

# Visual Analytics: Mining, Mapping, and Accelerating Local and Global Science and Technology

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*New Science Roadmaps for Global Research Panel, AAAS 2016  
Wilson C, Marriott Wardman Park, Washington, DC*

*Saturday, February 13, 2016, 3:00-4:30PM*

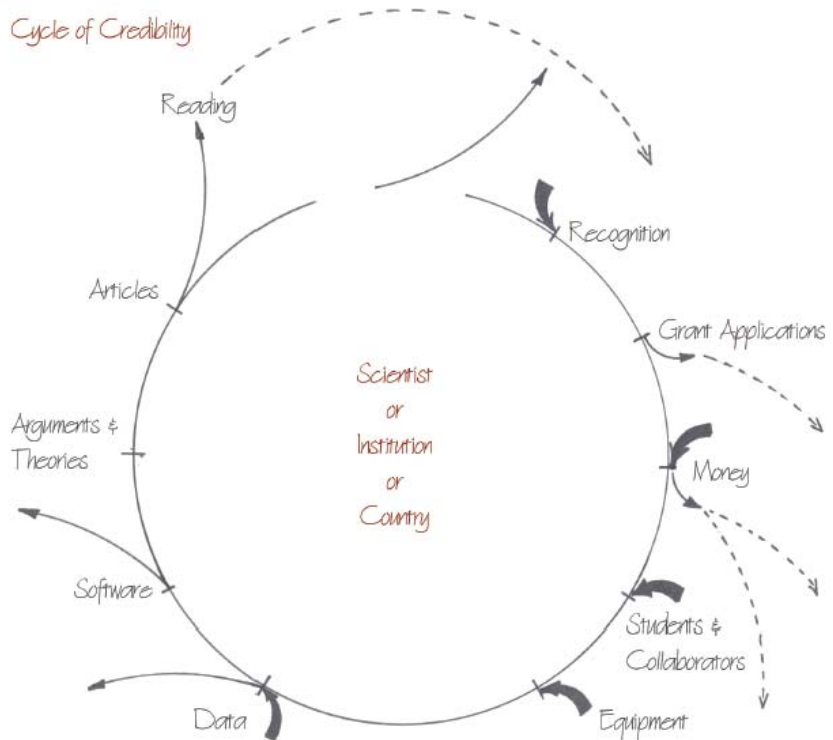


## Map of Scientific Collaborations from 2005-2009

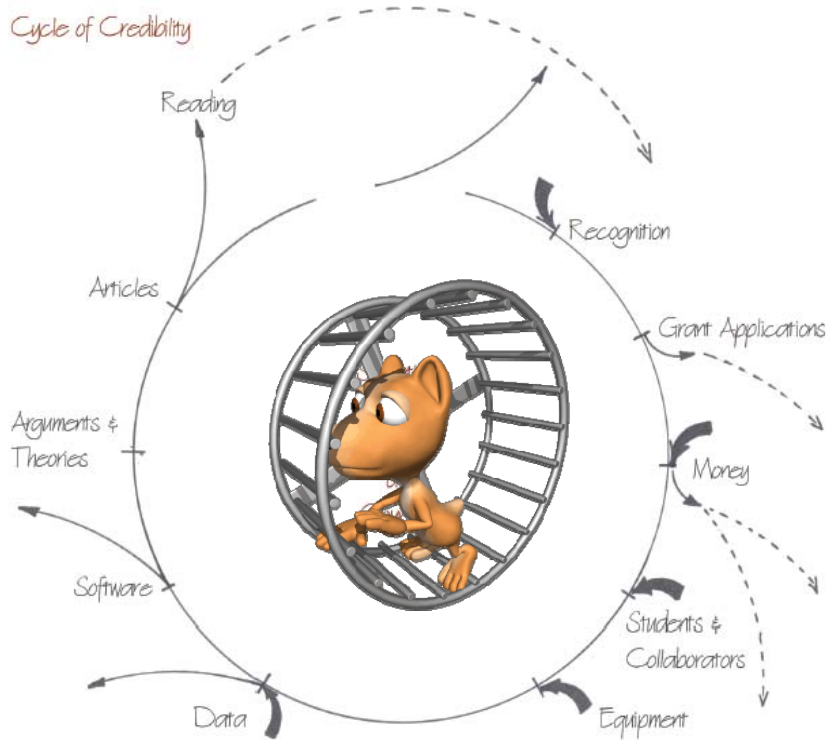


Computed Using Data from Elsevier's Scopus

Olivier H. Beauchesne, 2011. Map of Scientific Collaborations from 2005-2009

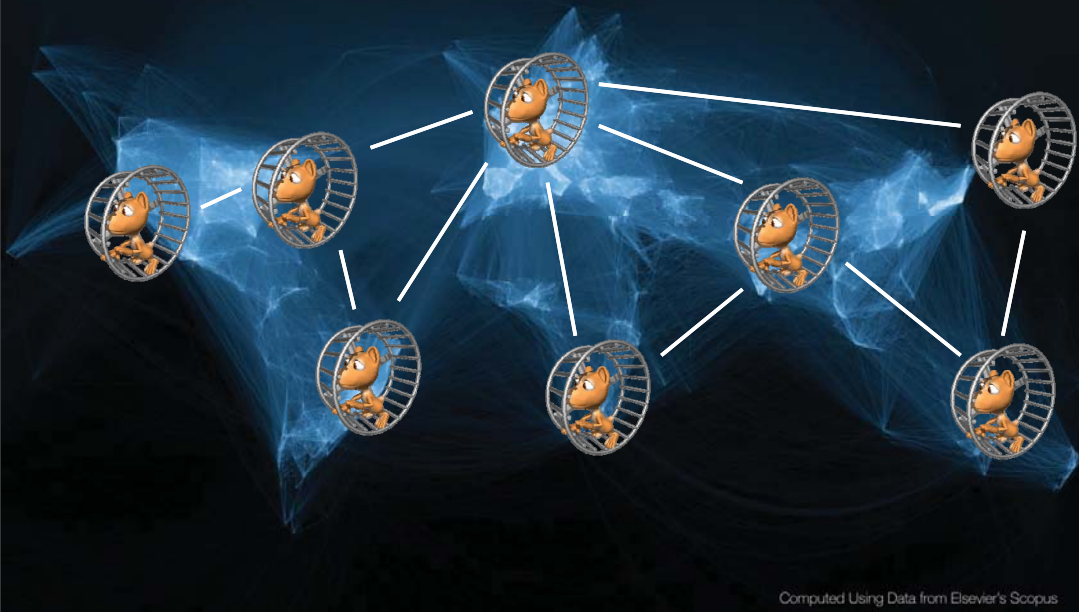


Bruno Latour and Steve Woolgar, 1986. Cycle of Credibility.



Bruno Latour and Steve Woolgar, 1986. Cycle of Credibility.

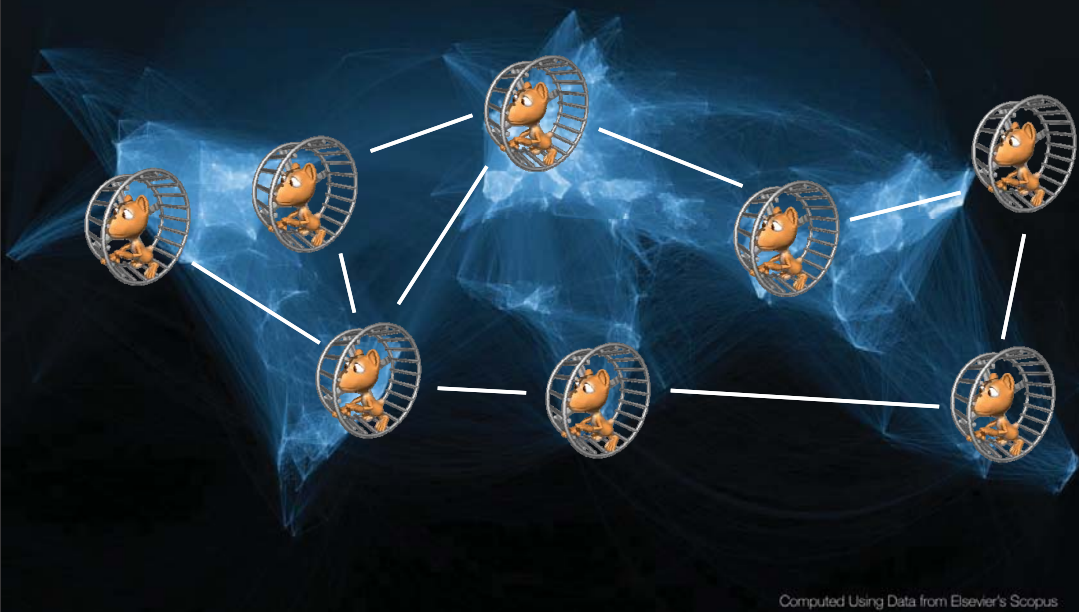
# Map of Scientific Collaborations from 2005-2009



Olivier H. Beauchesne, 2011. Map of Scientific Collaborations from 2005-2009

