Data Visualizations: Drawing Actionable Insights From Data

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Indiana University, USA

Inaugural Lecture
Auditorium A, CDC Tom Harkin Global Comm. Center, Atlanta, GA

February 4, 2016

PLACES & SPACES
MAPPING SCIENCE

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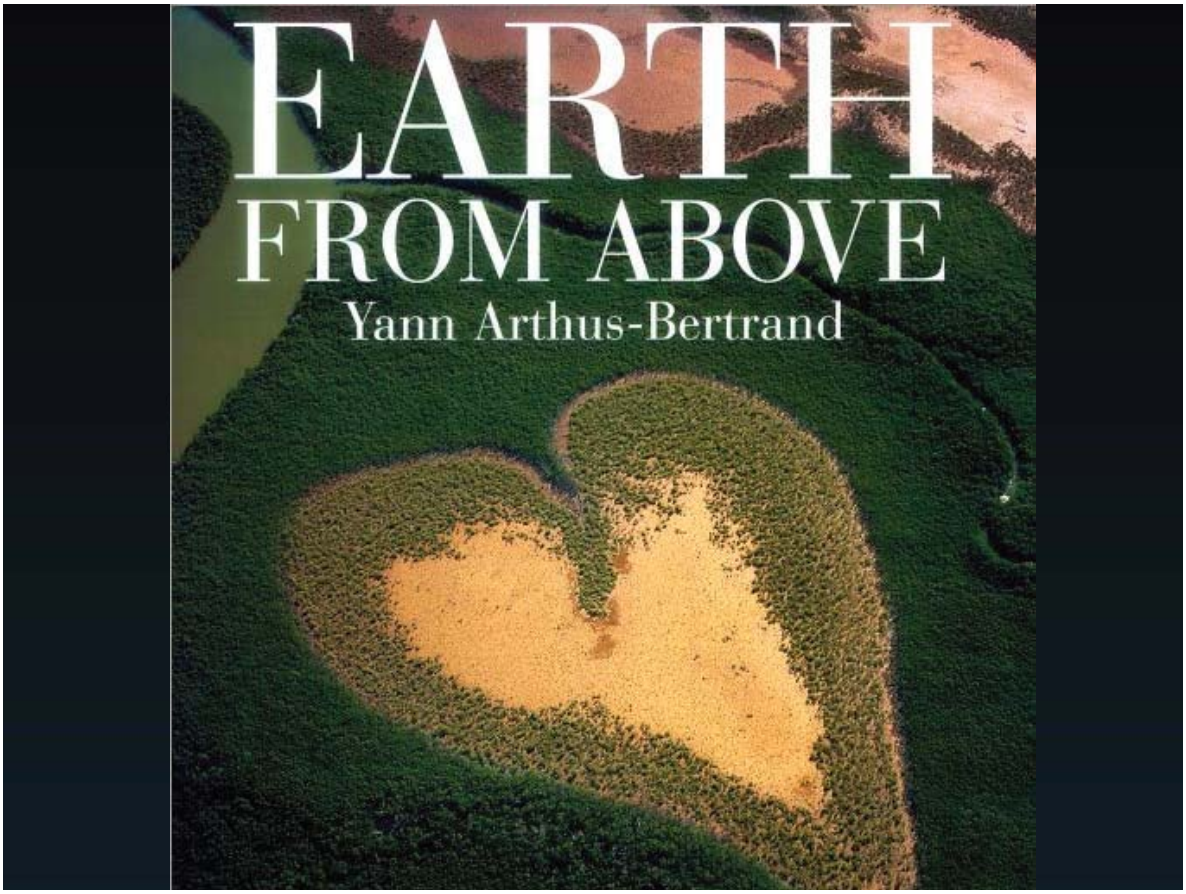
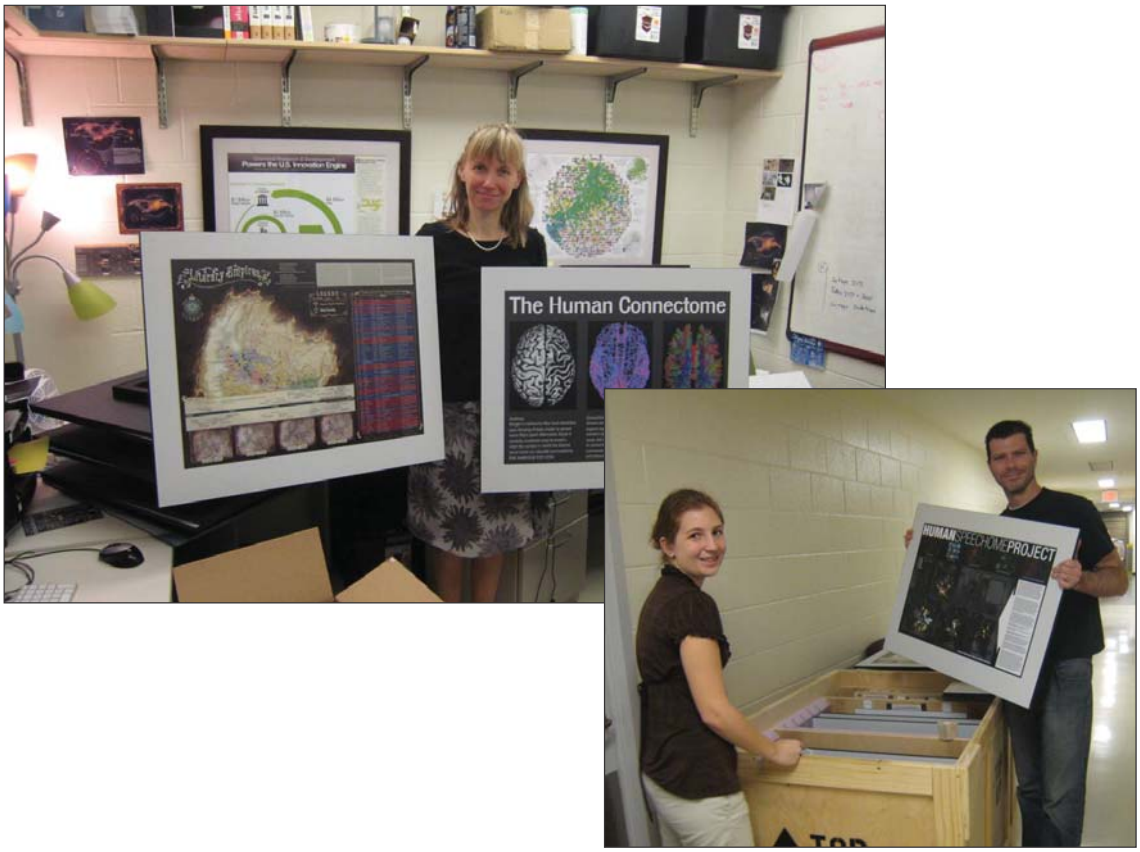


