists with the goal of accelerating progress toward reducing cancer incidence, morbidity, and mortality associated with energy imbalance, obesity, and low levels of physical activity. They also aim to conduct research to elucidate the mechanisms linking energetics and cancer and to provide training opportunities for new and established scientists who can carry out integrative research on energetics and energy balance (www.compass.fhcrc.org/trec). This $54-million initiative was created through a combination of funding mechanisms that enable four research centers to have the support of a centralized coordination center. NCI is partnering with the centers to support developmental projects both within and between centers as well as an initiative-wide evaluation process" (Hall et al., 2008, p. S162).

The first year of the National Cancer Institute's (NCI) Transdisciplinary Research on Energetics and Cancer (TREC) initiative contributes to the literature on team science by developing, testing, and suggesting evaluation tools for this type of collaboration. The TREC One-year survey reveals a great deal about researchers' attitudes and aptitudes toward interdisciplinary work.

They found (1) an inverse relationship between scores on unidisciplinary and multidisciplinary and interdisciplinary/transdisciplinary factors, suggesting that those who collaborate more at the start can benefit from the added infrastructure of interdisciplinary institutions and funding; (2) those who excelled at interdisciplinary collaboration and held a positive outlook on future collaboration felt that their institutions supported them with more resources; (3) the number of years researchers engaged in the initiative was inversely related to how effective they felt; and (4) the nature of the relationships within the center held direct bearing on how effective researchers felt the center was in its work.

Tags: case study, domestic partnerships, evaluation, researcher attitudes, team science, transdisciplinary health research

Abstract: Growing interest in promoting cross-disciplinary collaboration among health scientists has prompted several federal agencies, including the NIH, to establish large, multicenter initiatives intended to foster collaborative research and training. In order to assess whether these initiatives are effective in promoting scientific collaboration that ultimately results in public health improvements, it is necessary to develop new strategies for evaluating research processes and products as well as the longer-term societal outcomes associated with these programs. Ideally, evaluative measures should be administered over the entire course of large initiatives, including their near-term and later phases. The present study focuses on the development of new tools for assessing the readiness for collaboration among health scientists at the outset (during the first year) of their participation in the National Cancer Institute's Transdisciplinary Research on Energetics and Cancer (TREC) initiative. Indexes of collaborative readiness, along with additional measures of near-term collaborative processes, were administered as part of the TREC Year-One evaluation survey. Additionally, early progress toward scientific collaboration and integration was assessed, using a protocol for evaluating written research products. Results from the Year-One survey and the ratings of written products provide evidence of cross-disciplinary collaboration among participants during the first year of the initiative, and also reveal opportunities for enhancing collaborative processes and outcomes during subsequent phases of the project. The implications of these findings for future evaluations of team science initiatives are discussed.

DOA: 4.3.2020
https://doi.org/10.1016/j.amepre.2008.03.035

INSciTS. (2020). *Science of Team Science Library*. Building the Knowledge Base for Effective Team Science. https://www.inscits.org/scits-library

This library for team science provides resources for practitioners, and opportunities to engage in interest groups, interact with blogs and social media, or participate in team science conferences. For example, a 2020 article by Strekalova and McCormack suggest activities for brainstorming expertise areas, resources, opportunities, "big easy" collaborative opportunities, and specific action steps that can result in new team science projects (INSciTS, 2020).
https://i2insights.org/2020/06/02/questions-to-catalyse-collaborations/

Tags: library, team science

Abstract: The reference library in the "Science of Team Science (SciTS)" public group on Mendeley constitutes the most comprehensive and authoritative source of empirical literature on team science and scientific collaboration—the SciTS field—in the world. Launched in 2013, it is a free, community resource available via the web and through the free Mendeley Desktop software providing over 2,500 team science references from a wide range of knowledge domains, most curated and organized into over three dozen topical folders. As a public group, anyone with a basic Mendeley profile can access the library in its entirety and any member of the group's community can directly add references to the library in a crowdsourcing fashion, including creating new folders. The SciTS library on Mendeley is a reliable source of references for individuals and initiatives alike; it was used for all three national team science reports: Enhancing the Effectiveness of Team Science consensus report by the National Research Council of the US National Academy of Science; the UK Academy of Medical Sciences team science report, Improving Recognition of Team Science Contributions in Biomedical Research Careers; and the report by the Canadian Academy of Health Science team science panel, Academic Recognition of Team Science: How to Optimize the Canadian Academic System.

DOA: 6.11.2020
https://www.mendeley.com/community/science-of-team-science-(scits)/

Leahey, E. (2016). From Sole Investigator to Team Scientist: Trends in the Practice and Study of Research Collaboration | Annual Review of Sociology. *Annual Review of Sociology*, *42*, 81–100.

The increasing cost and specialization of science drive an imperative toward team science. Therefore, fields that require costly methods or time-consuming data collection are the most collaborative. The benefits include productivity, publishing volume, and grant mobilization. The costs include articulation work (translating between disciplines, managing people and logistics, updating funding agencies) which draws researchers away from actual research; and the reproduction of status and gendered inequalities through exploitation disguised as mentorship.

The authors suggest several strategies for collaboration that mitigate the costs: focus on depth in a single research area; complement and extend the work in other parts of the network; collaborate with and through students; collaborate across scientific domains; emphasize cross-university collaborations; emphasize cross-disciplinary collaborations (Leahey, 2016).

Tags: cost of collaboration, drivers, team science

Abstract: This article reviews trends in the practice and study of research collaboration, focusing on journal publications in academic science. I briefly describe the different styles and types of collaboration and then focus on the drivers of the trend toward increased collaboration and on its consequences for both individual researchers and science more generally. Scholarship on collaboration seems partial to delineating its benefits; this review highlights the increasing body of research that focuses instead on the possible costs of collaboration. The synthesis reveals several topics that are ripe for investigation, including the impact of collaboration on the

contributing authors and their work, the use of multiple methods and measures, and research integrity. I applaud a few recent efforts to overcome the perennial file-drawer problem by gaining access to collaborations that do not result in publication and thus are typically removed from public review and the research analyst's eye.

DOA: 5.26.2020
https://www-annualreviews-org.er.lib.k-state.edu/doi/full/10.1146/annurev-soc-081715-074219#_i3

Marino, A. H., Suda-Blake, K. A., & Fulton, K. R. (2019). Innovative Collaboration Formation: The National Academies Keck Futures Initiative. In K. L. Hall, A. L. Vogel, & R. T. Croyle (Eds.), *Strategies for Team Science Success: Handbook of Evidence-Based Principles for Cross-Disciplinary Science and Practical Lessons Learned from Health Researchers* (pp. 241–250). Springer International Publishing. https://doi.org/10.1007/978-3-030-20992-6_18

This book chapter analyzes the National Academies Keck Futures Initiative (NAKFI), and explains how it used seed grants and the NAFKI conference to network researchers in transdisciplinary programs, Key features included built-in flexibility, and evaluation mechanisms that encouraged expansion (Marino et al., 2019).

Tags: collaboration, innovation, interdisciplinary research, seed funding, team science, venture science

Abstract: Founded in 2003 as a 15-year undertaking with generous support from the W. M. Keck Foundation, the National Academies Keck Futures Initiative (NAKFI) occupied a unique space within the National Academies of Sciences, Engineering, and Medicine and in the broader landscape of inter- and transdisciplinary research programs. It was one of a myriad of programs, workshops, models, and activities which aim to expand the boundaries about how we view, support, and conduct interdisciplinary science. The program provided collaborative opportunities to nearly 2000 professionals across a broad range of fields and made conceptual and methodological contributions to how team science is fostered and evaluated. This chapter will describe the key features of the NAKFI conference and seed grants program, how it evolved over time, and demonstrate how adaptation and evaluation contributed to the program's development. It will also explore the strengths and limitations of this approach and address strategies that have been used to overcome challenges during the program's 15-year duration. Additional information about each of these topics can be found at https://www.nap.edu/catalog/25239/.

DOA: 5.27.2020
https://link.springer.com/chapter/10.1007/978-3-030-20992-6_18

National Cancer Institute. (2020). ***Team Science Toolkit*****.**
https://www.teamsciencetoolkit.cancer.gov/Public/Home.aspx

The toolkit provides a database of resources that can be used to connect professionals across disciplines through knowledge and tools sharing for effective team science projects. The purpose is to integrate knowledge, discuss best practices, and prevent redundancy. It includes:

- models to support new collaborations
- training materials for team science skills
- data management guides
- survey/interview guides
- metrics, algorithms, validity, and reliability scales for evaluators
- a platform for institutional infrastructure sharing
- sources of funding
- a background on the science of team science

(National Cancer Institute, 2020)

Tags: team science, toolkit, knowledge sharing resources, National Cancer Institute

Abstract: Team science is a collaborative effort to address a scientific challenge that leverages the strengths and expertise of professionals trained in different fields. Although traditional single investigator driven approaches are ideal for many scientific endeavors, coordinated teams of investigators with diverse skills and knowledge may be especially helpful for studies of complex social problems with multiple causes. Over the past two decades, there has been an emerging emphasis on scientifically addressing multi-factorial problems, such as climate change, the rise of chronic disease, and the health impacts of social stratification. This has contributed to a surge of interest and investment in team science. Increasingly, scientists across many disciplines and settings are engaging in team-based research initiatives. These include small and large teams, uni- and multi-disciplinary groups, and efforts that engage multiple stakeholders such as scientists, community members, and policy makers. Academic institutions, industry, national governments, and other funders are also investing in team science initiatives.

A growing trend within team science is cross-disciplinary science in which team members with training and expertise in different fields work together to combine or integrate their perspectives in a single research endeavor. Cross-disciplinary team science has been identified as a means to engage in expansive studies that address a broad array of complex and interacting variables. It is seen as a promising approach to accelerate scientific innovation and the translation of scientific findings into effective policies and practices. The success of team science is influenced by a variety of contextual environmental influences. These factors influence each stage of a scientific initiative, with implications for efficiency, productivity, and overall effectiveness. They include:

- Funding trends
- Institutional infrastructure and resources for communication and data sharing

- Organizational policies—such as promotion and tenure policies—that impact team-based endeavors
- Team processes, including the existence of agreements related to proprietary rights to data and discovery, as well as mechanisms for feedback and reflection
- Interpersonal dynamics among team members
- Team members' collaborative skills and experiences

The science of team science (SciTS) is a rapidly emerging field focused on understanding and enhancing the processes and outcomes of team science. A key goal of SciTS is to learn more about factors that maximize the efficiency, productivity, and effectiveness of team science initiatives. A diverse group of scholars contributes to SciTS. They bring conceptual, historical, and methodological approaches from a wide variety of disciplines and fields, including public health, management, communications, and psychology. They have created measures to assess team science processes and outcomes, and to influence contextual and environmental conditions. Applying these measures can help researchers evaluate team science, improve the quality of ongoing initiatives, and develop best practices.

Major areas of inquiry in SciTS include:

- Methods and models for the study of team science
- The structure and organization of team science, particularly the collaborative processes moderated by a variety of contextual environmental factors
- Team characteristics and dynamics, such as the elements of effective leadership, ideal team composition, and communication styles
- Design and outcomes of training programs to support team science
- Translation of team science findings to practice and policy
- Scientific and societal outcomes of team science such as scientific discoveries and innovations, knowledge dissemination, and long-term public health impacts.

DOA: 6.11.2020
https://www.teamsciencetoolkit.cancer.gov/Public/Home.aspx

Stokols, D., Misra, S., Moser, R. P., Hall, K. L., & Taylor, B. K. (2008). The Ecology of Team Science: Understanding Contextual Influences on Transdisciplinary Collaboration. *American Journal of Preventive Medicine*, *35*(2, Supplement), S96–S115. https://doi.org/10.1016/j.amepre.2008.05.003

[See notes in "Evidence"]

Wu, L., Wang, D., & Evans, J. A. (2017). Large Teams Have Developed Science and Technology; Small Teams Have Disrupted It (SSRN Scholarly Paper ID 3034125). Social Science Research Network. https://doi.org/10.2139/ssrn.3034125

[See notes in "Motivations"]

X. Overview

Network-to-network literature builds upon previously existing "team science" literature that recognizes the value and necessity of large-scale collaborative work to support social progress towards sustainability and innovation in an ever-expanding scientific and global community (Falk et al., 2010; Leahey, 2016; Stokols et al. 2008; Kahn, 1994; Jasanoff, 2004; Cundill et al. 2019). These networks can best be understood through mapping practices that explain how knowledge and resources are shared and how the trajectory of future research is affected by current clusters of collaborators (Archembault, 2010; Boyack et al., 2005).

Among these examples are networks of medical research networks that intertwine with healthcare practitioner networks such as the National Cancer Institute, the Cancer Research Network, the National Institute of Health, and the First Veterans Health Administration (Hall et al., 2008; Harris et al., 2012; Steiner et al., 2014; Pomernacki et al. 2015), which operate with the goal of collaborating on prevention, treatment, and medical innovation for pressing public health concerns. Similarly, networks of nano scientists, engineers and agricultural scientists work closely with industry stakeholders to innovate patented technology, economic growth, and food security (Zhou & Leydesdorff, 2006; Almeida & Kolgut, 1999; Youtie et al., 2019; The National Academies, 2020; Moock, 2016). By contrast, the MacArthur Foundation and the National Academies Keck Futures Initiative offer some insight into funding structures and the logistics of initiating and mandating networks of networks (Rose, n.d.; Marino et al., 2019). Rose & Prager (2009) offer a comprehensive guide to network formation.

Networks of ecological teams, exemplified by the ILTER and CZ Observatories help to establish scientific data sharing on interconnected issues related to the environment that will be vital to the future knowledge and training in the biological and physical sciences (Aronova et al., 2010; Venderbilt & Gaiser, 2017; Brantley et al., 2017; Baatz et al. 2018; Gaillardet et al. 2018). These last two are perhaps the best case study examples that this bibliography offers with specific details about what has worked well and what has failed, funding structures, evaluation principles, and impact.

Three challenges emerge. First, keywords such as "network science" mostly return literature about "open science", or open-source science, which involves the public in scientific data collection or which opens up scientific journals to the public (Nielson, 2020), rather than truly organized network-to-network scientific collaboration. Although these efforts are beyond the scope of this bibliography, they bring up an important conundrum where public access to science and the impact of scientific research on the general population is important to societal knowledge, but it is often distorted by biased private funding, sensationalized by scientific media reporting, or corrupted by predatory publishing that can dilute the impact and robustness of science. Networks of collaborative scientists, like those outlined in this bibliography hold great power to shape public knowledge and to overcome these setbacks. How networked scientists form and maintain complex relationships between research and implementation; the ways that science impacts society; and the agency that scientists and the public hold in those relationships are areas to further explore.

Secondly, the category of impact- what is the impact of network participation on individuals- is largely unexplored. Cruz-Castro & Sanz-Menendez (2020), Kwiek & Roszka (2020), and Pina et al. (2019) offer important insights into the gender, seniority, and geographical bibliometric output and funding disparities within networks. However, more research is needed to determine how network participation affects other intersections of researchers (especially in the formerly colonized world, where colonial patterns of inequality still emerge in research power dynamics), the barriers to participation, the rewards of participation, and the impacts on careers and knowledge that fall outside of bibliometric measures.