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# Map of Scientific Collaborations from 2005-2009



Olivier H. Beauchesne, 2011. Map of Scientific Collaborations from 2005-2009

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# The Global 'Scientific Food Web'

Mazlounian, Amin, Dirk Helbing, Sergi Lozano, Robert Light, and Katy Börner. 2013. "Global Multi-Level Analysis of the 'Scientific Food Web'". *Scientific Reports* 3, 1167.

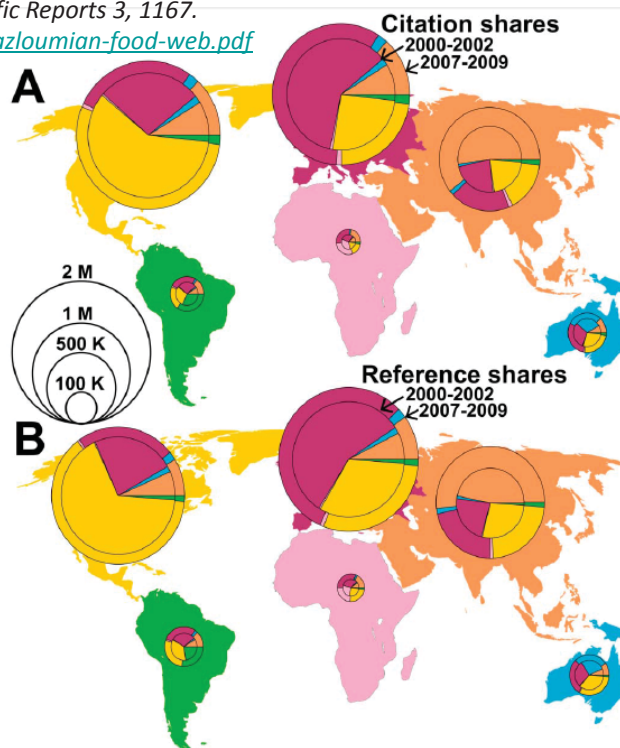
<http://cns.iu.edu/docs/publications/2013-mazlounian-food-web.pdf>

## Contributions:

Comprehensive global analysis of scholarly knowledge production and diffusion on the level of continents, countries, and cities.

Quantifying knowledge flows between 2000 and 2009, we identify global sources and sinks of knowledge production. Our knowledge flow index reveals, where ideas are born and consumed, thereby defining a global 'scientific food web'.