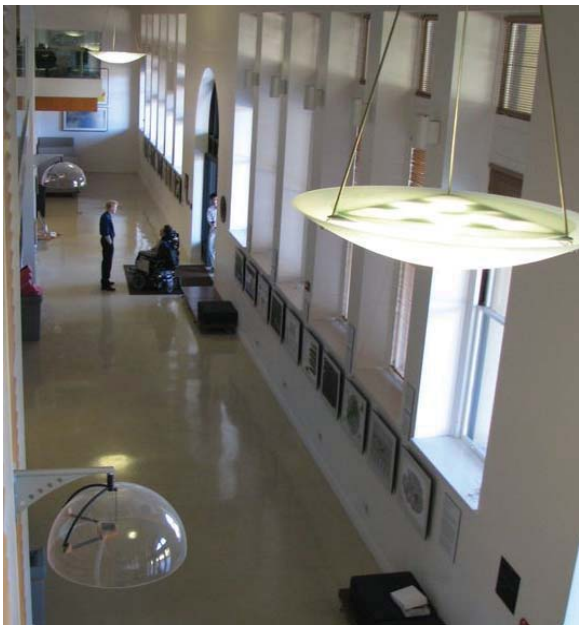
How can we communicate the beauty, structure, and dynamics of science to a general audience?