Finally, more research is needed to document and analyze the pathways for scaling team science collaborations into larger and more complex networks. As research questions become larger, and the social imperative of collaboration becomes even more necessary to solve problems that are key to the survival of human society, it will become even more important to understand how to support team science in this imperative as it scales up to network-to-network science.

References

Aarons, G. A., Reeder, K., Miller, C. J., & Stadnick, N. A. (2019). Identifying strategies to promote team science in dissemination and implementation research. *Journal of Clinical and Translational Science*, 1–8. https://doi.org/10.1017/cts.2019.413

Adams, J. (2013). The fourth age of research. *Nature*, *497*(7451), 557–560. https://doi.org/10.1038/497557a

Almeida, P., & Kogut, B. (1999). The localization of knowledge and the mobility of engineers in regional networks. *Management Science*, 905–917.

Archambault, E. (2010). 30 Years in Science—Secular Movements in Knowledge Creation. *Science Metrix*, 16.

Aronova, E., Baker, K. S., & Oreskes, N. (2010). Big Science and Big Data in Biology: From the International Geophysical Year through the International Biological Program to the Long Term Ecological Research (LTER) Network, 1957—Present. *Historical Studies in the Natural Sciences*, *40*(2), 183–224. https://doi.org/10.1525/hsns.2010.40.2.183

Asencio, R., Carter, D. R., DeChurch, L. A., Zaccaro, S. J., & Fiore, S. M. (2012). Charting a course for collaboration: A multiteam perspective. *Translational Behavioral Medicine*, *2*(4), 487–494. https://doi.org/10.1007/s13142-012-0170-3

Baas, J., Schotten, M., Plume, A., Côté, G., & Karimi, R. (2020). Scopus as a curated, high-quality bibliometric data source for academic research in quantitative science studies. *Quantitative Science Studies*, *1*(1), 377–386. https://doi.org/10.1162/qss_a_00019

Baatz, R., Sullivan, P., Li, L., Weintraub, S., Loescher, H., Mirtl, M., Groffman, P., Wall, D., Young, M., White, T., Wen, H., Zacharias, S., Kühn, I., Tang, J., Gaillardet, J., Braud, I., Flores, A., Kumar, P., Lin, H., … Looy, K. V. (2018). Steering Operational Synergies in Terrestrial Observation Networks: Opportunity for Advancing Earth System Dynamics Modelling. *Earth System Dynamics*, *9*(2), 593–609. http://dx.doi.org/10.5194/esd-9-593-2018

Barnard, H., Cowan, R., & Müller, M. (2012). Global excellence at the expense of local diffusion, or a bridge between two worlds? Research in science and technology in the developing world. *Research Policy*, *41*(4), 756–769. https://doi.org/10.1016/j.respol.2011.12.002

Barzel, B., & Barabási, A.-L. (2013). Universality in network dynamics. *Nature Physics*, *9*(10), 673–681. https://doi.org/10.1038/nphys2741

Börner, K., Contractor, N., Falk-Krzesinski, H. J., Fiore, S. M., Hall, K. L., Keyton, J., Spring, B., Stokols, D., Trochim, W., & Uzzi, B. (2010). A Multi-Level Systems Perspective for the Science of Team Science. *Science Translational Medicine*, *2*(49), 49cm24-49cm24. https://doi.org/10.1126/scitranslmed.3001399

Boyack, K. W., Klavans, R., & Börner, K. (2005). Mapping the backbone of science. *Scientometrics*, *64*(3), 351–374. https://doi.org/10.1007/s11192-005-0255-6

Bozeman, B. (2003). *Managing the New Multipurpose, Multidiscipline University Research Centers: Institutional Innovation in the Academic Community* (Transforming

Organizationa, pp. 1–60). IBM Center for the Business of Government. http://www.businessofgovernment.org/sites/default/files/UniversityResearchCenter.pdf

Brantley, S. L., McDowell, W. H., Dietrich, W. E., White, T. S., Kumar, P., Anderson, S. P., Chorover, J., Lohse, K. A., Bales, R. C., Richter, D. D., Grant, G., & Gaillardet, J. (2017). Designing a network of critical zone observatories to explore the living skin of the terrestrial Earth. *Earth Surface Dynamics*, *5*(4), 841. https://doi.org/10.5194/esurf-5-841-2017

Chen, K., Zhang, Y., & Fu, X. (2019). International research collaboration: An emerging domain of innovation T studies? *Research Policy*, *48*, 149–168.

Clauset, A., Newman, M. E. J., & Moore, C. (2004). Finding community structure in very large networks. *Physical Review E*, *70*(6), 066111. https://doi.org/10.1103/PhysRevE.70.066111

Coccia, M., & Wang, L. (2016). Evolution and convergence of the patterns of international scientific collaboration. *Proceedings of the National Academy of Sciences*, *113*(8), 2057–2061. https://doi.org/10.1073/pnas.1510820113

Cochrane, L., Cundill, G., Ludi, E., New, M., Nicholls, R. J., Wester, P., Cantin, B., Murali, K. S., Leone, M., Kituyi, E., & Landry, M. (2017). A reflection on collaborative adaptation research in Africa and Asia. *Regional Environmental Change; Dordrecht*, *17*(5), 1553–1561. http://dx.doi.org.er.lib.k-state.edu/10.1007/s10113-017-1140-6

Coddington, J. A., Barker, K., Droege, G., Astrin, J. J., Bartels, P., Butler, C., Cantrill, D., Forest, F., Gemeinholzer, B., Hobern, D., Mackenzie-Dodds, J., Tuama, É. Ó., Petersen, G., Sanjur, O. I., Schindel, D. E., & Seberg, O. (2014). GGBN: Making Genomic Collections Discoverable for Research through a Networked Community of Biodiversity Repositories. In *DNA Banking for the 21st Century, edited by Applequist, W. A. and Campbell, L. M.* http://repository.si.edu/xmlui/handle/10088/30885

Cruz-Castro, L., & Sanz-Menéndez, L. (2020). *Grant Allocation Disparities from a Gender Perspective: Literature Review. Synthesis Report* (D.1.1.; GRANteD Project). CSIC Institute of Public Goods and Policies. https://digital.csic.es/handle/10261/200024

Cundill, G., Currie-Alder, B., & Leone, M. (2019). The future is collaborative. *Nature Climate Change*, *9*(5), 343–345. https://doi.org/10.1038/s41558-019-0447-3

Cundill, Georgina, Harvey, B., Tebboth, M., Cochrane, L., Currie-Alder, B., Vincent, K., Lawn, J., Nicholls, R. J., Scodanibbio, L., Prakash, A., New, M., Wester, P., Leone, M., Morchain, D., Ludi, E., DeMaria-Kinney, J., Khan, A., & Landry, M.-E. (2019). Large-Scale Transdisciplinary Collaboration for Adaptation Research: Challenges and Insights. *Global Challenges*, *3*(4), 1700132. https://doi.org/10.1002/gch2.201700132

Currie-Alder, B., Arvanitis, R., & Hanafi, S. (2018). Research in Arabic-speaking countries: Funding competitions, international collaboration, and career incentives. *Science and Public Policy*, *45*(1), 74–82. https://doi.org/10.1093/scipol/scx048

Currie-Alder, B., Cundill Kemp, G., Scodanibbio, L., Vincent, K., Prakash, A., & Nathe, N. (2019). *Building climate resilience in Africa & Asia: Lessons on organisation, management & collaboration from research consortia* [Working Paper]. IDRC. https://idl-bnc-idrc.dspacedirect.org/handle/10625/57587

De Dreu, C. K. W., & West, M. A. (2001). Minority dissent and team innovation: The importance of participation in decision making. *Journal of Applied Psychology*, *86*(6), 1191–1201. https://doi.org/10.1037/0021-9010.86.6.1191

D'Ippolito, B., & Ruling, C.-C. (2019). Research collaboration in Large Scale Research Infrastructures: Collaboration types and policy implications. *Research Policy*, *48*, 1282–1296.

EFSA (European Food Safety Authority. (2015). *Annual report of the Scientific Network on Microbiological Risk Assessment 2015* (No. 2015:EN-914; EFSA Supporting Publication, p. 14).

Falk-Krzesinski, H. J., Börner, K., Contractor, N., Fiore, S. M., Hall, K. L., Keyton, J., Spring, B., Stokols, D., Trochim, W., & Uzzi, B. (2010). Advancing the Science of Team Science. *Clinical and Translational Science*, *3*(5), 263–266. https://doi.org/10.1111/j.1752-8062.2010.00223.x

Falk-Krzesinski, H. J., Contractor, N., 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*, *20*(2), 145–158. https://doi.org/10.3152/095820211X12941371876580

Fischer, B. B., Queiroz, S., & Vonortas, N. S. (2018). On the location of knowledge-intensive entrepreneurship in developing countries: Lessons from São Paulo, Brazil. *Entrepreneurship & Regional Development*, *30*(5/6), 612–638. https://doi.org/10.1080/08985626.2018.1438523

Fortunato, S., Bergstrom, C. T., Börner, K., Evans, J. A., Helbing, D., Milojević, S., Petersen, A. M., Radicchi, F., Sinatra, R., Uzzi, B., Vespignani, A., Waltman, L., Wang, D., & Barabási, A.-L. (2018). Science of science. *Science*, *359*(6379). https://doi.org/10.1126/science.aao0185

Franco, M., & Pinho, C. (2019). A case study about cooperation between University Research Centres: Knowledge transfer perspective. *Journal of Innovation & Knowledge*, *4*(1), 62–69. https://doi.org/10.1016/j.jik.2018.03.003

Franzoni, C., & Sauermann, H. (2014). Crowd science: The organization of scientific research in open collaborative projects. *Research Policy*, *43*(1), 1–20. https://doi.org/10.1016/j.respol.2013.07.005

Fu, B., Li, S., Yu, X., Yang, P., Yu, G., Feng, R., & Zhuang, X. (2010). Chinese ecosystem research network: Progress and perspectives. *Ecological Complexity*, *7*(2), 225–233. https://doi.org/10.1016/j.ecocom.2010.02.007

Gaillardet, J., Braud, I., Hankard, F., Anquetin, S., Bour, O., Dorfliger, N., Dreuzy, J. R. de, Galle, S., Galy, C., Gogo, S., Gourcy, L., Habets, F., Laggoun, F., Longuevergne, L., Borgne, T. L., Naaim-Bouvet, F., Nord, G., Simonneaux, V., Six, D., … Zitouna, R. (2018). OZCAR: The French Network of Critical Zone Observatories. *Vadose Zone Journal*, *17*(1), 180067. https://doi.org/10.2136/vzj2018.04.0067

Global Land Programme. (2020). *Our History | Global Land Programme*. The Evolution of the Global Land Program. https://glp.earth/who-we-are/our-history

Goldstein, K. M., Vogt, D., Hamilton, A., Frayne, S. M., Gierisch, J., Blakeney, J., Sadler, A., Bean-Mayberry, B. M., Carney, D., DiLeone, B., Fox, A. B., Klap, R., Yee, E., Romodan, Y., Strehlow, H., Yosef, J., & Yano, E. M. (2018). Practice-based research networks add value to evidence-based quality improvement. *Healthcare*, *6*(2), 128–134. https://doi.org/10.1016/j.hjdsi.2017.06.008

Government of Canada, I. (2017). *Evaluation of the Canadian Institute for Advanced Research – 2017—Audits and evaluations* (Innovation, Science, and Economic Development Canada, pp. 1–33) [Audit Reports]. Canadian Institute for Advanced Research. https://www.ic.gc.ca/eic/site/ae-ve.nsf/eng/h_03844.html

Graf, H., & Kalthaus, M. (2018). International research networks: Determinants of country embeddedness. *Research Policy*, *47*(7), 1198–1214. https://doi.org/10.1016/j.respol.2018.04.001

Guimerà, R., Uzzi, B., Spiro, J., & Amaral, L. A. N. (2005). Team Assembly Mechanisms Determine Collaboration Network Structure and Team Performance. *Science*, *308*(5722), 697–702. https://doi.org/10.1126/science.1106340

Guise, J.-M., Winter, S., Fiore, S. M., Regensteiner, J. G., & Nagel, J. (2017). Organizational and training factors that promote team science: A qualitative analysis and application of theory to the National Institutes of Health's BIRCWH career development program. *Journal of Clinical and Translational Science*, *1*(2), 101–107. https://doi.org/10.1017/cts.2016.17

Hall, K. L., Stokols, D., Moser, R. P., Taylor, B. K., Thornquist, M. D., Nebeling, L. C., Ehret, C. C., Barnett, M. J., McTiernan, A., Berger, N. A., Goran, M. I., & Jeffery, R. W. (2008). The Collaboration Readiness of Transdisciplinary Research Teams and Centers: Findings from the National Cancer Institute's TREC Year-One Evaluation Study. *American Journal of Preventive Medicine*, *35*(2, Supplement), S161–S172. https://doi.org/10.1016/j.amepre.2008.03.035

Harris, J. K., Provan, K. G., Johnson, K. J., & Leischow, S. J. (2012). Drawbacks and benefits associated with inter-organizational collaboration along the discovery-development-delivery continuum: A cancer research network case study. *Implementation Science*, *7*(1), 69. https://doi.org/10.1186/1748-5908-7-69

Harvey, B., Cochrane, L., & Epp, M. V. (2019). Charting knowledge co-production pathways in climate and development. *Environmental Policy and Governance*, *29*(2), 107–117. https://doi.org/10.1002/eet.1834

Huang, J. S. (2014). Building Research Collaboration Networks—An Interpersonal Perspective for Research Capacity Building. *The Journal of Research Administration*, *45*(2), 89–112.

INSciTS. (2020). *Science of Team Science Library*. Building the Knowledge Base for Effective Team Science. https://www.inscits.org/scits-library

International Institute for Applied Systems Analysis. (2019). *Annual Report 2018*. https://iiasa.ac.at/

Jacob, M., & Meek, V. L. (2013). Scientific mobility and international research networks: Trends and policy tools for promoting research excellence and capacity building. *Studies in Higher Education*, *38*(3), 331–344. https://doi.org/10.1080/03075079.2013.773789

Jasanoff, S. (2004). *States of Knowledge: The Co-Production of Science and the Social Order*. Routledge.

Jeong, S., Choi, J. Y., & Kim, J.-Y. (2014). On the drivers of international collaboration: The impact of informal communication, motivation, and research resources. *Science and Public Policy*, *41*(4), 520–531. https://doi.org/10.1093/scipol/sct079

Kahn, R. (1994). Interdisciplinary Collaborations Are A Scientific And Social Imperative. *The Scientist Magazine*. https://www.the-scientist.com/opinion-old/interdisciplinary-collaborations-are-a-scientific-and-social-imperative-59085

Knecht, F., Spiesberger, M., & Carrieri, S. (2019). *COST European Cooperation in Science & Technology: Impact assessment study* (No. 19003; p. 77). Erdyn- ZSI (Center for Social Innovation). https://www.cost.eu/wp-content/uploads/2019/09/Targeted-impact-assessment-on-career-development.pdf

Kwiek, M., & Roszka, W. (2020). Gender Disparities in International Research Collaboration: A Large-scale Bibliometric Study of 25,000 University Professors. *ArXiv:2003.00537 [Cs]*. http://arxiv.org/abs/2003.00537

Kwiek, P. M. (2019). Internationalists and Locals: International Research Collaboration in Resource- Poor Systems. *Scientometrics*, *Preprint*, 44.