While Asia is quickly catching up in terms of publications and citation rates, we find that its dependence on knowledge consumption has further increased.



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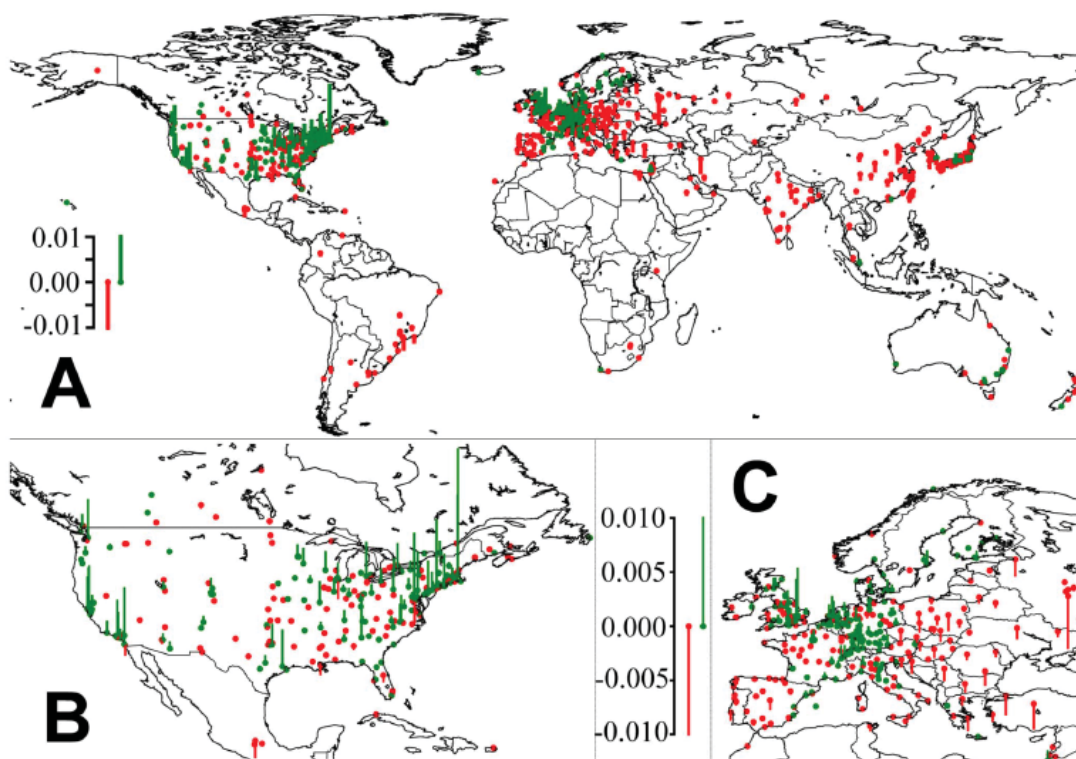


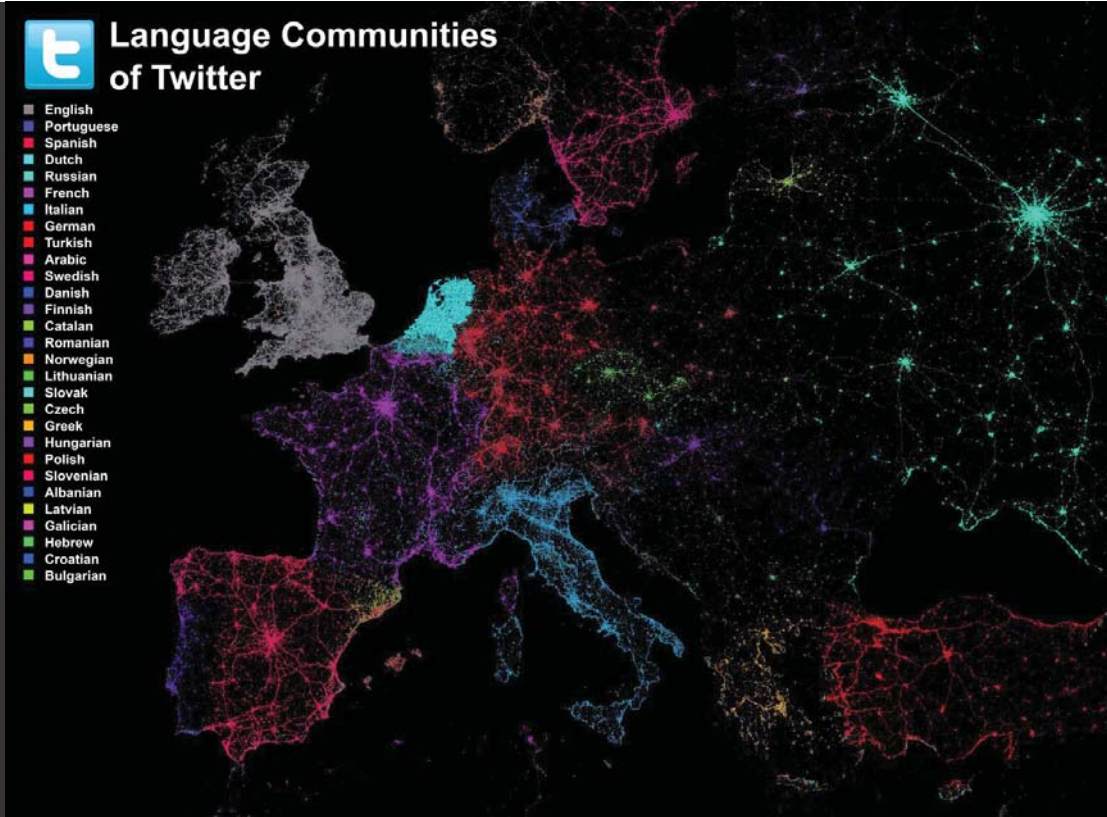
Figure 2 | World map of the greatest knowledge sources and sinks, based on our scientific fitness index. Green bars indicate that the number of citations received is over-proportional, red that the number of citations received is lower than expected (according to a homogeneous distribution of citations over all cities that have published more than 500 papers). It can be seen that most scientific activity occurs in the temperate zone. Moreover, areas of high fitness tend to be areas that are performing economically well (but the opposite does not hold).