April, 2005: 101st Annual Meeting of the
Association of American Geographer, Denver, Colorado.

05: 101st Annual Meeting
merican Geographer, De

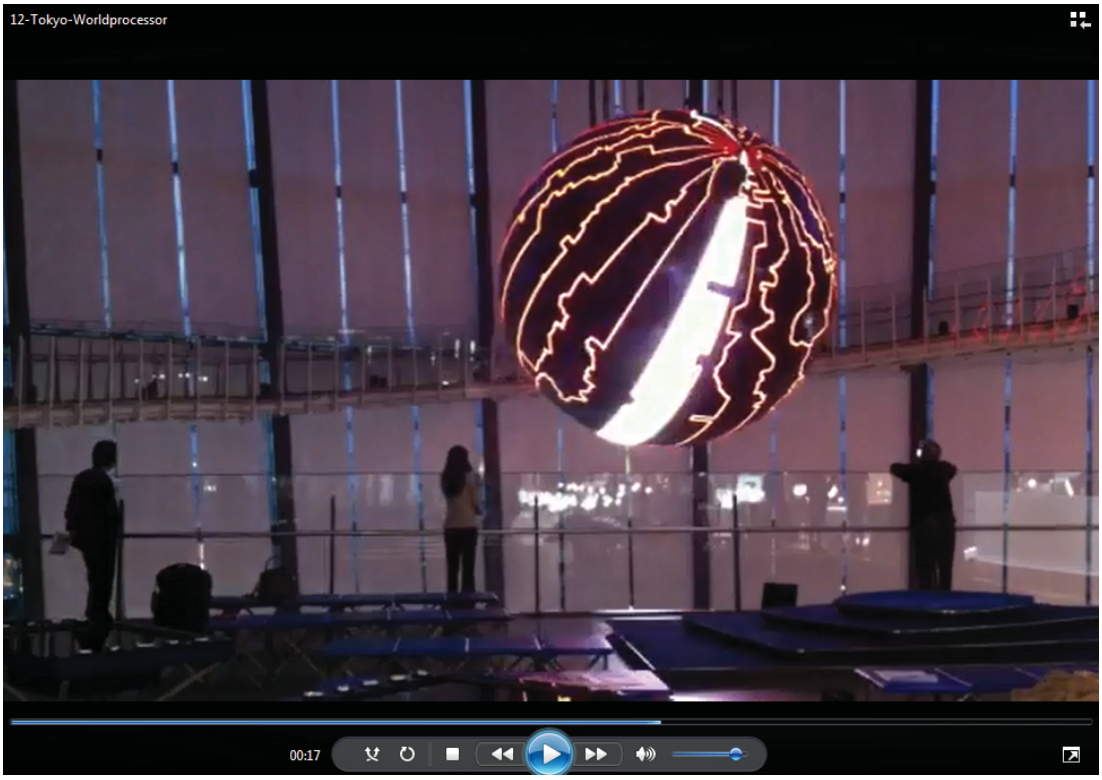

INDIANA
UNIVERSITY
PLACES AND SPACES
EXHIBIT


The Human Connectome
HUMAN SEED PLUME PROJECT



Debut of 5th Iteration of the Mapping Science Exhibit at MEDIA X was in 2009 at Wallenberg Hall, Stanford University.

Science Maps in "Expedition Zukunft" science train visited 62 cities in 7 months. Opening on April 23rd, 2009 by German Chancellor Merkel



Ingo Gunther's Worldprocessor globe design on display at the Museum of Emerging Science and Innovation in Tokyo, Japan.

Places & Spaces Digital Display in North Carolina State's Immersion Theater

Places & Spaces at Duke University

January 12 - April 10, 2015

Places & Spaces at Northwestern University
May 14 - September 23, 2015

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

10 iterations over 10 years

equal

10 x 10 = 100 maps!