Kyvik, S., & Reymert, I. (2017). Research collaboration in groups and networks: Differences across academic fields. *Scientometrics*, *113*(2), 951–967. https://doi.org/10.1007/s11192-017-2497-5

Leahey, E. (2016). From Sole Investigator to Team Scientist: Trends in the Practice and Study of Research Collaboration | Annual Review of Sociology. *Annual Review of Sociology*, *42*, 81–100.

Leite, D., & Pinho, I. (2016). *Evaluating Collaboration Networks in Higher Education Research: Drivers of Excellence*. Springer.

Lendemer, J., Thiers, B., Monfils, A. K., Zaspel, J., Ellwood, E. R., Bentley, A., LeVan, K., Bates, J., Jennings, D., Contreras, D., Lagomarsino, L., Mabee, P., Ford, L. S., Guralnick, R., Gropp, R. E., Revelez, M., Cobb, N., Seltmann, K., & Aime, M. C. (2020). The Extended Specimen Network: A Strategy to Enhance US Biodiversity Collections, Promote Research and Education. *BioScience*, *70*(1), 23–30. https://doi.org/10.1093/biosci/biz140

Leung, R. C. (2013). Networks as sponges: International collaboration for developing nanomedicine in China. *Research Policy*, *42*(1), 211–219. https://doi.org/10.1016/j.respol.2012.05.001

Leydesdorff, L., Wagner, C. S., & Bornmann, L. (2019). Interdisciplinarity as diversity in citation patterns among journals: Rao-Stirling diversity, relative variety, and the Gini coefficient. *Journal of Informetrics*, *13*(1), 255–269. https://doi.org/10.1016/j.joi.2018.12.006

Li, Y., Li, H., Liu, N., & Liu, X. (2018). Important institutions of interinstitutional scientific collaboration networks in materials science. *Scientometrics*, *117*(1), 85–103. https://doi.org/10.1007/s11192-018-2837-0

Liao, C. H. (2010). How to improve research quality? Examining the impacts of collaboration intensity and member diversity in collaboration networks. *Scientometrics*, *86*(3), 747–761. https://doi.org/10.1007/s11192-010-0309-2

Marino, A. H., Suda-Blake, K. A., & Fulton, K. R. (2019). Innovative Collaboration Formation: The National Academies Keck Futures Initiative. In K. L. Hall, A. L. Vogel, & R. T. Croyle (Eds.), *Strategies for Team Science Success: Handbook of Evidence-Based Principles for Cross-Disciplinary Science and Practical Lessons Learned from Health Researchers* (pp. 241–250). Springer International Publishing. https://doi.org/10.1007/978-3-030-20992-6_18

Mohrman, S., Galbraith, J., & Monge, P. (2006). Network Attributes Impacting the Generation and Flow of Knowledge within and from the Basic Science Community. In *Innovation, Science, and Institutional Change: A Research Handbook Edited by Jerald Hage and Marius Meeus*. OUP Oxford.

Moock, J. L. (2011). *Network Innovations: Building the Next Generation of Agricultural Scientists in Africa* (Agricultural R&D: Investing in Africa’s Future). ASTI-IFPRI/FARA.

Moock, J. L. (2016). *Network Innovations: Building the Next Generation of Agricultural Scientists in Africa* (Chapter 10; 0 ed., Agricultural Research in Africa: Investing in Future Harvests). International Food Policy Research Institute. https://doi.org/10.2499/9780896292123

National Cancer Institute. (2020). *Team Science Toolkit*. https://www.teamsciencetoolkit.cancer.gov/Public/Home.aspx

National Institute of Food and Agriculture. (2016). *AFRI Annual Review: Agriculture and Food Research Initiative (AFRI) | National Institute of Food and Agriculture*. National Institute of Food and Agriculture. https://nifa.usda.gov/program/agriculture-and-food-research-initiative-afri

Newman, M. E. J. (2001). The structure of scientific collaboration networks. *Proceedings of the National Academy of Sciences*, *98*(2), 404–409. https://doi.org/10.1073/pnas.98.2.404

Newman, M. E. J. (2004). Coauthorship networks and patterns of scientific collaboration. *Proceedings of the National Academy of Sciences*, *101*(suppl 1), 5200–5205. https://doi.org/10.1073/pnas.0307545100

Nielsen, M. (2020). *Reinventing Discovery: The New Era of Networked Science*. Princeton University Press.

Paolino, A. R., Lauf, S. L., Pieper, L. E., Rowe, J., Vargas, I. M., Goff, M. A., Daley, M. F., Tuzzio, L., & Steiner, J. F. (2014). Accelerating Regulatory Progress in Multi-Institutional Research. *EGEMS*, *2*(1). https://doi.org/10.13063/2327-9214.1076

Perianes-Rodriguez, A., & Ruiz-Castillo, J. (2018). The impact of classification systems in the evaluation of the research performance of the Leiden Ranking universities. *Journal of* *the Association for Information Science and Technology*, *69*(8), 1046–1053. https://doi.org/10.1002/asi.24017

Petersen, A. M., Riccaboni, M., Stanley, H. E., & Pammolli, F. (2012). Persistence and uncertainty in the academic career. *Proceedings of the National Academy of Sciences*, *109*(14), 5213–5218. https://doi.org/10.1073/pnas.1121429109

Pina, D. G., Barać, L., Buljan, I., Grimaldo, F., & Marušić, A. (2019). Effects of seniority, gender and geography on the bibliometric output and collaboration networks of European Research Council (ERC) grant recipients. *PLoS ONE*, *14*(2). https://doi.org/10.1371/journal.pone.0212286

Pohl, C., Rist, S., Zimmermann, A., Fry, P., Gurung, G. S., Schneider, F., Speranza, C. I., Kiteme, B., Boillat, S., Serrano, E., Hadorn, G. H., & Wiesmann, U. (2010). Researchers' roles in knowledge co-production: Experience from sustainability research in Kenya, Switzerland, Bolivia and Nepal. *Science & Public Policy (SPP)*, *37*(4), 267–281. https://doi.org/10.3152/030234210X496628

Pomernacki, A., Carney, D. V., Kimerling, R., Nazarian, D., Blakeney, J., Martin, B. D., Strehlow, H., Yosef, J., Goldstein, K. M., Sadler, A. G., Bean-Mayberry, B. A., Bastian, L. A., Bucossi, M. M., McLean, C., Sonnicksen, S., Klap, R., Yano, E. M., & Frayne, S. M. (2015). Lessons from Initiating the First Veterans Health Administration (VA) Women's Health Practice-based Research Network (WH-PBRN) Study. *The Journal of the American Board of Family Medicine*, *28*(5), 649–657. https://doi.org/10.3122/jabfm.2015.05.150029

Qualls, L. G., Phillips, T. A., Hammill, B. G., Topping, J., Louzao, D. M., Brown, J. S., Curtis, L. H., & Marsolo, K. (n.d.). Evaluating Foundational Data Quality in the National Patient-Centered Clinical Research Network (PCORnet®). *EGEMs*, *6*(1). https://doi.org/10.5334/egems.199

Radosevic, S., & Yoruk, E. (2014). Are there global shifts in the world science base? Analysing the catching up and falling behind of world regions. *Scientometrics*, *101*(3), 1897–1924. https://doi.org/10.1007/s11192-014-1344-1

Rahm, A. K., Ladd, I., Burnett-Hartman, A. N., Epstein, M. M., Lowery, J. T., Lu, C. Y., Pawloski, P. A., Sharaf, R. N., Liang, S.-Y., & Hunter, J. E. (n.d.). The Healthcare Systems Research Network (HCSRN) as an Environment for Dissemination and Implementation Research: A Case Study of Developing a Multi-Site Research Study in Precision Medicine. *EGEMs*, *7*(1). https://doi.org/10.5334/egems.283

Rose, R. M. (n.d.). *A Guide to Conceiving, Organizing, Implementing, and Monitoring Interdisciplinary Research Networks* (Finding Answers to Big Questions: Overcoming Disciplinary Boundaries Through Research Networks, pp. 1–25). MacArthur Foundation. https://www.macfound.org/media/files/RoseNetworkMonograph.pdf

Rose, R., & Prager, D. (2009). The Value of Interdisciplinary Research Networks. *Views Form the Field*, 2.

Rosenfield, P. L. (1992). The potential of transdisciplinary research for sustaining and extending linkages between the health and social sciences. *Social Science & Medicine*, *35*(11), 1343–1357. https://doi.org/10.1016/0277-9536(92)90038-R

Steiner, J. F., Paolino, A. R., Thompson, E. E., & Larson, E. B. (2014). Sustaining Research Networks: The Twenty-Year Experience of the HMO Research Network. *EGEMs*, *2*(2). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4371441/

Stirling, A. (2007). A general framework for analysing diversity in science, technology and society. *Journal of The Royal Society Interface*, *4*(15), 707–719. https://doi.org/10.1098/rsif.2007.0213

Stokols, D., Misra, S., Moser, R. P., Hall, K. L., & Taylor, B. K. (2008). The Ecology of Team Science: Understanding Contextual Influences on Transdisciplinary Collaboration. *American Journal of Preventive Medicine*, *35*(2, Supplement), S96–S115. https://doi.org/10.1016/j.amepre.2008.05.003

Subklew, G., Ulrich, J., Fürst, L., & Höltkemeier, A. (2010). Environmental impacts of the Yangtze Three Gorges project: An overview of the Chinese-German research cooperation. *Journal of Earth Science; Dordrecht*, *21*(6), 817–823. http://dx.doi.org.er.lib.k-state.edu/10.1007/s12583-010-0133-x

Sugimoto, C. R., Robinson-Garcia, N., Murray, D. S., Yegros-Yegros, A., Costas, R., & Larivière, V. (2017). Scientists have most impact when they're free to move. *Nature*, *550*(7674), 29–31. https://doi.org/10.1038/550029a

Syme, S. L. (2008). The Science of Team Science: Assessing the Value of Transdisciplinary Research. *American Journal of Preventive Medicine*, *35*(2), S94–S95. https://doi.org/10.1016/j.amepre.2008.05.017

The InterAcademy Partnership. (2020a). *InterAcademy Council*. IAP. https://interacademies.org/34864/InterAcademy-Council

The InterAcademy Partnership. (2020b). *The InterAcademy Partnership: Science, Heath, Policy*. IAP. http://interacademies.org/31840/About

The National Academies. (2020). *Science, Engineering, & Medicine: Working Toward a Better World- International activities of the U.S. National Academies*. https://sites.nationalacademies.org/International/INTERNATIONAL_051878

UKRI. (2019). *Global Research Hubs tackle world's toughest challenges—UK Research and Innovation*. UK Research and Innovation. https://www.ukri.org/news/global-research-hubs/

Ulnicane, I. (2015). Why do international research collaborations last? Virtuous circle of feedback loops, continuity and renewal. *Science and Public Policy*, *42*(4), 433–447. https://doi.org/10.1093/scipol/scu060

UNESCO Science Report 2015. (2015). *UNESCO science report: Towards 2030—UNESCO Digital Library* (pp. 1–40). https://unesdoc.unesco.org/ark:/48223/pf0000235406

Uwituze, S., Chindime, M. S., Osiru, M., & Adipala, E. (2016). *Building capacity of African Universities to train proactive graduates through partnerships: The case of RUFORUM and Carnegie*. Regional Universities Forum for Capacity Building in Agriculture (RUFORUM); RUFORUM Working Document Series (ISSN 1607-9345) No. 14 (1): 185-196. https://repository.ruforum.org/

Uzzi, B., Mukherjee, S., Stringer, M., & Jones, B. (2013). Atypical Combinations and Scientific Impact. *Science*, *342*(6157), 468–472. JSTOR.

Vanderbilt, K., & Gaiser, E. (2017). The International Long Term Ecological Research Network: A platform for collaboration. *Ecosphere*, *8*(2), e01697. https://doi.org/10.1002/ecs2.1697

Vanderlinden, J.-P., Baztan, J., Chouinard, O., Cordier, M., Da Cunha, C., Huctin, J.-M., Kane, A., Kennedy, G., Nikulkina, I., Shadrin, V., Surette, C., Thiaw, D., & Thomson, K. T. (2020). Meaning in the face of changing climate risks: Connecting agency, sensemaking and narratives of change through transdisciplinary research. *Climate Risk Management*, *29*, 100224. https://doi.org/10.1016/j.crm.2020.100224

Wagner, C. S. (2011). The Shifting Landscape of Science. *Issues in Science and Technology*, *28*(1), 77–81. JSTOR.

Wagner, C. S. (2018). *The Collaborative Era in Science: Governing the Network* (C. S. Wagner, Ed.). Springer International Publishing. https://doi.org/10.1007/978-3-319-94986-4_9

Wagner, C. S., & Jonkers, K. (2017). Open countries have strong science. *Nature News*, *550*(7674), 32. https://doi.org/10.1038/550032a

Wagner, C. S., & Leydesdorff, L. (2009). Network Structure, Self-Organization and the Growth of International Collaboration in Science. *ArXiv:0911.4299 [Physics]*. http://arxiv.org/abs/0911.4299

Wagner, C. S., Park, H. W., & Leydesdorff, L. (2015). The Continuing Growth of Global Cooperation Networks in Research: A Conundrum for National Governments. *PLoS ONE*, *10*(7). https://doi.org/10.1371/journal.pone.0131816

Wagner, C. S., Roessner, J. D., Bobb, K., Klein, J. T., Boyack, K. W., Keyton, J., Rafols, I., & Börner, K. (2011). Approaches to understanding and measuring interdisciplinary scientific research (IDR): A review of the literature. *Journal of Informetrics*, *5*(1), 14–26. https://doi.org/10.1016/j.joi.2010.06.004

Wagner, C. S., Whetsell, T. A., & Leydesdorff, L. (2017). Growth of international collaboration in science: Revisiting six specialties. *Scientometrics*, *110*(3), 1633–1652. https://doi.org/10.1007/s11192-016-2230-9

Wagner, C. S., Whetsell, T. A., & Mukherjee, S. (2019). International research collaboration: Novelty, conventionality, and atypicality in knowledge recombination. *Research Policy*, *48*(5), 1260–1270. https://doi.org/10.1016/j.respol.2019.01.002

Waltman, L., van Eck, N. J., van Leeuwen, T. N., Visser, M. S., & van Raan, A. F. J. (2011). Towards a new crown indicator: Some theoretical considerations. *Journal of Informetrics*, *5*(1), 37–47. https://doi.org/10.1016/j.joi.2010.08.001

Wu, L., Wang, D., & Evans, J. A. (2017). *Large Teams Have Developed Science and Technology; Small Teams Have Disrupted It* (SSRN Scholarly Paper ID 3034125). Social Science Research Network. https://doi.org/10.2139/ssrn.3034125

Young, J. R. (2010, May 28). Crowd Science Reaches New Heights. *The Chronicle of Higher Education*. https://www.chronicle.com/article/The-Rise-of-Crowd-Science/65707

Youtie, J., Shapira, P., Reinsborough, M., & Fisher, E. (2019). Research network emergence: Societal issues in nanotechnology and the center for nanotechnology in society. *Science and Public Policy*, *46*(1), 126–135. https://doi.org/10.1093/scipol/scy043

Zhou, P., & Leydesdorff, L. (2006). The emergence of China as a leading nation in science. *Research Policy*, *35*(1), 83–104. https://doi.org/10.1016/j.respol.2005.08.006

Appendix — Images

Archambault, E. (2010). 30 Years in Science — Secular Movements in Knowledge Creation. *Science Metrix*, 16.