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# Language Communities of Twitter

- English
- Portuguese
- Spanish
- Dutch
- Russian
- French
- Italian
- German
- Turkish
- Arabic
- Swedish
- Danish
- Finnish
- Catalan
- Romanian
- Norwegian
- Lithuanian
- Slovak
- Czech
- Greek
- Hungarian
- Polish
- Slovenian
- Albanian
- Latvian
- Galician
- Hebrew
- Croatian
- Bulgarian

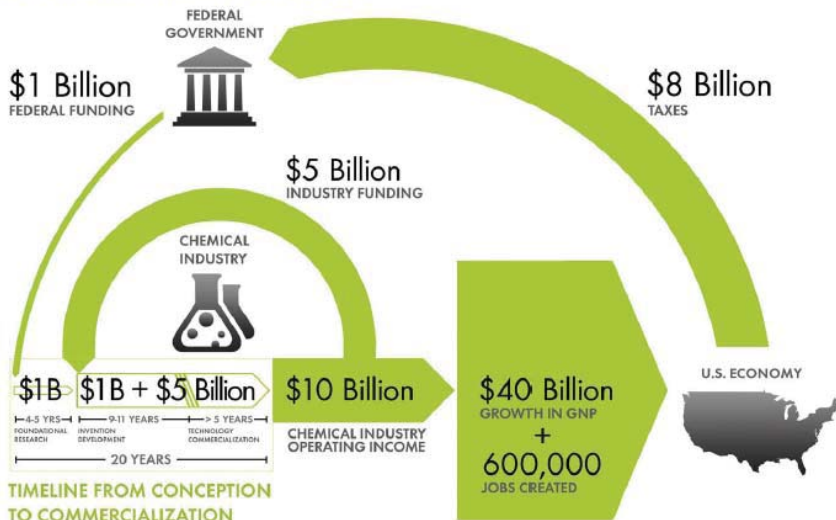


Language Communities of Twitter - Eric Fischer - 2012

## Chemical Research & Development Powers the U.S. Innovation Engine

Macroeconomic Implications of Public and Private R&D Investments in Chemical Sciences

### INVESTMENT IN CHEMICAL SCIENCE R&D



### The Council for Chemical Research (CCR)

has provided the U.S. Congress and government policy makers with important results regarding the impact of Federal Research & Development (R&D) investments on U.S. innovation and global competitiveness through its commissioned 5-year two phase study. To take full advantage of typically brief access to policy makers, CCR developed the graphic below as a communication tool that distills the complex data produced by these studies in direct, concise and clear terms.



The design shows that an input of \$1B in federal investment, leveraged by \$5B in industry investment, brings new technologies to market and results in \$10B of operating income for the chemical industry, \$40B growth in the Gross National Product (GNP) and further impacts the US economy by generating approximately 600,000 jobs, along with a return of \$8B in taxes. Additional details, also reported in the CCR studies, are depicted in the map to the left. This map clearly shows the two R&D investment cycles; the shorter industry investment cycle at the innovation stage to commercialization cycle; and the longer federal investment cycle which begins in basic research and culminates in national economic and job growth along with the increase tax base that in turn is available for investment in basic research.

Council for Chemical Research. 2009. Chemical R&D Powers the U.S. Innovation Engine. Washington, DC. Courtesy of the Council for Chemical Research.



Illuminated Diagram Display  
 on display at the Smithsonian in DC.  
[http://scimaps.org/exhibit\\_info/#ID](http://scimaps.org/exhibit_info/#ID)

### Geographic Map: Where Science Gets Done

**About**  
 This Illuminated Diagram display adds the flexibility of an interactive program to the incredibly high data density of a print. This technique is generally useful when there is too much pertinent data to be displayed on a screen but the data is relatively stable. The computer can direct the eye to what's important by using projectors or screens as smart spotlights, animating the research impact of individuals, giving a "grand tour" of science, or highlighting query results (as when you touch the lectern or use the keyboard) with an overlay of moving light.

### Science Map: How Scientific Disciplines Relate

Copyright © 2006 The Regents of the University of California

**Top Five Continents**

- North America - 4,000 records
- South & East Asia - 3,589
- Australia - 2,431
- Africa - 2,206
- South America - 1,562

**Top Five Scientific Disciplines**

- Math & Physics - 4,000 records
- Health Professionals - 3,589
- Social Sciences - 2,431
- Aeronautical, Chemical, Mechanical & Civil Engineering - 2,206
- Humanities - 1,562

**Search**

The keyboard supports retrieval and display of papers based on their Medical Subject Headings (MeSH) and MeSH qualifier terms. If multiple terms are entered in a field, they are automatically combined using "OR". So, "breast cancer" matches any record with "breast" or "cancer" in that field. You can put AND between terms to combine with "AND". Thus "breast AND cancer" would only match records that contain both terms. Double quotation can be used to match compound terms, e.g., "breast cancer" retrieves records with the phrase "breast cancer", and not records where "breast" and "cancer" are both present, but the exact phrase.

Input your search query here.