The Power of Maps 2005

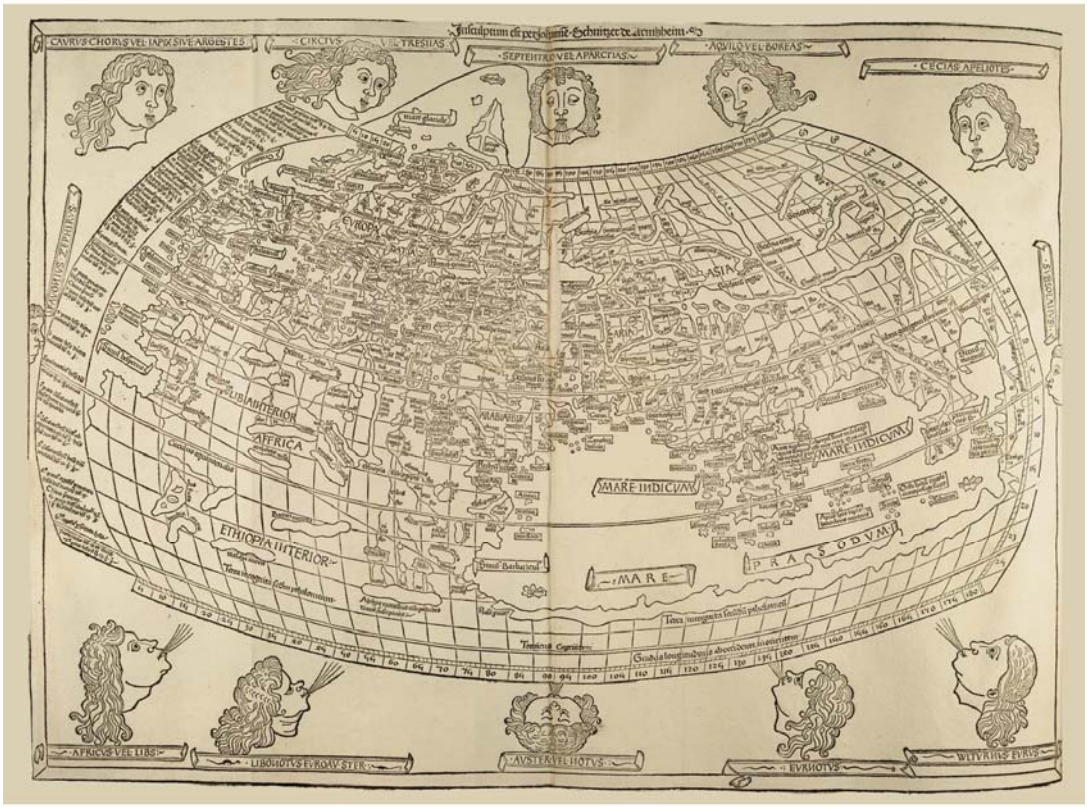
I.1 I.3 I.5 I.7 I.9

I.2 I.4 I.6 I.8 I.10

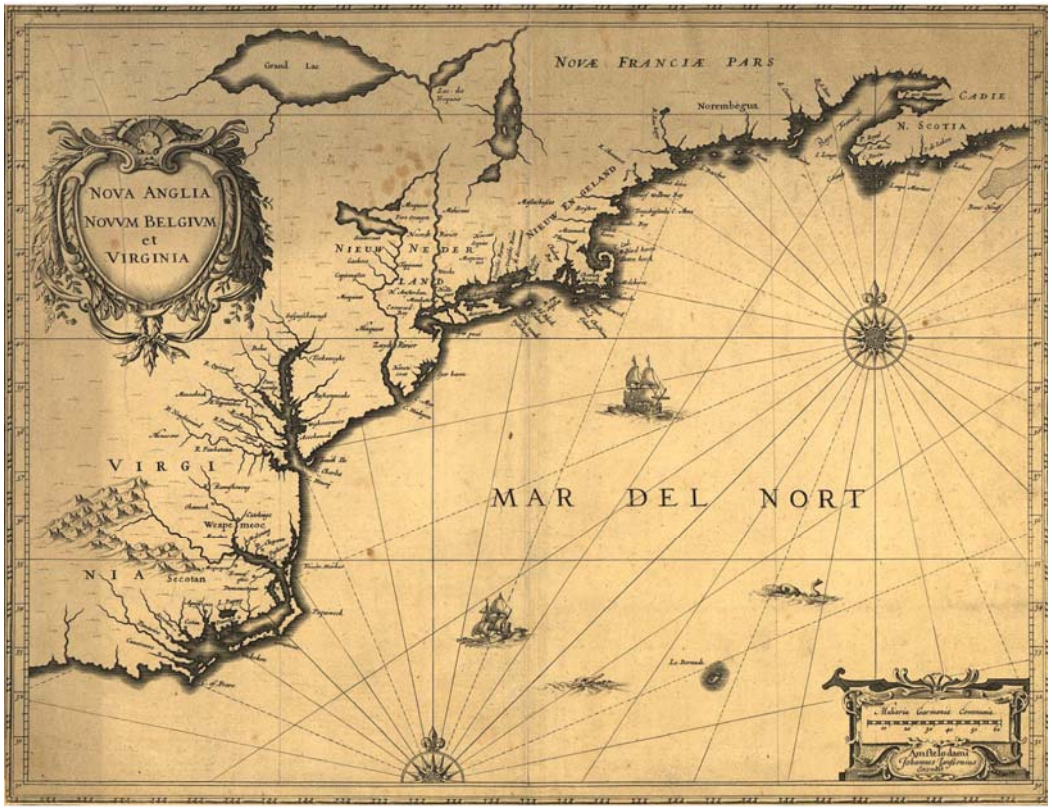
Cartographic maps of physical places have guided mankind's explorations for centuries.