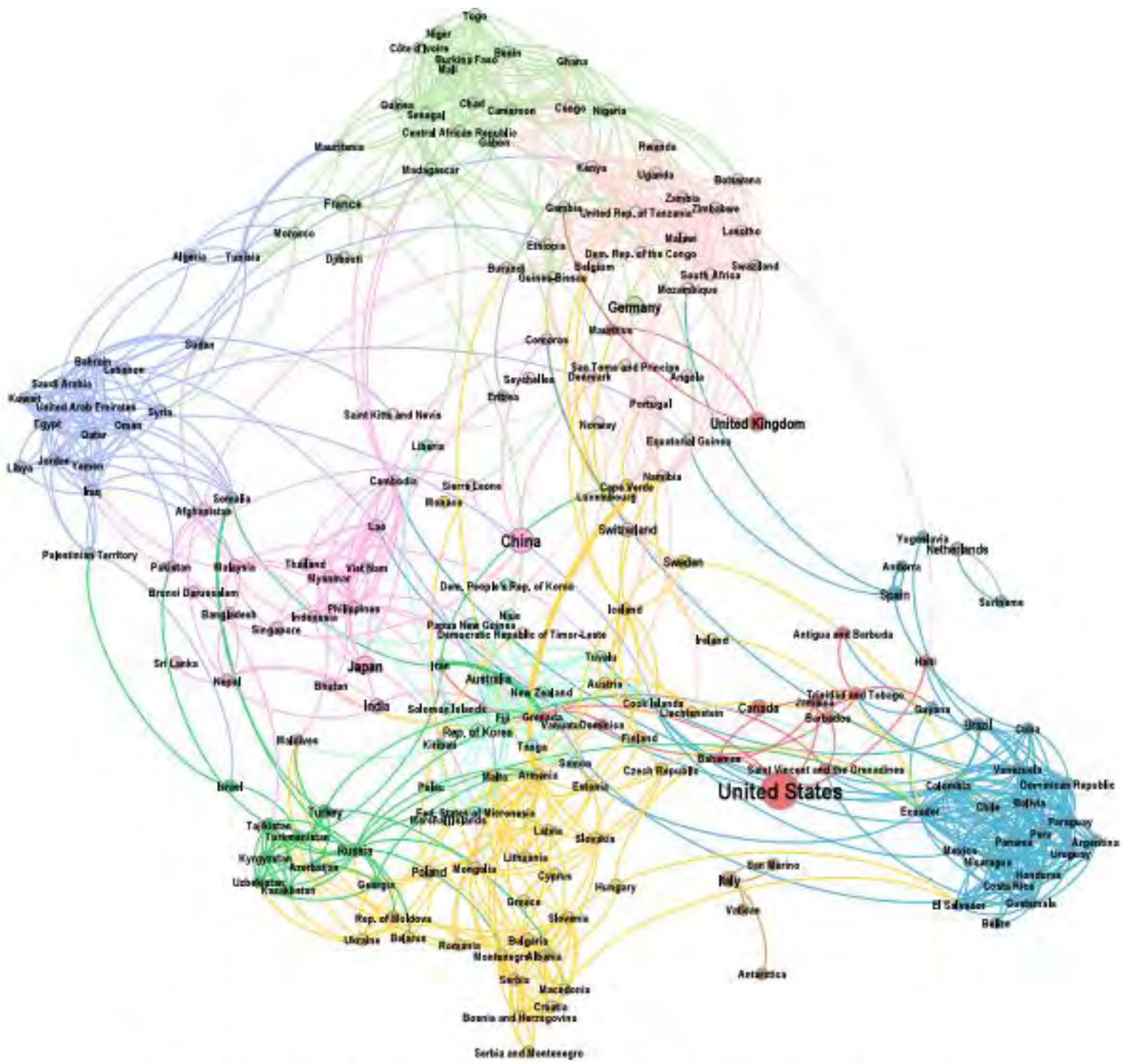


Figure 5. Affinity for international collaboration, 2003-2009 (Scopus)

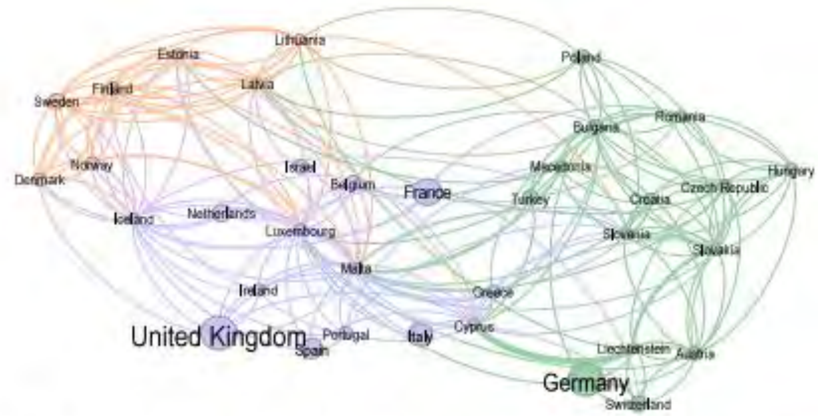


Figure 6. Affinity for intra-European Research Area collaboration, 2003-2009 (Scopus)

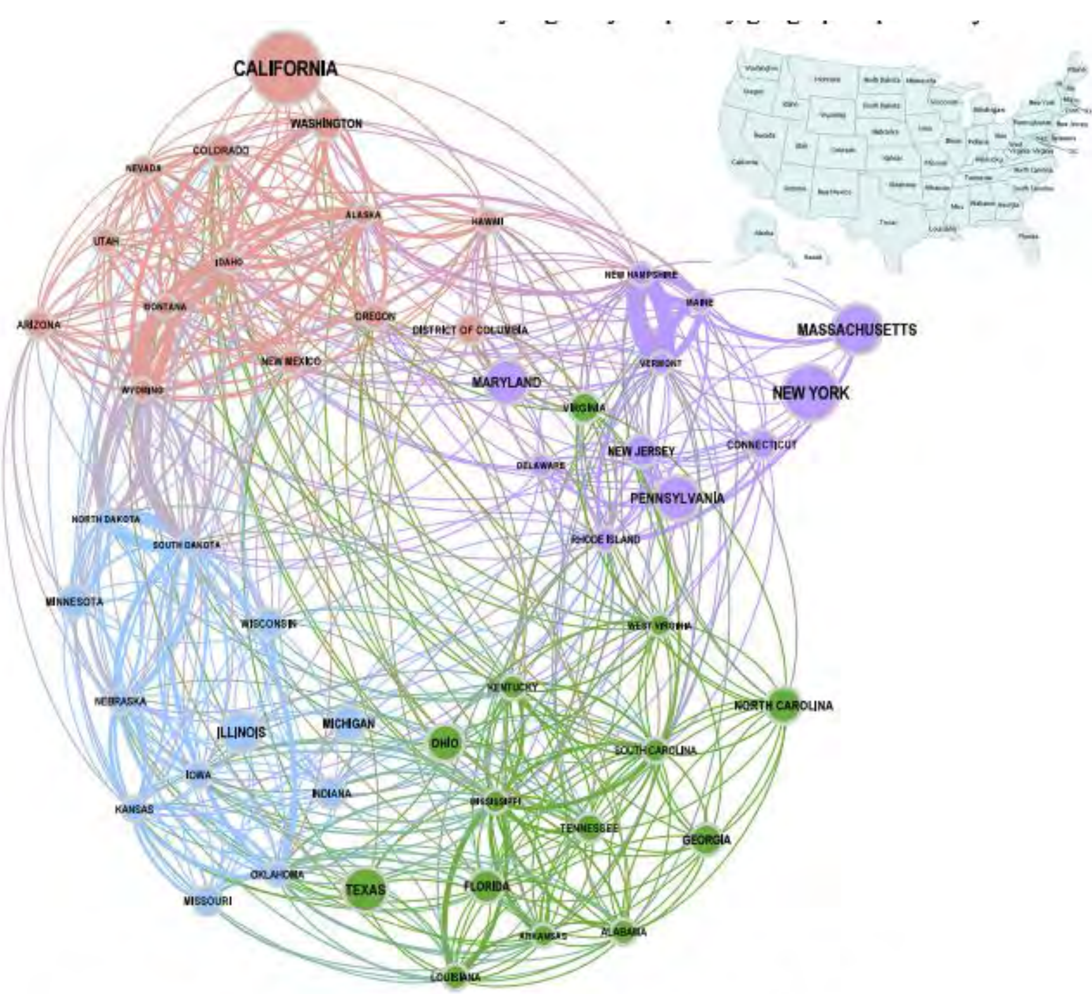


Figure 7. Affinity for Interstate collaboration, USA 2001-2010 (Web of Science)

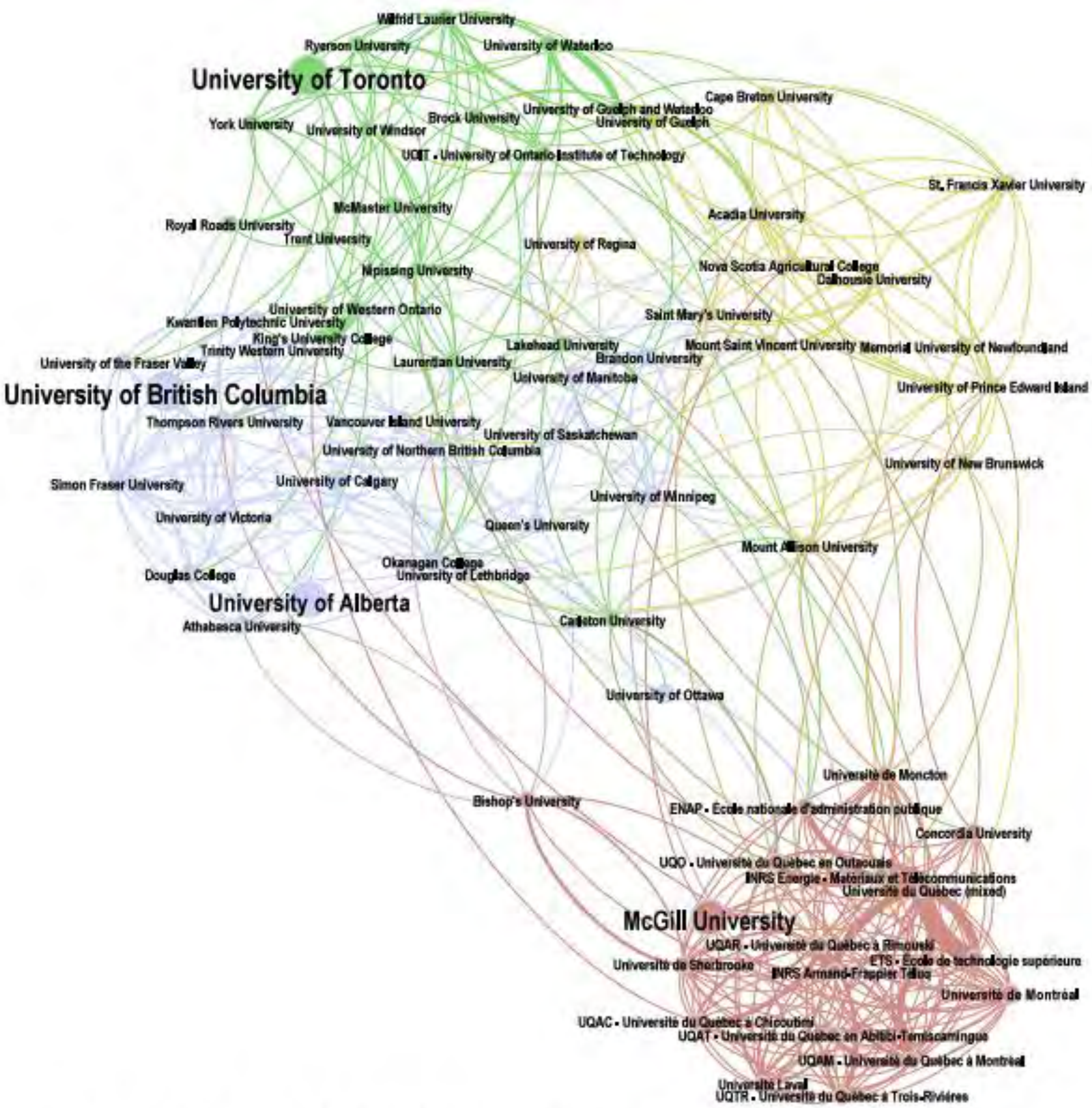


Figure 8. Affinity for inter-university collaboration, Canada, 1996-2009 (Scopus)

Baatz, R., Sullivan, P., Li, L., Weintraub, S., Loescher, H., Mirtl, M., Groffman, P., Wall, D., Young, M., White, T., Wen, H., Zacharias, S., Kühn, I., Tang, J., Gaillardet, J., Braud, I., Flores, A., Kumar, P., Lin, H., … Looy, K. V. (2018). Steering Operational Synergies in Terrestrial Observation Networks: Opportunity for Advancing Earth System Dynamics Modelling. Earth System Dynamics, 9(2), 593–609. http://dx.doi.org/10.5194/esd-9-593-2018

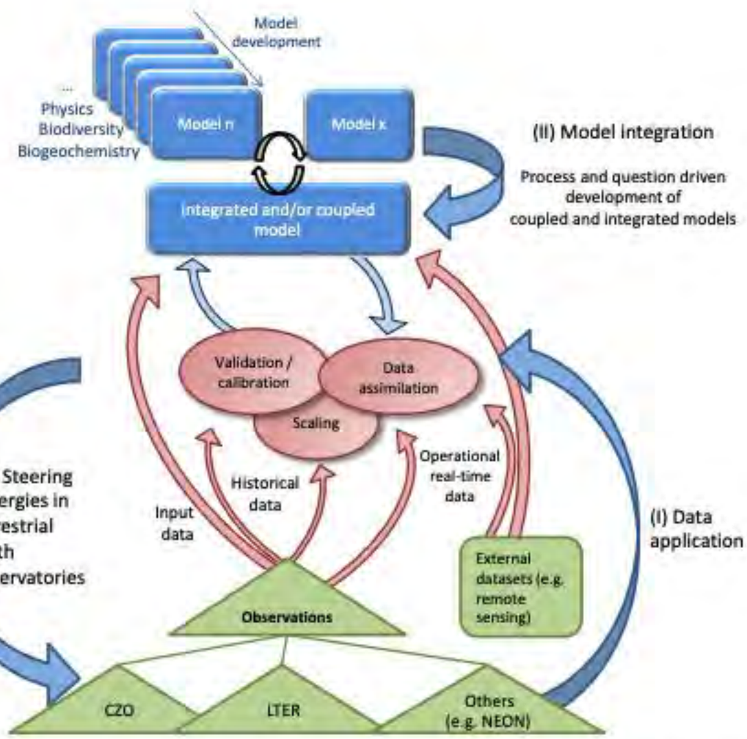


Figure 1. Flowchart of concepts, pathways, and processes of applying terrestrial observatory network data to Earth system dynamics models; identifying the three challenges of (I) data application, (II) model integration, and (III) steering synergies in observation networks.