Q	W	E	R	T	Y	U	I	O	P
A	S	D	F	G	H	J	K	L	"
Z	X	C	V	B	N	M			
Space									Go

<http://scimaps.org>

People & Topics

### Geographic Map: Where Science Gets Done

### Science Map: How Scientific Disciplines Relate

Copyright © 2008 The Regents of the University of California

#### About

This Illuminated Diagram display adds the flexibility of an interactive program to the incredibly high data density of a print. This technique is generally useful when there is too much pertinent data to be displayed on a screen but the data is relatively stable. The computer can direct the eye to what's important by using projectors or screens as smart spotlights, animating the research impact of individuals, giving a "grand tour" of science, or highlighting query results (as when you touch the lectern or use the keyboard) with an overlay of moving light.

#### Elinor Ostrom - Nobel Prize in Economic Sciences 2009

**Born:** 7 August 1933, New York, NY, USA  
**Affiliation at the time of the award:** Indiana University, Bloomington, IN, USA, Arizona State University, Tempe, AZ, USA  
**Prize motivation:** "for her analysis of economic governance, especially the commons"  
**Field:** Economic governance  
**Contribution:** Challenged the conventional wisdom by demonstrating how local property can be successfully managed by local commons without any regulation by central authorities or privatization.


<http://sciurmaps.org>


Cancer	Cloning	HIV	Robert G. Edwards	Roger D. Kornberg	Elinor Ostrom
Obesity	Quality of Life	Smoking	Stanley B. Prusiner	Ahmed H. Zewail	View All

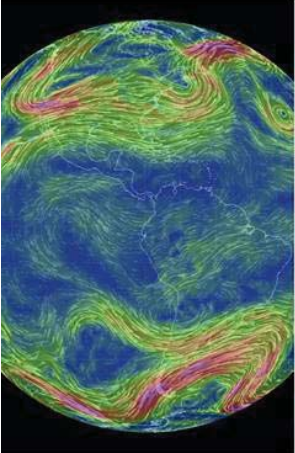
Keyword Search

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Science Maps in "Expedition Zukunft" science train visiting 62 cities in 7 months 12 coaches, 300 m long Opening was on April 23<sup>rd</sup>, 2009 by German Chancellor Merkel  
<http://www.expedition-zukunft.de>