They enabled the discovery of new worlds while also marking territories inhabited by the unknown.

Without maps, we would be lost.



Cosmographia World Map - Claudius Ptolemy - 1482

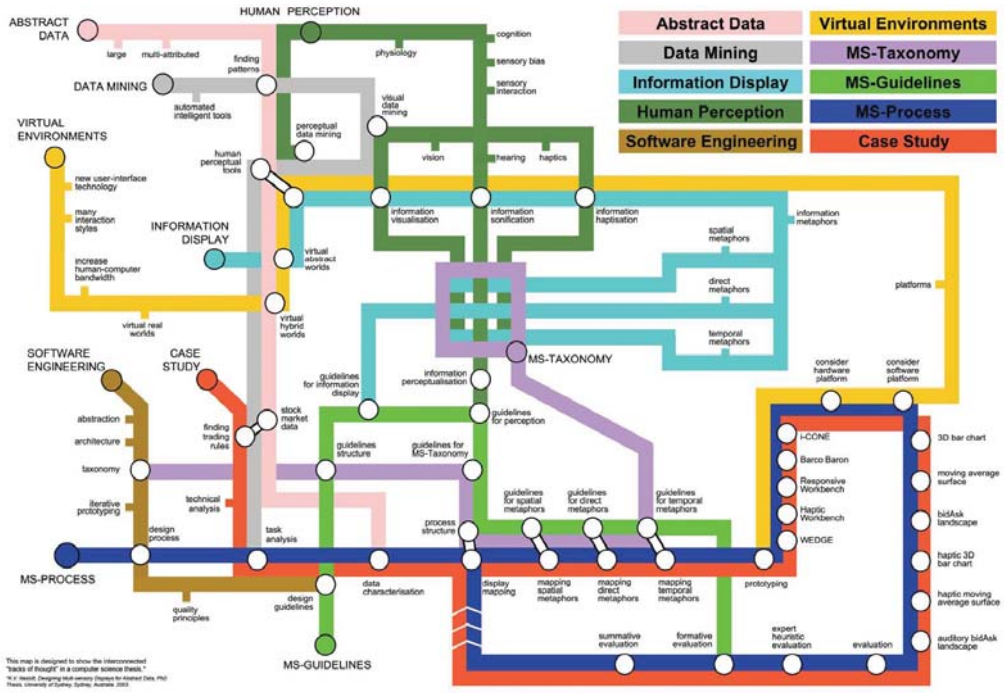


Nova Anglia, Novvm Belgivm et Virginia - Jan Jannson - 1642

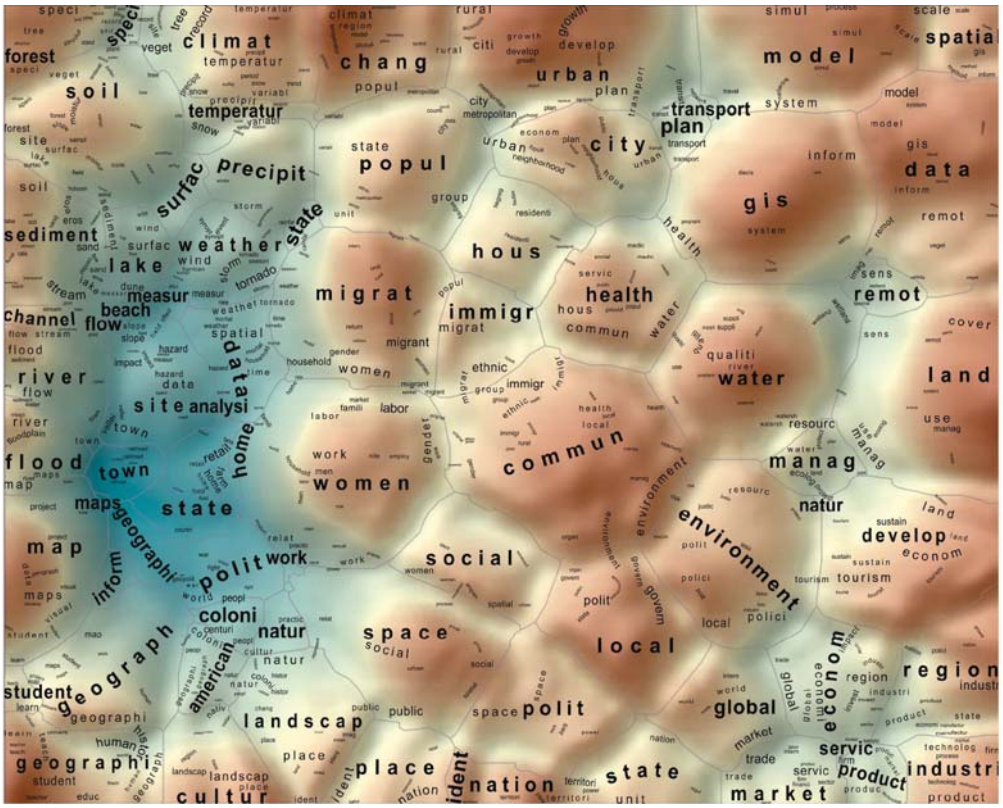
A New Map of the Whole World with Trade Winds According to the Latest and Most Exact Observations - Herman Moll - 1736

Science maps of abstract semantic spaces aim to serve today's explorers navigating the world of science.