Boyack, K. W., Klavans, R., & Börner, K. (2005). Mapping the backbone of science. *Scientometrics*, *64*(3), 351–374. https://doi.org/10.1007/s11192-005-0255-6

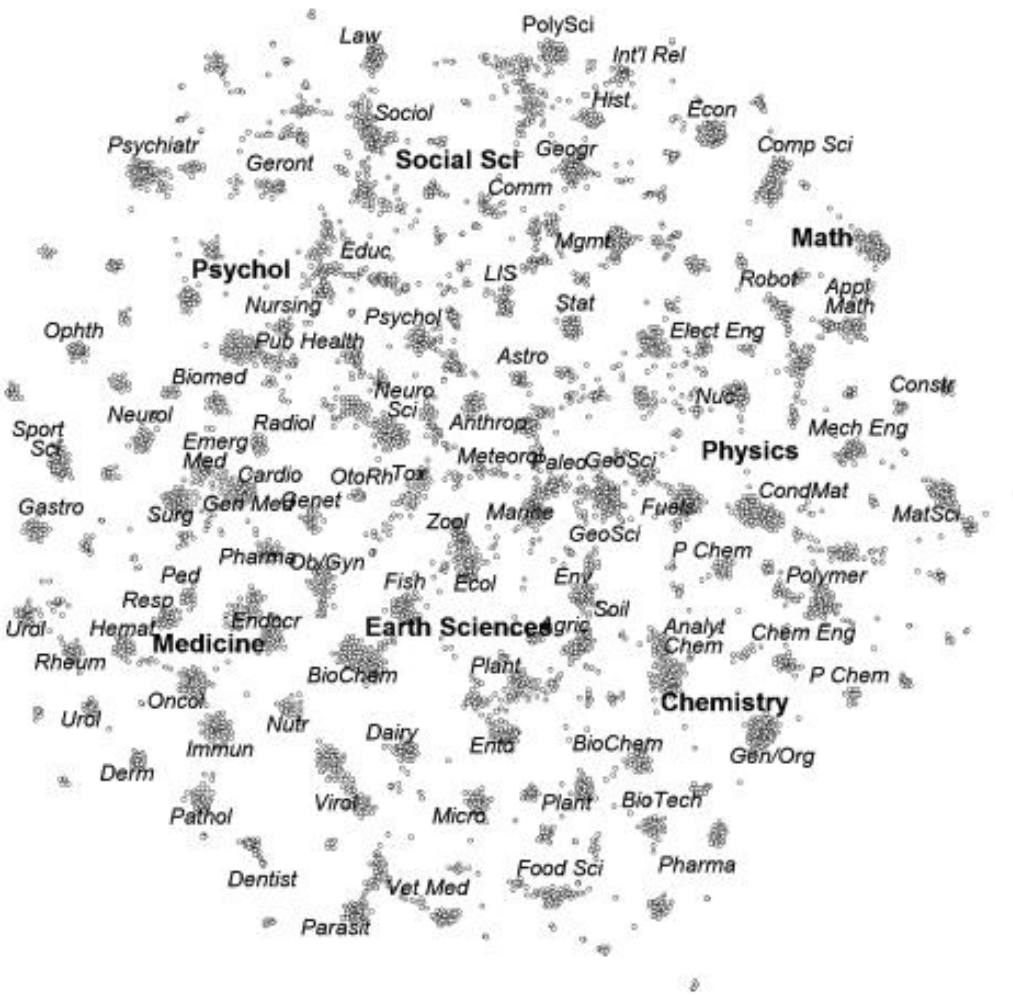


Figure 3. Map of science generated using the CC-K50 similarity measure. The map is comprised of 7,121 journals from year 2000. Large font size labels identify major areas of science. Small labels denote the disciplinary topics of nearby large clusters of journals

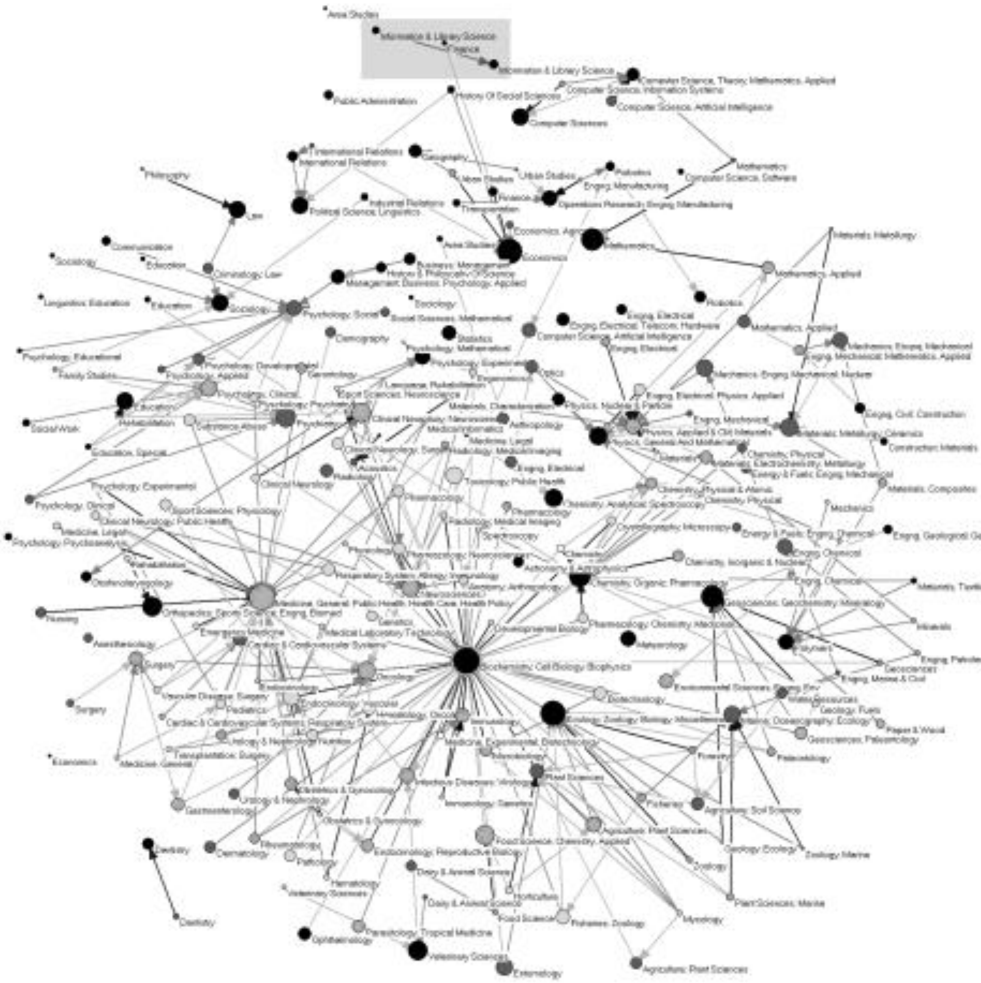


Figure 5. Map of the backbone of science with 212 clusters comprising 7000 journals. Clusters are denoted by circles that are labeled with their dominant ISI category names. Circle sizes (area) denote the number of journals in each cluster. Circle color depicts the independence of each cluster, with darker colors depicting greater independence. Dominant cluster-to-cluster citing patterns are indicated by arrows. Arrows show all relationships where the citing cluster gives more than 7.5% of its total citations to the cited cluster, with darker arrows indicating a greater fraction of citations given by the citing cluster. Some cluster positions have been adjusted slightly to avoid covering labels for neighboring clusters. The gray box near the top shows clusters detailed in Figure 6

Currie-Alder, B., Cundill Kemp, G., Scodanibbio, L., Vincent, K., Prakash, A., & Nathe, N. (2019). *Building climate resilience in Africa & Asia: Lessons on organisation, management & collaboration from research consortia* [Working Paper]. IDRC. https://idl-bnc-idrc.dspacedirect.org/handle/10625/57587

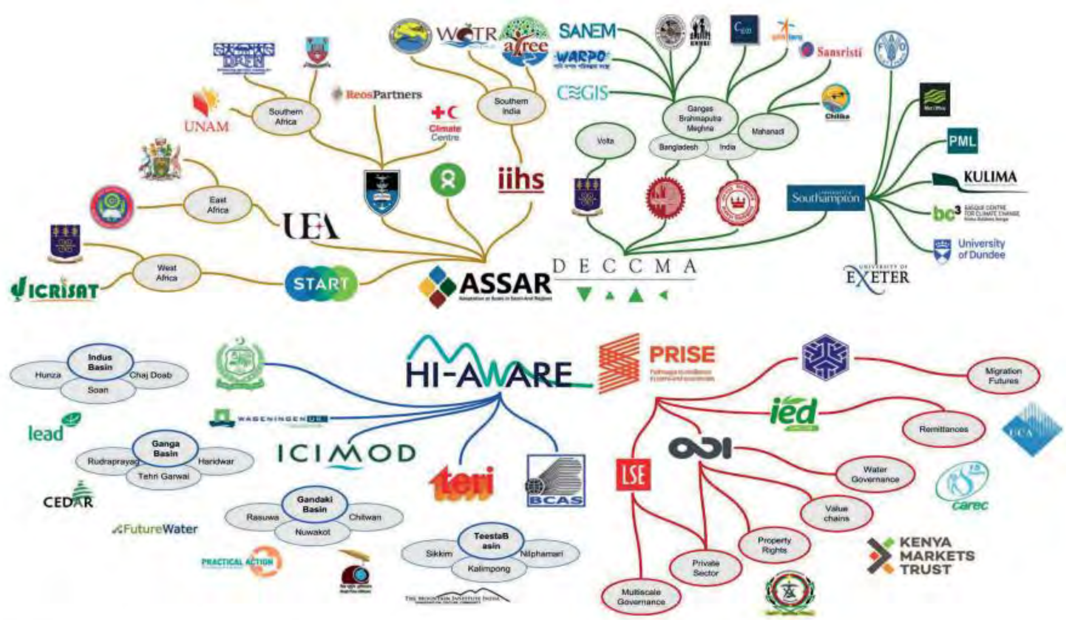
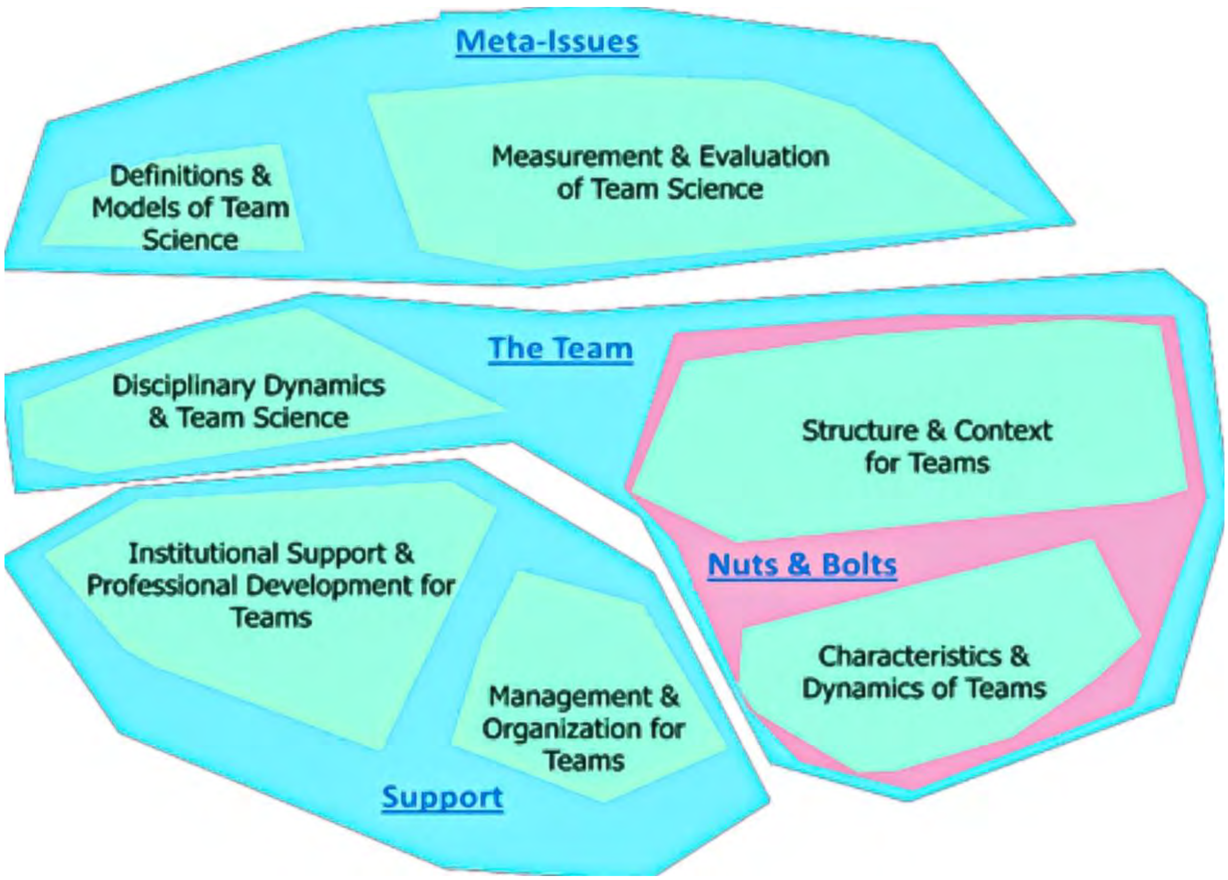


Figure 3: Network of CARIAA structure Each of the consortia involved steering committee of core partners, overseeing diverse activities grouped by either four geographic nodes, or seven research projects (in case of PRISE).

Falk-Krzesinski, H. J., Börner, K., Contractor, N., Fiore, S. M., Hall, K. L., Keyton, J., Spring, B., Stokols, D., Trochim, W., & Uzzi, B. (2010). Advancing the Science of Team Science. *Clinical and Translational Science*, *3*(5), 263–266. https://doi.org/10.1111/j.1752-8062.2010.00223.x



International Institute for Applied Systems Analysis. (2019). ***Annual Report 2018*****. https://iiasa.ac.at/**

Selected impacts

IIASA and partners researched the impacts of **land-use change** and related greenhouse gas emissions from biofuel feedstocks consumed in the European Union (EU). This provided inputs into the revisions of the **EU Renewable Energy Directive**, which introduced biofuel sustainability criteria for all biofuels produced or consumed in the EU.

IIASA published the **Global Energy Assessment** (GEA), the first ever fully integrated assessment of policy measures on energy security, air pollution, and climate change.

IIASA contributed 12 of the lead authors from a total of 91 authors and 133 contributing authors from 40 countries for the **Intergovernmental Panel on Climate Change Special Report on Global Warming of 1.5°C**, which highlights the strong benefits to humanity and ecosystems of keeping global warming to 1.5°C above pre-industrial levels.