**MACROSCOPES FOR INTERACTING WITH SCIENCE**

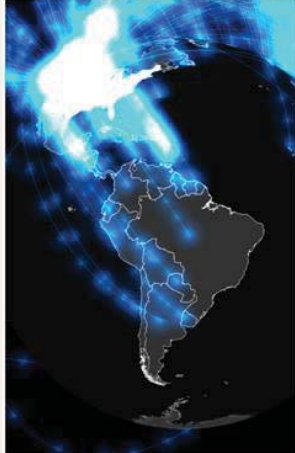





Earth



AcademyScope



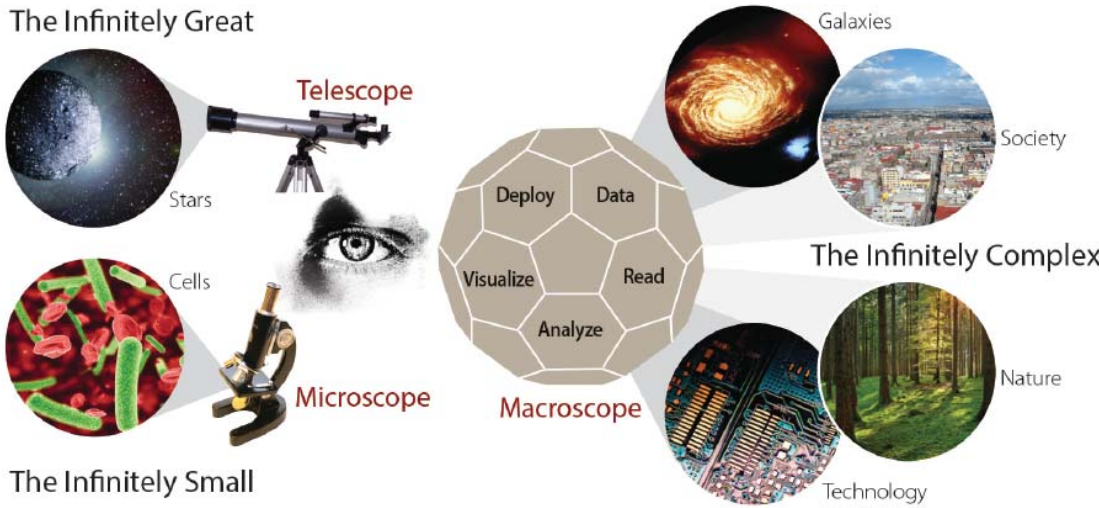
Mapping Global Society



Charting Culture

<http://scimaps.org/iteration/11>

Microscopes, Telescopes, Macrosopes Plug-and-Play Macrosopes

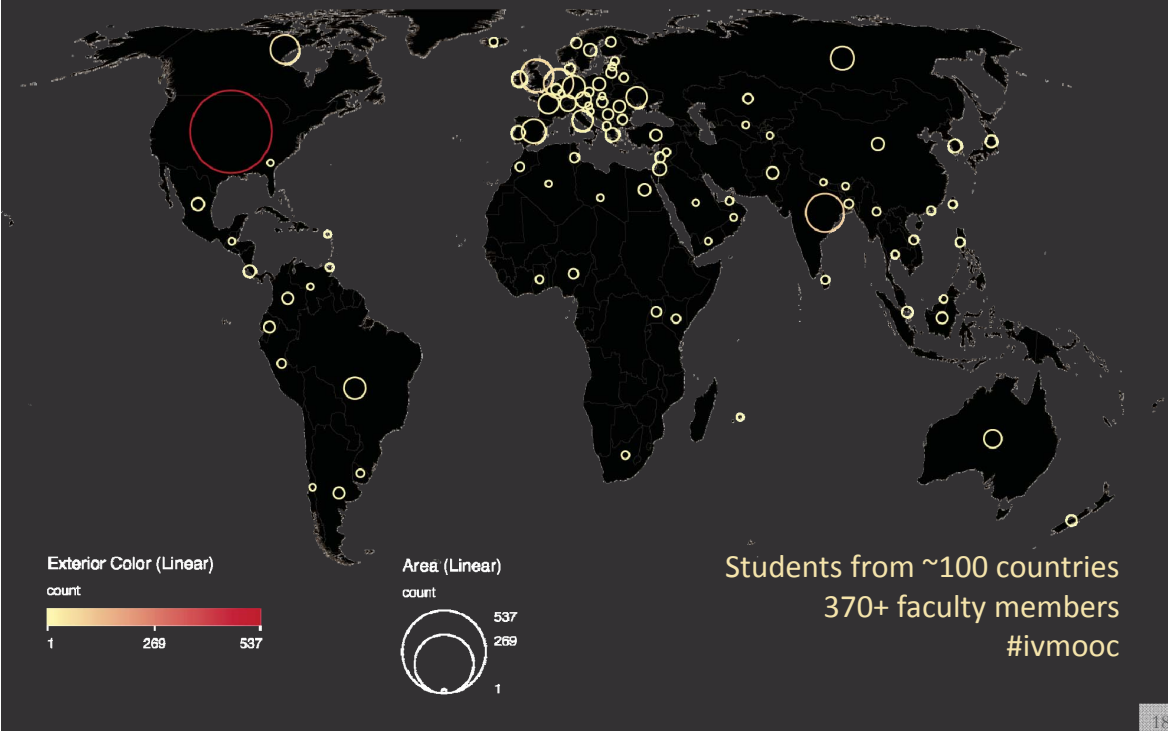






Register for free: <http://ivmooc.cns.iu.edu>. Class restarts Jan 12, 2016.

The Information Visualization MOOC  
ivmooc.cns.iu.edu



# Course Schedule

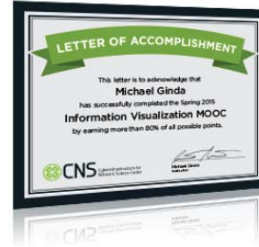
## Part 1: Theory and Hands-On

- **Session 1** – Workflow Design and Visualization Framework
- **Session 2** – “When:” Temporal Data
- **Session 3** – “Where:” Geospatial Data
- **Session 4** – “What:” Topical Data

## Mid-Term

- **Session 5** – “With Whom:” Trees
- **Session 6** – “With Whom:” Networks
- **Session 7** – Dynamic Visualizations and Deployment

## Final Exam

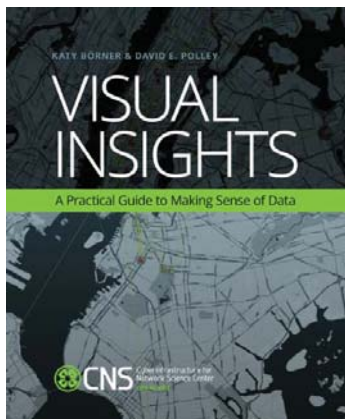


## Part 2: Students work in teams on client projects.

Final grade is based on Class Participation (10%), Midterm (30%), Final Exam (30%), and Client Project(30%).

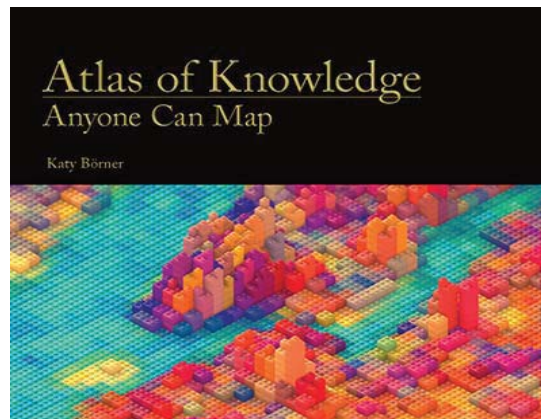
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# Books Used in the IVMOOC



### Teaches timely knowledge:

Advanced algorithms, tools, and hands-on workflows.



### Teaches timeless knowledge:

Visualization framework—exemplified using generic visualization examples and pioneering visualizations.

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*Places & Spaces Exhibit at the David J. Sencer CDC Museum, Atlanta, GA  
January 25-June 17, 2016*

**Seeing for  
Action - Using  
Maps and  
Graphs  
to Protect the  
Public's Health.**



**CDC Opening Event: Maps of Health  
Tutorial and Symposium  
February 4-5, 2016**



Hidalgo, César A., Bailey Klinger, Albert-László Barabási, and Ricardo Hausmann. 2007. See also *The Product Space* map from Phase I of Places & Spaces.

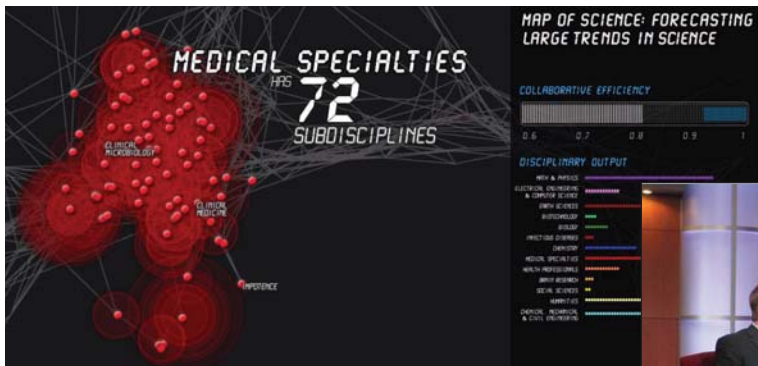
## Call for Macroscopic Tools for the *Places & Spaces: Mapping Science* Exhibit (2016) <http://scimaps.org/call>