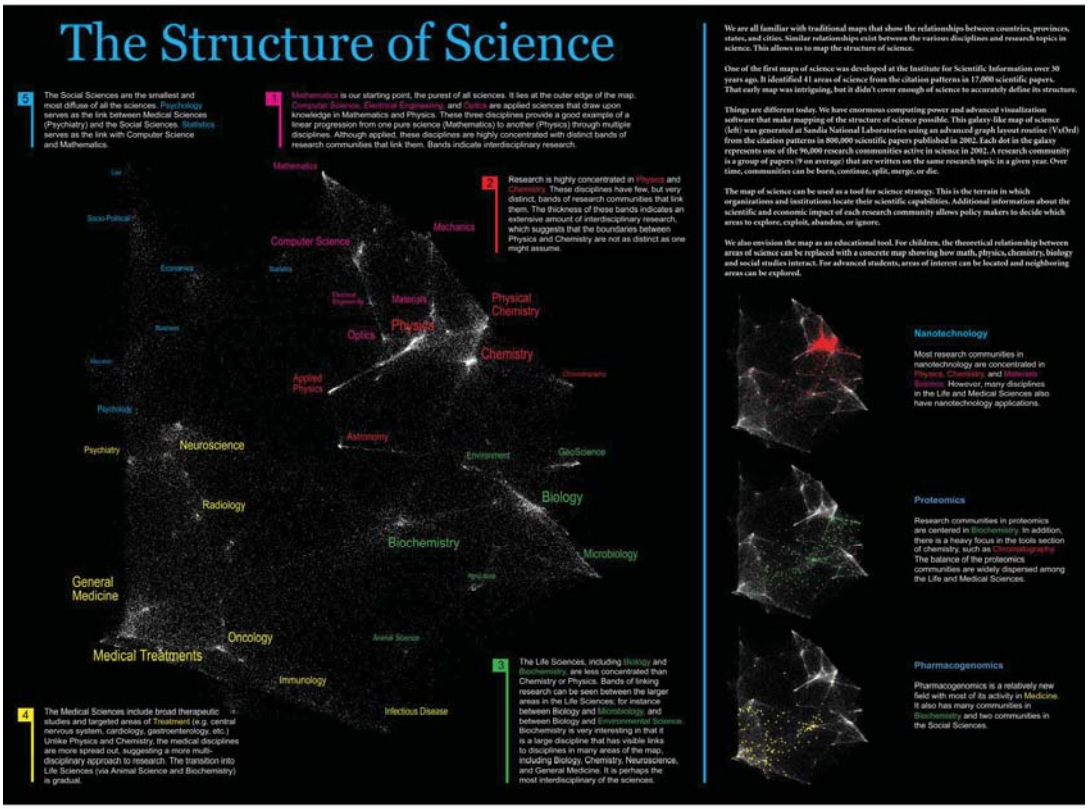
They can be used to identify objectively major experts, institutions, collections. They allow us to track the emergence, evolution, and disappearance of topics and help to identify the most promising areas of research.