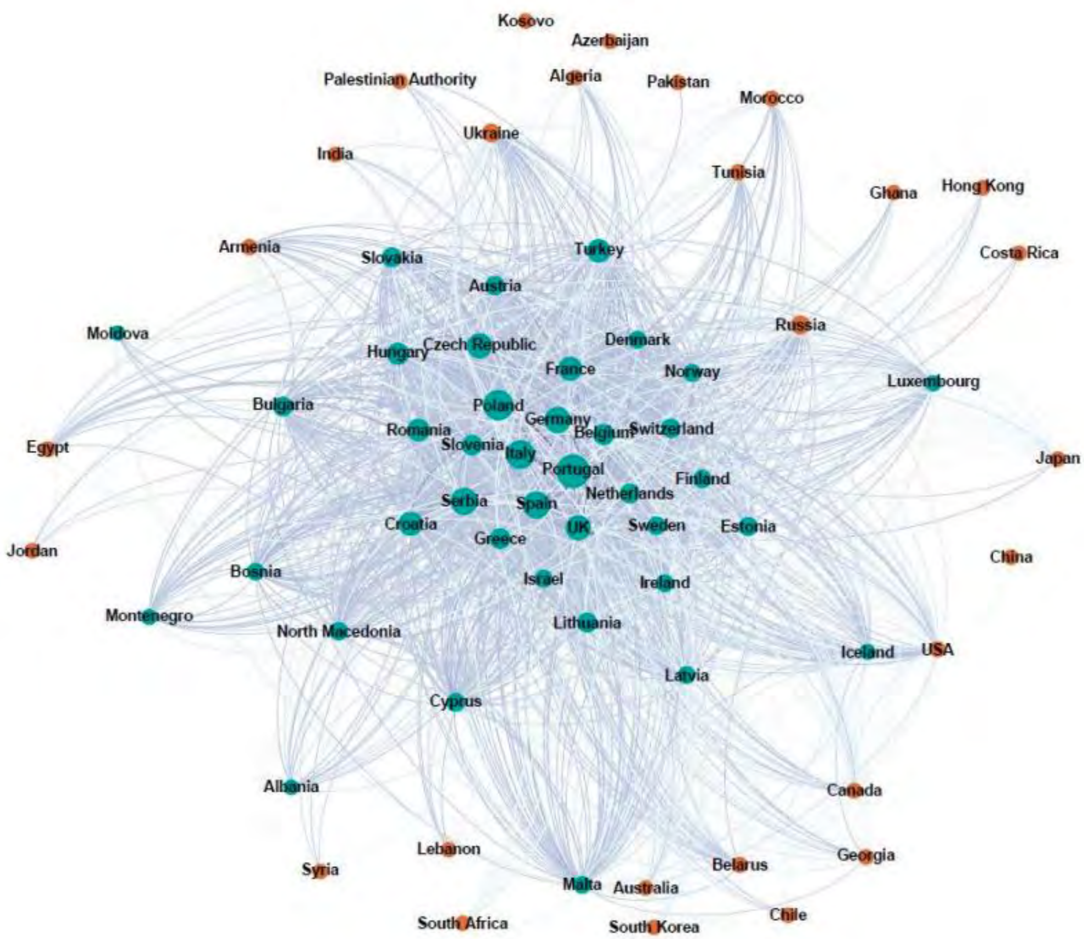
IIASA researchers provided the analysis behind the **European Clean Air policy**, which became law in 2016 and aims to reduce health impacts of pollution by 50% compared to 1990 levels in 2030. The research is based on the **GAINS** model which is being applied in other parts of the world including China, India, and Vietnam.

IIASA codeveloped and hosts the database for the **Representative Concentration Pathways** (RCPs), equipping the climate change research community with common greenhouse gas emissions data.

Analysis from the **IIASA Catastrophe Simulation** (CATSIM) model is being used as part of the rationale for the Loss and Damage Mechanism of the **UN Framework Convention on Climate Change** (UNFCCC).

IIASA developed new measures for understanding population aging that were incorporated by the UN Population Division into UN data and used in the **UN World Population Ageing report 2017.**

Knecht, F., Spiesberger, M., & Carrieri, S. (2019). ***COST European Cooperation in Science & Technology: Impact assessment study*** **(No. 19003; p. 77). Erdyn- ZSI (Center for Social Innovation). https://www.cost.eu/wp-content/uploads/2019/09/Targeted-impact-assessment-on-career-development.pdf**



Network analysis with non-COST countries included

Leite, D., & Pinho, I. (2016). ***Evaluating Collaboration Networks in Higher Education Research: Drivers of Excellence*****. Springer.**

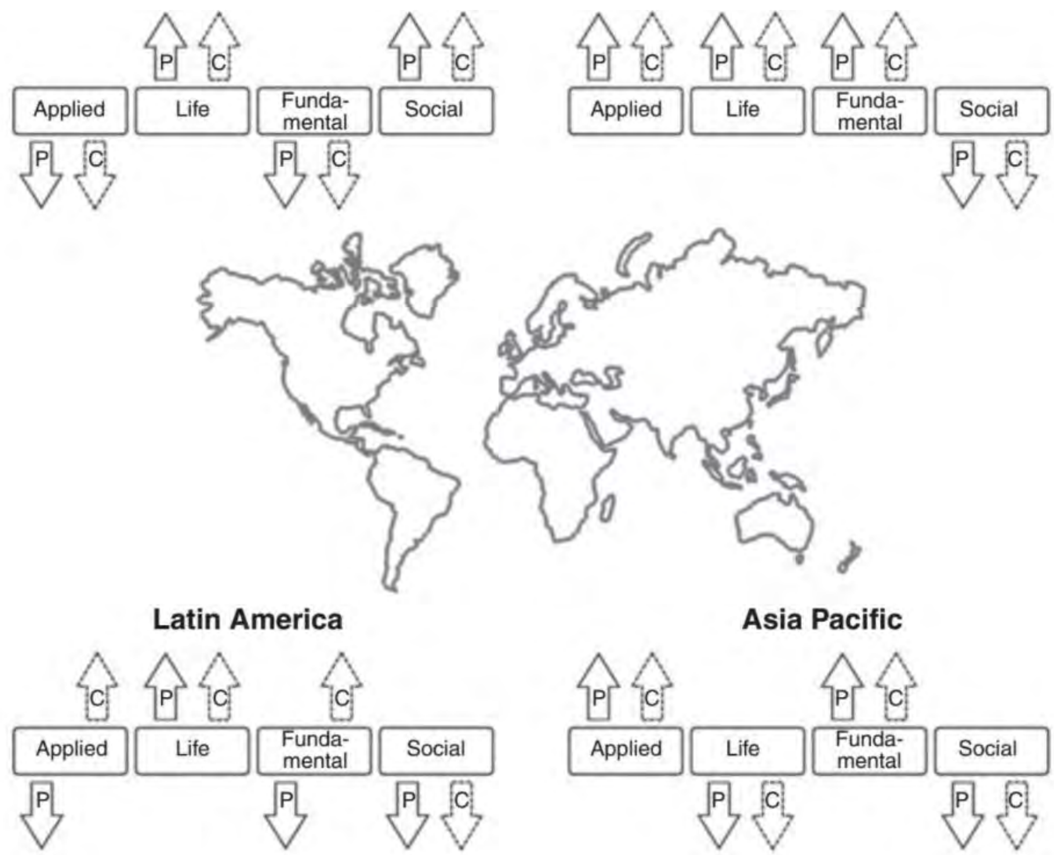


Fig. 1.1 Changing role of the four world regions in major fields of science publications and citations. (*Source*: Based on Radosevic and Yoruk (2014))

Table 5.5 Collaboration indicators: Leiden ranking

Acronym	*Collaboration indicators*
P (collab) and PP (collab)	The number and the proportion of a university's publications that have been coauthored with one or more other organizations
P (int collab) and PP (int collab)	The number and the proportion of a university's publications that have been coauthored by two or more countries
P (industry) and PP (industry)	The number and the proportion of a university's publications that have been coauthored with one or more industrial partners
P (<100 km) and PP (<100 km)	The number and the proportion of a university's publications with a geographical collaboration distance of less than 100 km, where the geographical collaboration distance of a publication equals the largest geographical distance between two addresses mentioned in the publication's address list
P (>5000 km) and PP (>5000 km)	The number and the proportion of a university's publications with a geographical collaboration distance of more than 5000 km

Source: Leiden ranking (2016)

Table 6.3 Micro-level qualitative indicators for RNPE

Indicator	*Description*
Motivation	Themes; publications; network's prestige; personal and epistemological affinities among researchers; taking part in a consolidated group or network.
Interest and competition	Themes; graduate training; laboratories; leader's position and other members' positions in relation to the leader.
Communication	Fluid, permanent, constant; access to knowledge, access to methodologies; ethical principles; information on objectives, findings, results, difficulties and restrictions; critiques
Cohesion	Routine and work division maintenance and balance; personal conflicts management; epistemic clarity; routine and task execution monitoring
Scientific cooperation or collaboration	Continuous, discontinuous, punctual (one-project-only), guided by personal affinities, guided by knowledge complementarity, common projects with diverse entities (firms, universities, foundations, NGOs), bilateral or multilateral cooperation, benefits and fragilities
Interaction	Teamwork: inside the work, teaming-up, each one does their part Horizontal interaction: same or similar-level research topics; same-level agreements Vertical interaction: sequential research; themes between students (apprentice) and researchers (experts) Exchange of ideas, tasks, resources Discussion: individual work (accounts, calculations, equations) brought to the collective discussion—what is to be done; interpretation of findings; new ideas; decisions on what to do with the results; decisions on self-evaluation
Incentives	Rules (and incentives) setting and their divulgation; transparent distribution of financial, organizational, thematic, bibliographic and physical resources; coauthorships
Research themes	Multi, trans, interdisciplinarity; themes diversification; national and international dimensions of the research themes; societal impact of themes
Time	Intragroup production; extragroup collaboration; deadline setting; management and enforcement; time management
Coauthorship policy	Organization and division of tasks; decision about research topics to be exposed; writing responsibilities; authorship order; student presence in articles

Table 6.2 Micro-level quantitative indicators for RNPE

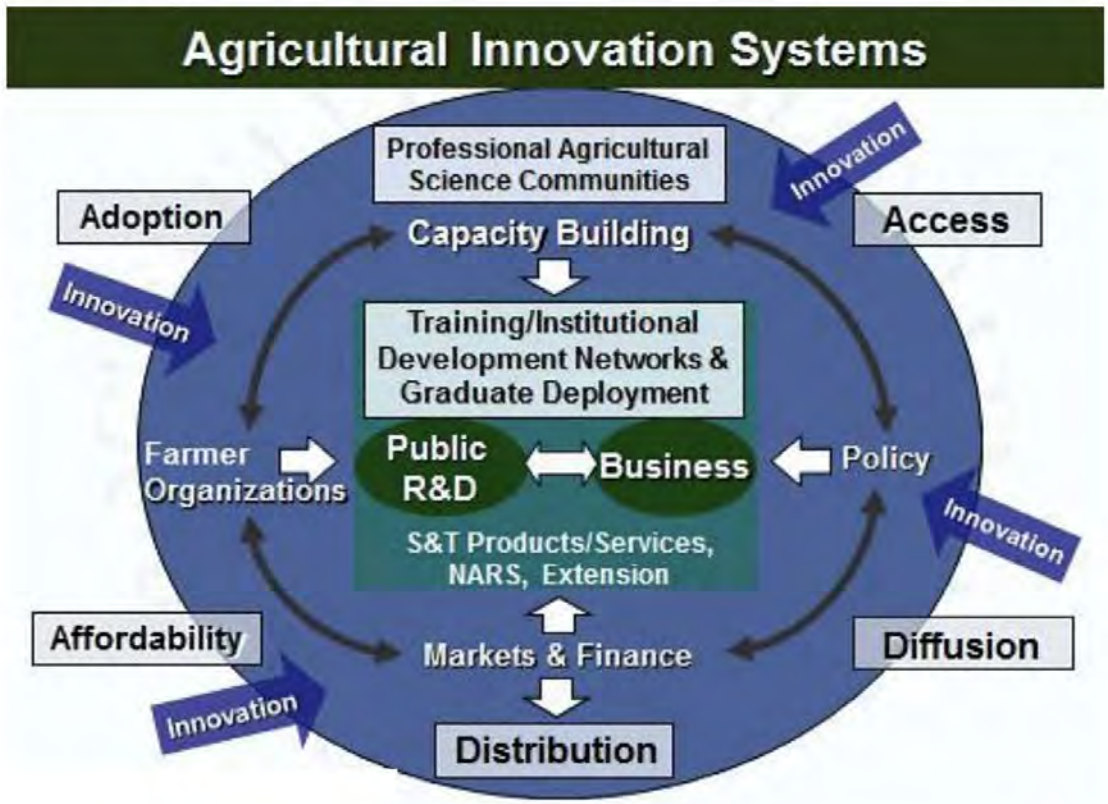
Indicator[a]	*Description*	*Categories*
Network actors	Network's composition according to coauthors' nationality and affiliation or not to the research group	Intragroup collaborators; extragroup domestic collaborators; overseas collaborators
Actors groupings	Group leader's ability to congregate collaborators as evidenced by coauthorships forming subnetworks	Actors linked only to the group leader; actors linked to another coauthor besides the group leader; actors linked to three or more coauthors
Actors' institutions by site	National or international reach of research collaboration, considering the institutions' locations	Domestic institutions; overseas institutions
Actors' institutions by type	Institutional reach of research collaboration considering the linked institutions' missions and goals	Academic institutions; extra-academic institutions (public sector; private sector; third sector)
Articles by number of authors	Absence of extent of collaboration within the network in coauthored articles	Single-authored articles; articles coauthored by number of authors
Articles by publication site	National and international reach of the network's outputs	Number of articles published within the group's country; number of articles published abroad
Journals by location	Geographic reach of the network's outputs considering the variety of the journals' locations	Number of domestic journals in which articles were published; number of foreign journals in which articles were published
Leadership style	Strength of the leader's brokerage role within the network, considering network connectivity	Hierarchical central to decentralize As detected by visual inspection of graphs, in a continuum from most hierarchic to most decentralized
Collaboration intensity	Diversity of relations established within the network	Average degree of the networks' vertices

[a]Our research pointed out that articles are the most useful type of publication on which to base the assessment. However, research managers may find it useful to conduct assessments based on other kinds of research outputs, such as books, books chapters, and conference papers.

Source: Leite et al. (2014b)

Moock, J. L. (2011). *Network Innovations: Building the Next Generation of Agricultural Scientists in Africa* (Agricultural R&D: Investing in Africa's Future). ASTI-IFPRI/FARA.

Figure 2. Capacity building for scientists as a critical part of an agricultural system



Source: Adapted from Morel et al. (2005).

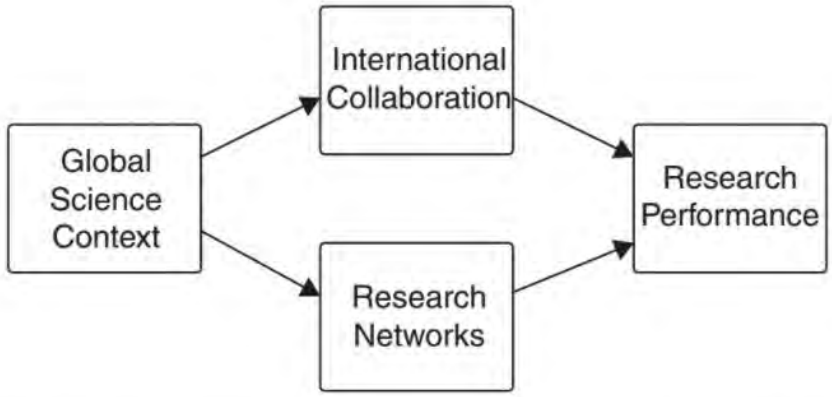


Fig. 1.2 Research performance framework. (*Source*: The authors, 2016)

Network Characteristics

Figure 3 illustrates these components as they relate to well-functioning networks engaged in postgraduate training; to research and institution strengthening in the agricultural sector; and, by extension, to cross-border networks in other fields.