### Background and Goals

The *Places & Spaces: Mapping Science* exhibit was created to in communicate human activity and scientific progress on a globe that enable the close inspection of large-scale maps in public conferences; (2) novel, interactive macroscopic tools that let

Themes for the upcoming iterations/years are:

- 11th Iteration (2015): Macroscopes for Interacting With Science
- 12th Iteration (2016): Macroscopes for Making Sense of Science
- 13th Iteration (2017): Macroscopes for Forecasting Science
- 14th Iteration (2018): Macroscopes for Economic Decision Makers
- 15th Iteration (2019): Macroscopes for Science Policy Makers



### Science Forecast S1:E1, 2015





**MAP THEMES**

**Small World**  
 After 20 years of basic research and development at the 100-nanometer scale, the importance of nanotechnology as a source of innovations and new capabilities in everything from materials science to medicine is already well understood. These tools, however, will allow how nanotechnology will unfold, and what impact it will have. First, nanotechnology is not a single field with a coherent intellectual program. It's an opportunistic hybrid, shaped by a combination of fundamental research questions, promising technical applications, and venture and state capital. Second, nanotechnology is moving away from the original vision of small-scale mechanical engineering—in which assemblers build mechanical systems from individual atoms—toward one in which molecular biology and biochemistry contribute essential tools, such as proteins that build nanowires. Finally, nanotechnology will also serve as a model for transdisciplinary science. It will support both fundamental research and commercially oriented innovation, and it will be conducted not within the boundaries of conventional academic or corporate research departments, but in institutional and social milieus that emphasize heterogeneity.

**Mathematical World**  
 The ability to process, compress, and convey information in large terms in enormous amounts of data will allow decoding of previously mysterious processes in everything from biological to social systems. Scientists are learning that at the core of many biological phenomena—reproduction, growth, repair, and other—are computational processes that can be modeled and simulated. Using techniques of computational science to uncover both patterns—whether these are physical, biological, or social—will likely expose an increasing array of computing topics in the next 50 years. Such massive computation will also make simulation widespread. Computer simulation will be used not only to help make decisions about large complex scientific and social problems but also to help individuals make better choices in their daily lives.

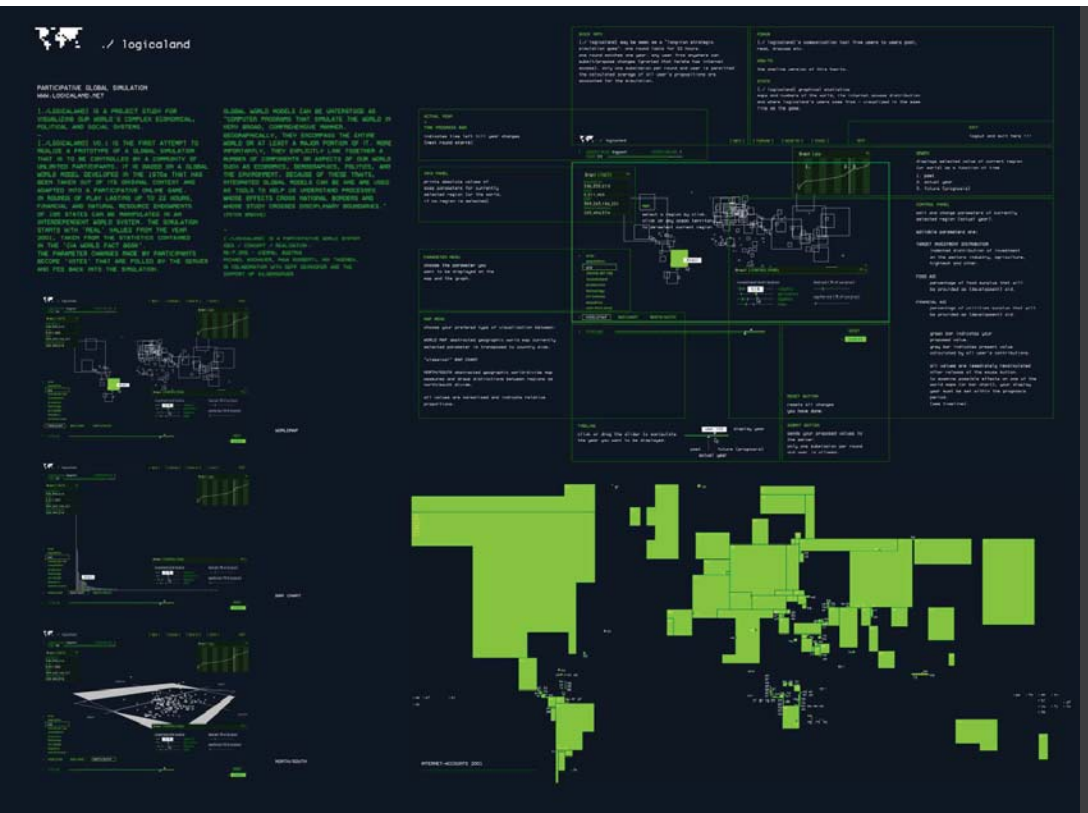
**Binary Transformation**  
 In the next ten years, physical objects, places, and even human beings themselves will increasingly become embedded with computational devices that can sense, understand, and act upon their environment. They will be able to react to contextual clues about the physical, social, and even emotional state of people and things in their surroundings. As a result, increasing demands will be placed on our visual, auditory, and other sensory abilities, information previously modeled as text and numbers will be displayed in richer sensory formats—as graphics, pictures, patterns, sounds, smells, and tactile experiences. The enriched sensory environment will coincide with major breakthroughs in our understanding of the brain—we will process sensory information and connect various sensory functions.

**Transdisciplinary**  
 In the last few centuries, natural philosophy and natural history branched into the new fields of physics, chemistry, biology, and so on. The sciences evolved into their current forms in response to intellectual and professional opportunities, pedagogical pressures, and economic and state needs. Through most of the 20th century, the growth of the sciences, and academic and career pressures, encouraged ever-greater specialization. In the coming decades, transdisciplinary research will become an imperative. According to Howard Rheingold, a prominent futurist and author, "transdisciplinarity goes beyond bringing together researchers from different disciplines to work in multidisciplinary teams. It means educating researchers who can speak languages of multiple disciplines—biologists who have understanding of mathematics, mathematicians who understand biology."

**Emergence**  
 The phenomenon of self-organizing swarms that generate complex behavior by following simple rules, will likely become an important research area, and an important model for understanding how the natural world works and how artificial worlds can be designed. Emergent phenomena have been observed across a variety of natural phenomena, from physics to biology to sociology. The concept has broad appeal due to the diversity of fields and problems to which it can be applied. It is proving useful for making sense of a very wide range of phenomena. Meanwhile, emergence can be modeled using relatively simple computational tools, although these models often require solutions as a way of thinking about designing complex, robust technological systems. Finally, emergence is an accessible and useful metaphor for understanding nature. Just as classical physics profited from popular treatments of Newtonian mechanics, so too will scientific study and technical reproductions of emergent phenomena likely draw benefits from the popularization of its underlying concepts.

**Meta-Themes**  
**Democratizing Innovation**  
 Before the 20th century, many of the greatest scientific discoveries and technical inventions were made by amateur scientists and independent inventors. In the last 100 years, a professional class of scientists and engineers, supported by universities, industry, and the state, pushed amateurs aside as a creative force. At the national scale, the capital-intensive character of scientific research made world-class research the property of progressively advanced nations. In the new century, a number of trends and technologies will lower the barriers to participation in science and technology again, both for individuals and for emerging countries. The result will be a renaissance of the serious amateurs, the growth of new scientific and technical centers of excellence in developing countries, and a more global distribution of world-class scientists and technologists.

Science & Technology Outlook: 2005-2055 - Alex Soojung-Kim Pang, David Pescovitz, Marina Gorbis, Jean Hagan - 2006



Logiland Participative Global Simulation - Michael Ashauer, Maia Gusberty, Nik Thoenen - 2002



# Modeling Science, Technology & Innovation Conference

WASHINGTON D.C. | MAY 17-18, 2016

[View Agenda](#)

*This conference is co-funded by the NSF Science of Science and Innovation Policy (SciSIP) program. It brings together international experts and practitioners that develop and apply mathematical, statistical, and computational models to increase our understanding of the structure and dynamics of science, technology and innovation, see details at <http://modsti.cns.iu.edu>.*

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## References

Börner, Katy, Chen, Chaomei, and Boyack, Kevin. (2003). **Visualizing Knowledge Domains**. In Blaise Cronin (Ed.), *ARIST*, Medford, NJ: Information Today, Volume 37, Chapter 5, pp. 179-255. <http://ivl.slis.indiana.edu/km/pub/2003-borner-arist.pdf>

Shiffrin, Richard M. and Börner, Katy (Eds.) (2004). **Mapping Knowledge Domains**. *Proceedings of the National Academy of Sciences of the United States of America*, 101(Suppl\_1). [http://www.pnas.org/content/vol101/suppl\\_1/](http://www.pnas.org/content/vol101/suppl_1/)

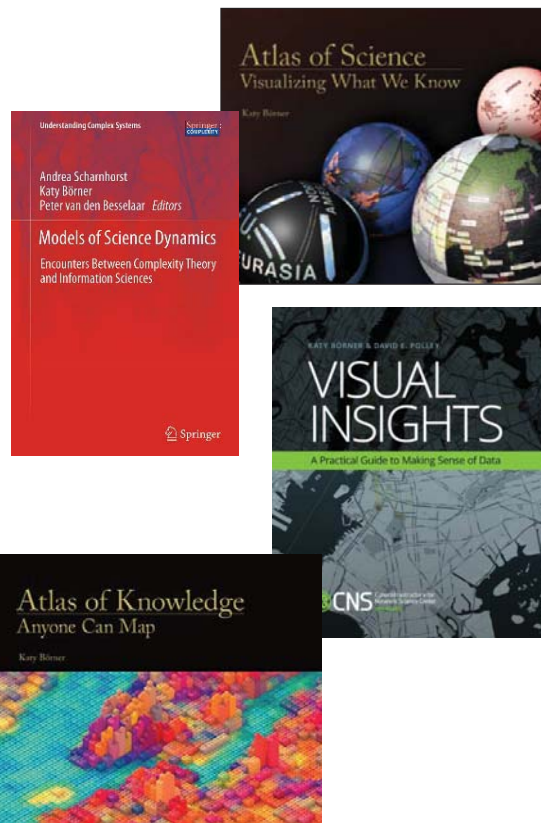
Börner, Katy (2010) **Atlas of Science: Visualizing What We Know**. The MIT Press. <http://scimaps.org/atlas>

Scharnhorst, Andrea, Börner, Katy, van den Besselaar, Peter (2012) **Models of Science Dynamics**. Springer Verlag.

Katy Börner, Michael Conlon, Jon Corson-Rikert, Cornell, Ying Ding (2012) **VIVO: A Semantic Approach to Scholarly Networking and Discovery**. Morgan & Claypool.

Katy Börner and David E Polley (2014) **Visual Insights: A Practical Guide to Making Sense of Data**. The MIT Press.

Börner, Katy (2015) **Atlas of Knowledge: Anyone Can Map**. The MIT Press. <http://scimaps.org/atlas2>



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All papers, maps, tools, talks, press are linked from <http://cns.iu.edu>  
 These slides are at <http://cns.iu.edu/docs/presentations>

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