Figure 3. Components of viable network programs under tenuous institutional conditions

Source: Devised by author.

Pohl, C., Rist, S., Zimmermann, A., Fry, P., Gurung, G. S., Schneider, F., Speranza, C. I., Kiteme, B., Boillat, S., Serrano, E., Hadorn, G. H., & Wiesmann, U. (2010). Researchers' roles in knowledge co-production: Experience from sustainability research in Kenya, Switzerland, Bolivia and Nepal. *Science & Public Policy (SPP)*, *37*(4), 267–281. https://doi.org/10.3152/030234210X496628

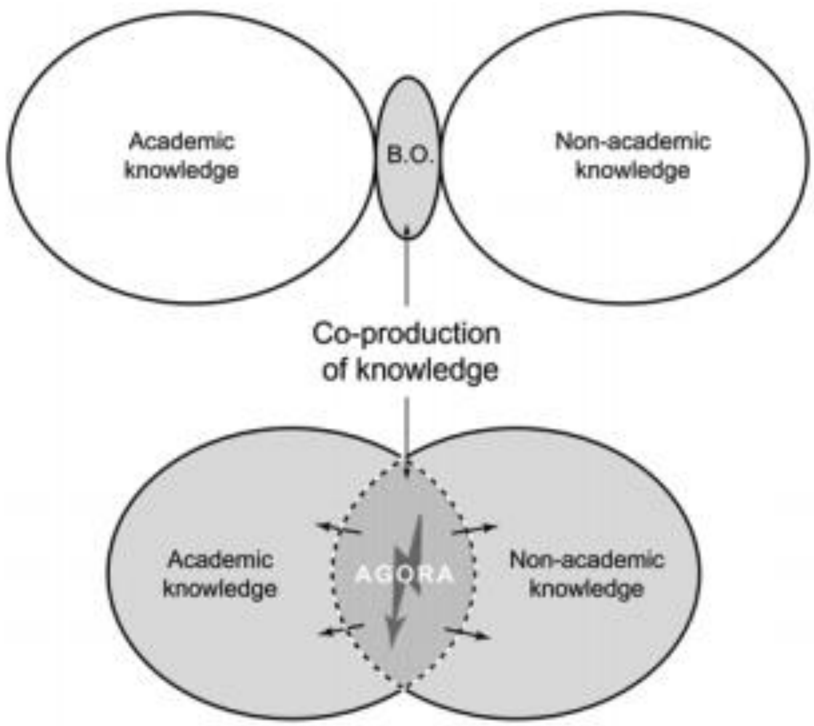
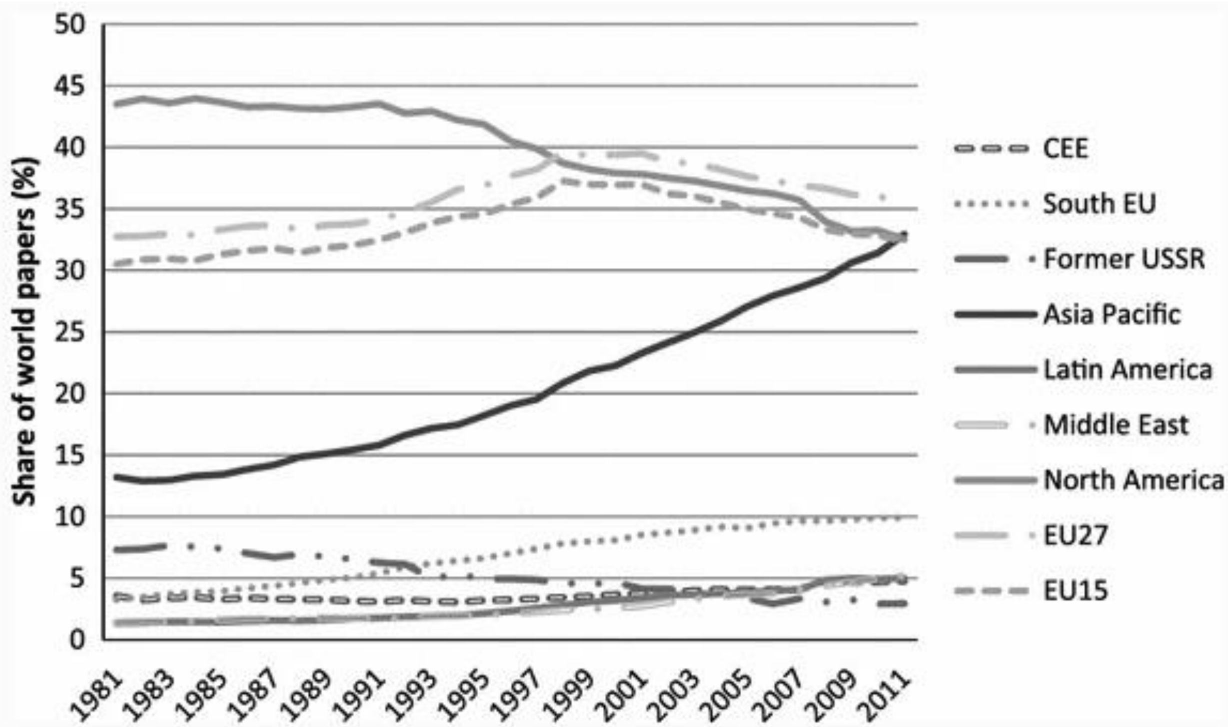
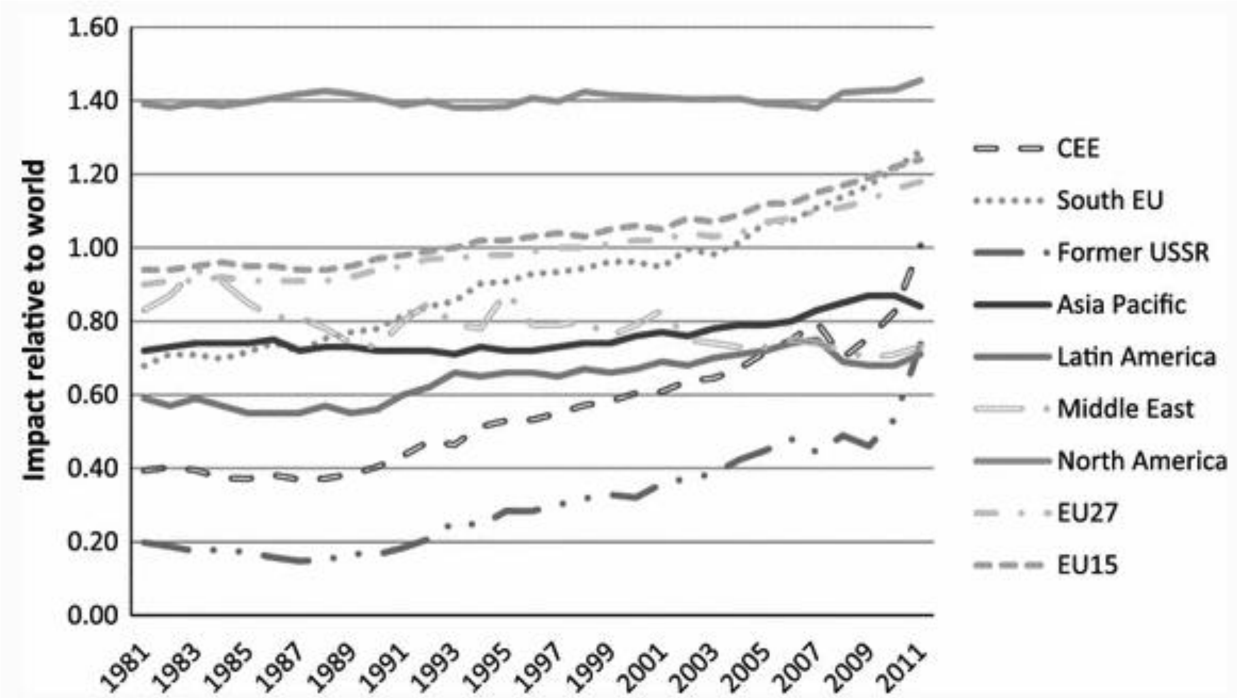


Figure 1. Two approaches to interactive knowledge production: boundary organizations (B.O.) stabilize the boundary between academic and non-academic communities. With co-production of knowledge, both realms are conceived of as overlapping in a permeable space, the *agora*

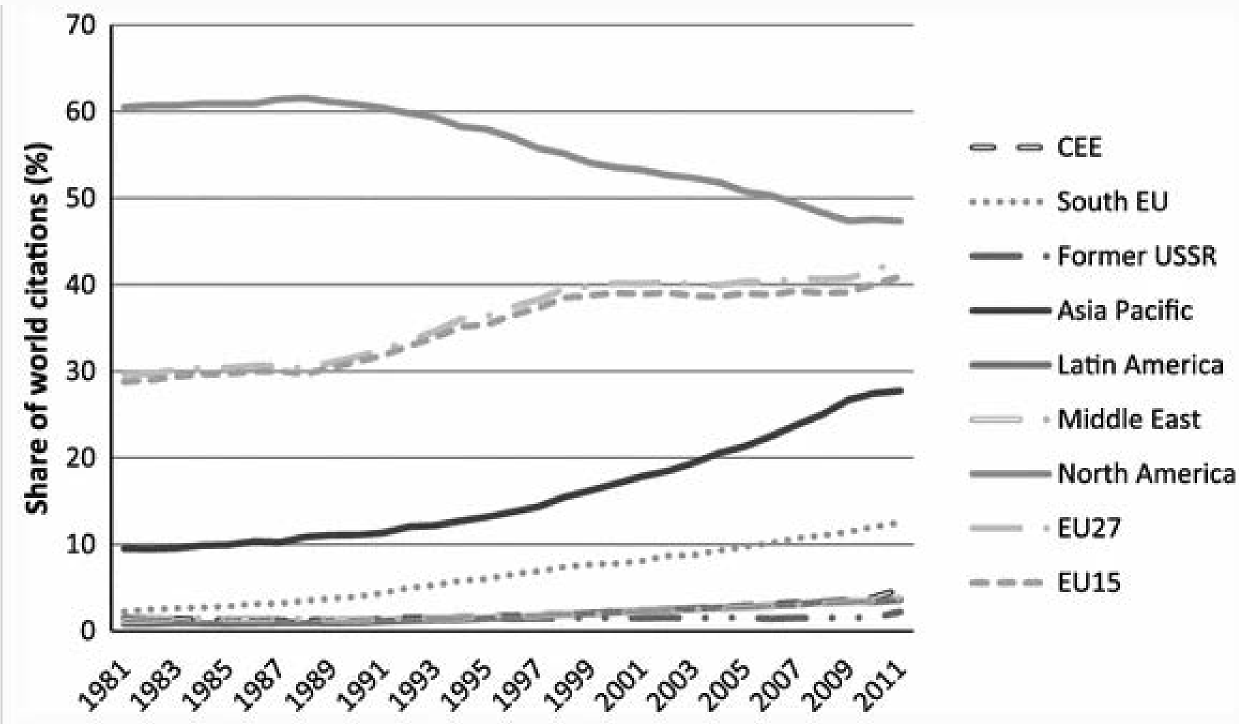
Radosevic, S., & Yoruk, E. (2014). Are there global shifts in the world science base? Analysing the catching up and falling behind of world regions. *Scientometrics*, *101*(3), 1897–1924. https://doi.org/10.1007/s11192-014-1344-1



Share of world papers by regions, all fields, 1981–2011



World regions by impact factors relative to world, all fields, 1981–2011



Share of world citations by regions, all fields, 1981–2011

In a bibliometrics context the algebra for the index is set up as follows for citations and published papers (Kozlowski et al. 1999):

$$\mathrm{RCACIT}_j^i = \frac{\left(\frac{\mathrm{Cit}_j^i}{\mathrm{TotCit}_j}\right)}{\left(\frac{\mathrm{Cit}_{\mathrm{world}}^i}{\mathrm{TotCit}_{\mathrm{world}}}\right)} \quad (1)$$

where, RCACIT = revealed comparative advantage index based on citations; Cit_j^i = citations in field i of country j; TotCit_j = total citations in all fields of country j; $\mathrm{Cit}_{\mathrm{world}}^i$ = world citations in field i; $\mathrm{TotCit}_{\mathrm{world}}$ = world citations in all fields.

$$\mathrm{RCAPAP}_j^i = \frac{\left(\frac{\mathrm{Pap}_j^i}{\mathrm{TotPap}_j}\right)}{\left(\frac{\mathrm{Pap}_{\mathrm{world}}^i}{\mathrm{TotPap}_{\mathrm{world}}}\right)} \quad (2)$$

where, RCAPAP = revealed comparative advantage index based on papers; Pap_j^i = papers in field i of country j; TotPap_j = total papers in all fields of country j; $\mathrm{Pap}_{\mathrm{world}}^i$ = world papers in field i; $\mathrm{TotPap}_{\mathrm{world}}$ = world papers in all fields.

The RCA index thus allows for a comparison of regional/national scientific specializations across different scientific fields. When RCA equals 1 for a given scientific field in a given

Franzoni, C., & Sauermann, H. (2014). Crowd science: The organization of scientific research in open collaborative projects. Research Policy, 43(1), 1–20. https://doi.org/10.1016/j.respol.2013.07.005

Examples of crowd science projects.

Name	URL	Hosting platform	Field	Primary tasks
Ancient Lives	http://ancientlives.org	Zooniverse	Archeology	Inspect fragments of Egyptian papyri and transcribe content
Argus	http://argus.survice.com/	None	Cartography	Measure seabed depth during navigation
Bat Detective	http://www.batdetective.org/	Zooniverse	Biology	Listen to bat calls and classify them
Connect2Decode (C2D)*	https://sites.google.com/a/osdd.net/c2d-01/	None	Genetics	Annotate genes of Mycobacterium tuberculosis
Connect2Decode: Cloning, Expression and Purification of Proteins	http://c2d.osdd.net/	Connect2Decode	Genetics	Clone genes in Mycobacterium tuberculosis
Connect2Decode: Cheminformatics and Chemical Data Mining	http://c2d.osdd.net/home/cheminformatics	Connect2Decode	Genetics	Use chemical descriptors and data mining to identify and annotate molecules with desirable properties
Crowd Computing for Cheminformatics	http://vinodscaria.rnabiology.org/2C4C	CSIR Network project on ncRNA biology	Bioinformatics	Develop predictive models for biological activities of chemical molecules
Cheminformatics Crowd Computing for Tubercolosis Drug Discovery	http://vinodscaria.rnabiology.org/cheminformatics-crowd-computing-for-tuberculosis	CSIR Network project on ncRNA biology	Bioinformatics	Annotate data set of active anti-tubercular molecules, by using existing or improved prioritization algorithms, to identify a small subset of drug candidates
Open Dinosaur Project	http://opendino.wordpress.com/about/	None	Paleontology	Search in published literature and report dinosaur limb length and/or measure and report from museum specimens
Cyclone Center	http://www.cyclonecenter.org/	Zooniverse	Climatology	Watch satellite images of cyclones and classify storms
Discover life	http://www.discoverlife.org/	None	Biology	Observe and report images and location of wild species
eBird	http://www.ebird.org/	Cornell Lab of Ornithology	Biology	Observe and report images and location of wild birds
EteRNA	http://eterna.cmu.edu/	None	Biochemistry	Game. Modify the shape of RNA bases combination to fit a folded structure
Foldit	http://www.fold.it	None	Biochemistry	Game. Modify a visual 3D model of protein to optimize its shape
Galaxy Zoo	http://www.galaxyzoo.org/	Zooniverse	Astronomy	Inspect and classify images of galaxies
Great Backyard Bird Count	http://birdsource.org/gbbc/	Cornell Lab of Ornithology	Biology	Report frequency of bird sightings occurring during 15 min periods
Great Sunflower Project	http://www.greatsunflower.org/	None	Biology	Grow flowers that attract bees and other pollination insects, observe and report frequency of insects visits
Ice Hunters*	http://www.icehunters.org	Zooniverse	Astronomy	Inspect telescope images and identify possible targets for New Horizons mission
Milkyway Project	http://www.milkywayproject.org	Zooniverse	Astronomy	Inspect telescope images, identify clouds and bubbles
Moon Zoo	http://www.moonzoo.org/	Zooniverse	Astronomy	Inspect satellite images of the Moon and report craters
Nestwatch	http://nestwatch.org	Cornell Lab of Ornithology	Biology	Observe nest activities (eggs, young, fledglings) and report count
Notes from Nature	http://www.notesfromnature.org/	Zooniverse	Biology	Inspect images of specimens digitized from natural history museums and transcribe their descriptions

Table 1 (*Continued*)

Name	URL	Hosting platform	Field	Primary tasks
Old Weather	http://www.oldweather.org	Zooniverse	Climatology	Inspect images of log books of Royal Navy ships or artic exploration ships and transcribe climate and location reports
Patientslikeme	http://www.patientslikeme.com/	None	Medicine	Input personal data about symptoms and treatment of diseases
Pigeon Watch*	http://www.birds.cornell.edu/pigeonwatch	Cornell Lab of Ornithology	Biology	Observe pigeon species and report images and/or location of observation
Phylo	http://phylo.cs.mcgill.ca	None	Genetics	Game. Inspect sequence of colored shapes and move shapes to optimize their alignment
Planet Hunters	http://www.planethunters.org	Zooniverse	Astronomy	Inspect starlight curves registered by the Kepler spacecraft and report possible planet transits
Polymath 1. Density Hales–Jewett*	http://gowers.wordpress.com/2009/02/01/a-combinatorial-approach-to-density-hales-jewett/	None	Mathematics	Solve a mathematical problem
Polymath 2. Banach Spaces*	http://gowers.wordpress.com/2009/02/17/must-an-explicitly-defined-banach-space-contain-c.0-or-ell-p/	None	Mathematics	Solve a mathematical problem
Polymath 3: Polynomial Hirsh Conjecture*	http://gilkalai.wordpress.com/2009/07/17/the-polynomial-hirsch-conjecture-a-proposal-for-polymath3/	None	Mathematics	Prove a mathematical conjecture
Polymath 4: Deterministic way to find primes*	http://polymathprojects.org/2009/07/27/proposal-deterministic-way-to-find-primes/	Polymathprojects	Mathematics	Solve a mathematical problem
Polymath 5: Erdos Discrepancy*	http://gowers.wordpress.com/2009/12/17/erdoss-discrepancy-problem/	Polymathprojects	Mathematics	Solve a mathematical problem
Polymath 6: Improving the bounds for Roth's theorem	http://polymathprojects.org/2011/02/05/polymath6-improving-the-bounds-for-roths-theorem/	Polymathprojects	Mathematics	Solve a mathematical problem
Polymath 7: Hot Spots Conjecture	http://polymathprojects.org/2012/06/03/polymath-proposal-the-hot-spots-conjecture-for-acute-triangles/	Polymathprojects	Mathematics	Prove a mathematical conjecture
Polymath 8: Bounded gaps between primes	http://polymathprojects.org/2013/06/04/polymath-proposal-bounded-gaps-between-primes/	Polymathprojects	Mathematics	Solve a mathematical problem
Project Feeder Watch	http://www.birds.cornell.edu/pfw/	Cornell Lab of Ornithology	Biology	Install a birdfeeder in backyard, observe and report frequency of bird visits
Seafloor Explorer	http://www.seafloorexplorer.org/	Zooniverse	Biology	Inspect seafloor images, identify and report target species
Setilive	http://setilive.org/	Zooniverse	Astronomy	Inspect live radio frequency signals broadcasted by the SETI Institute's Allen Telescope. Consistent simultaneous reports of potential extraterrestrial signals prompt a second telescope inspection within minutes
Secchi App	https://www1.plymouth.ac.uk/marine/secchidisk/Pages/default.aspx	None	Biology	Measure the turbidity of seawater using a Secchi disk and use a mobile app to report the corresponding concentration of phytoplankton
Snapshot Serengeti	http://www.snapshotserengeti.org/	Zooniverse	Biology	Inspect pictures of the Serengeti Lion Project and classify images of wildlife
Solar Stormwatch	http://www.solarstormwatch.com	Zooniverse	Astronomy	Watch videos of solar activity and report inception and length of solar explosions

C. Franzoni, H. Sauermann / Research Policy 43 (2014) 1–20

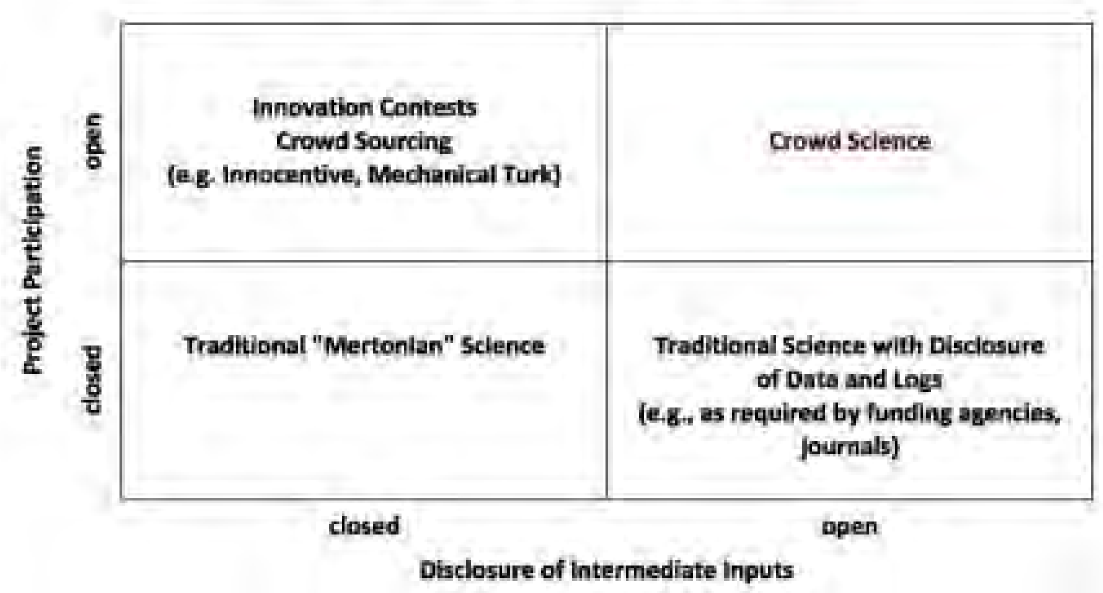


Fig. 3. Knowledge production regimes with different degrees of openness.

Wagner, C. S. (2018). *The Collaborative Era in Science: Governing the Network* (C. S. Wagner, Ed.). Springer International Publishing. https://doi.org/10.1007/978-3-319-94986-4_9

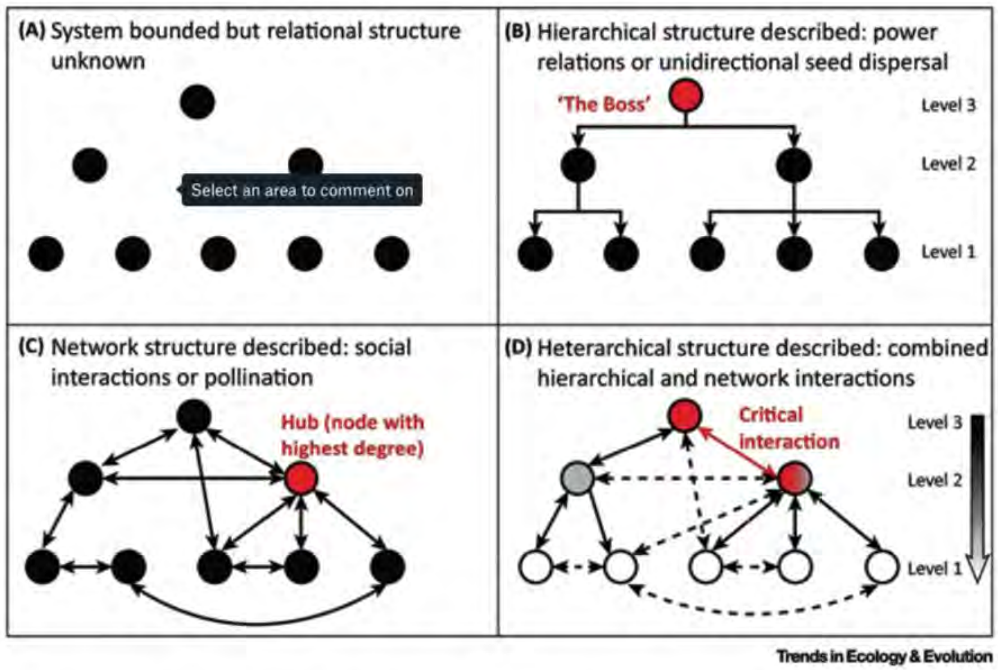


Fig. 3.1 From network to heterarchy in knowledge-creating groups

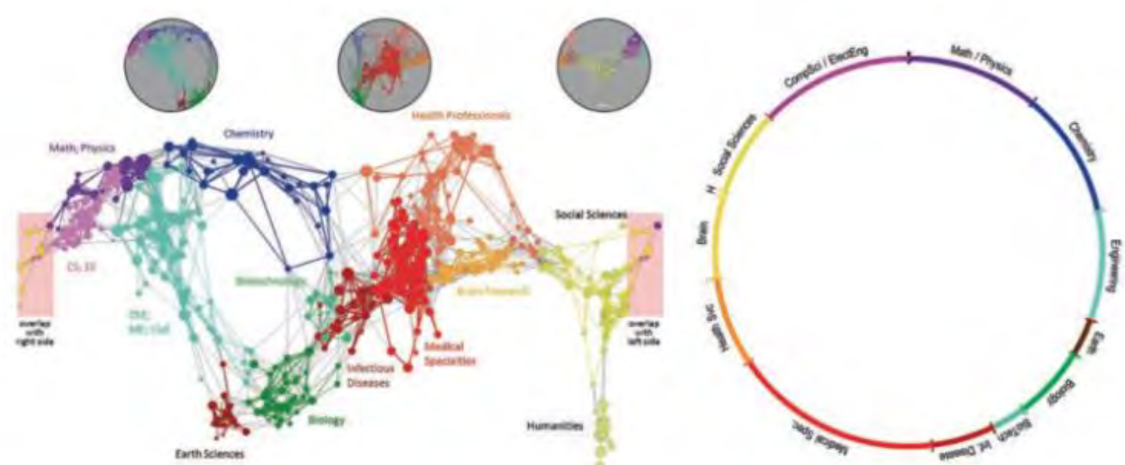


Fig. 3.2 The map of science based upon co-citation relations. (Source: Map of Science)

Wagner, C. S., Whetsell, T. A., & Leydesdorff, L. (2017). Growth of international collaboration in science: Revisiting six specialties. *Scientometrics*, *110*(3), 1633–1652. https://doi.org/10.1007/s11192-016-2230-9

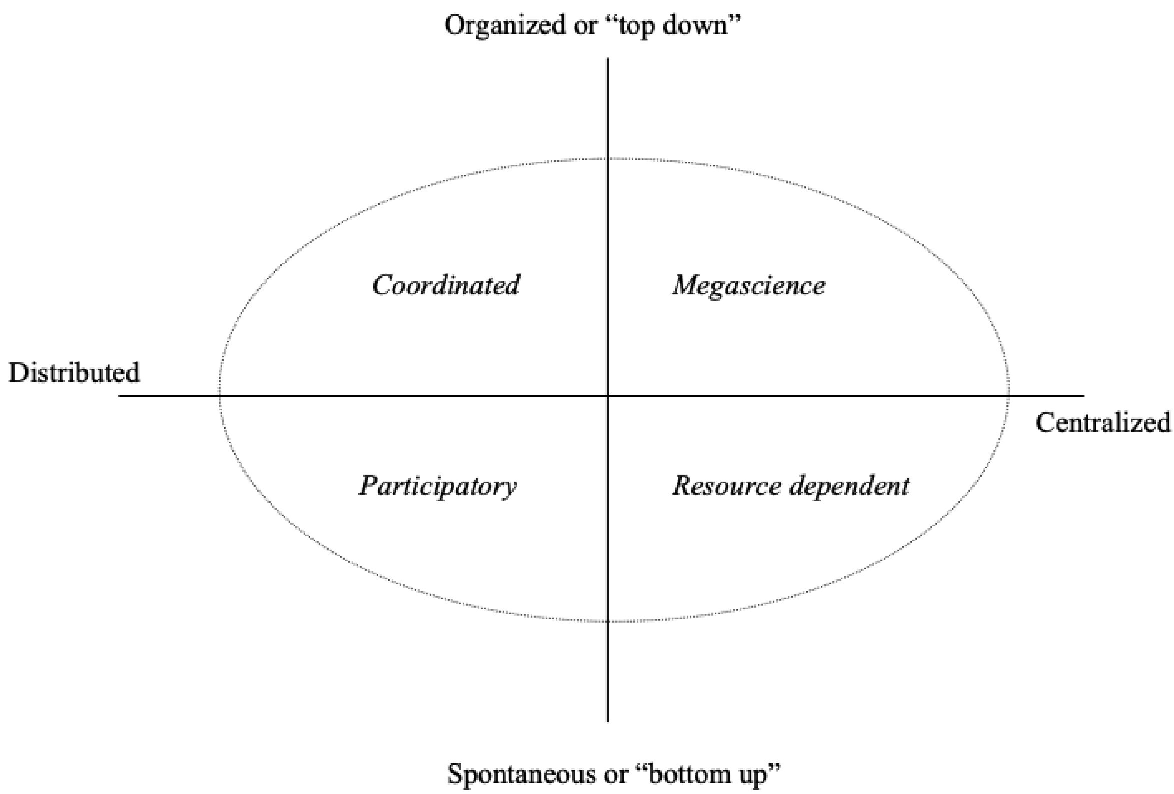


Figure 1. A schematic representation of factors relating to organization of ICS (Source: Wagner *et al.*, 2000.)