Ph.D. Thesis Map - Keith B. Nesbitt - 2004



In Terms of Geography - Andre Skupin - 2005

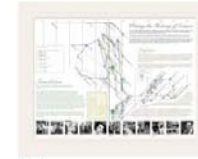


The Structure of Science - Kevin Boyack, Richard Klavans - 2005

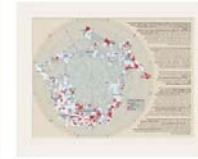
The Power of Reference Systems 2006


II.1


II.3

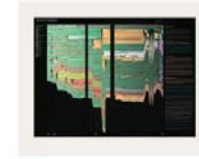

II.5


II.7


II.9

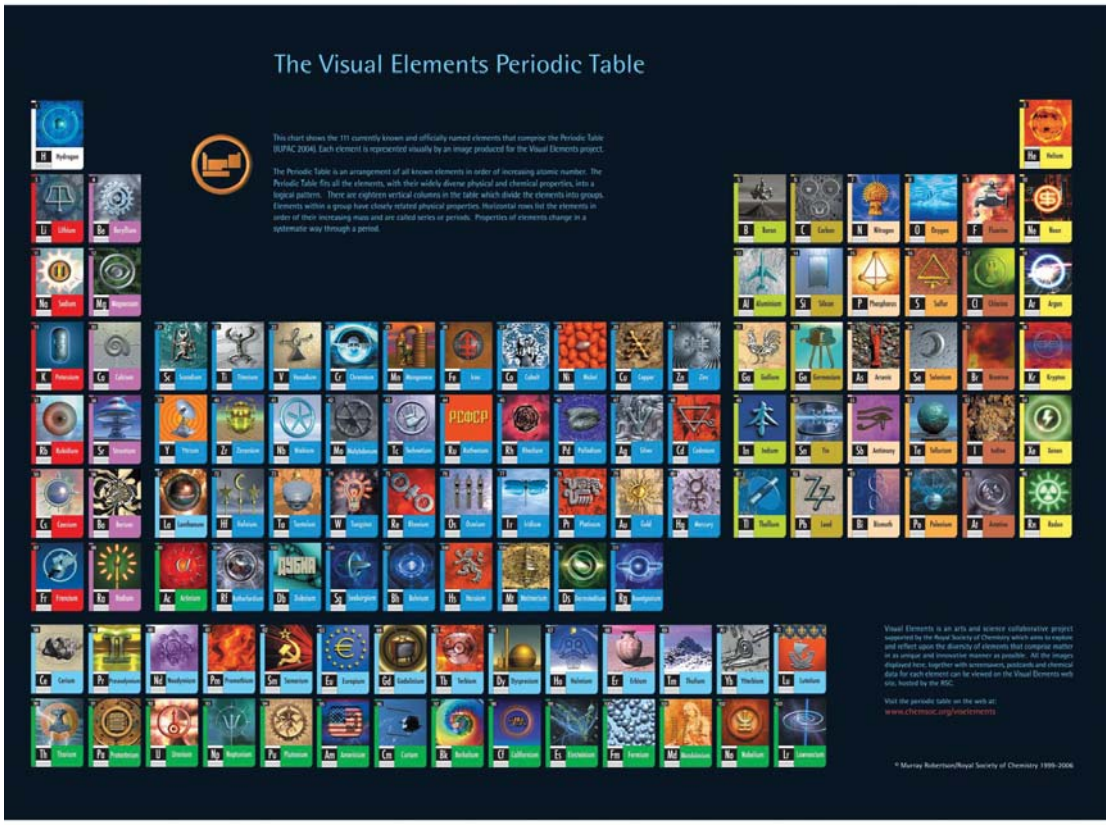

II.2


II.4

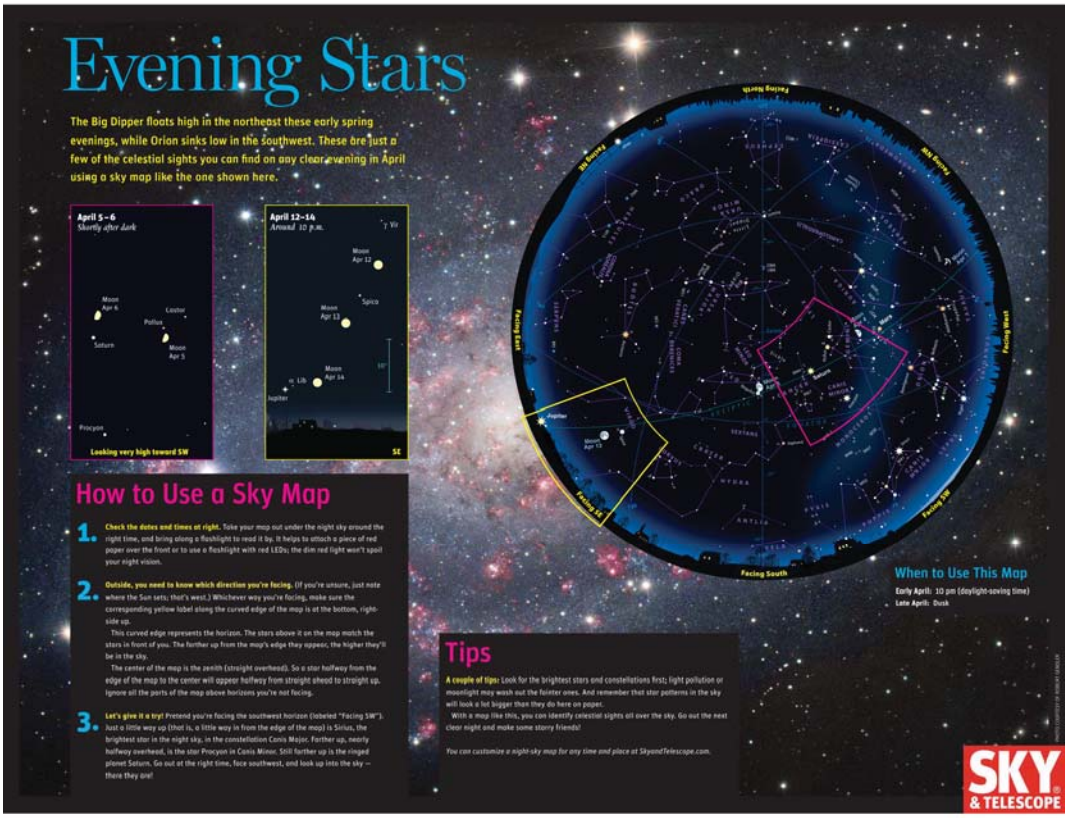

II.6


II.8


II.10



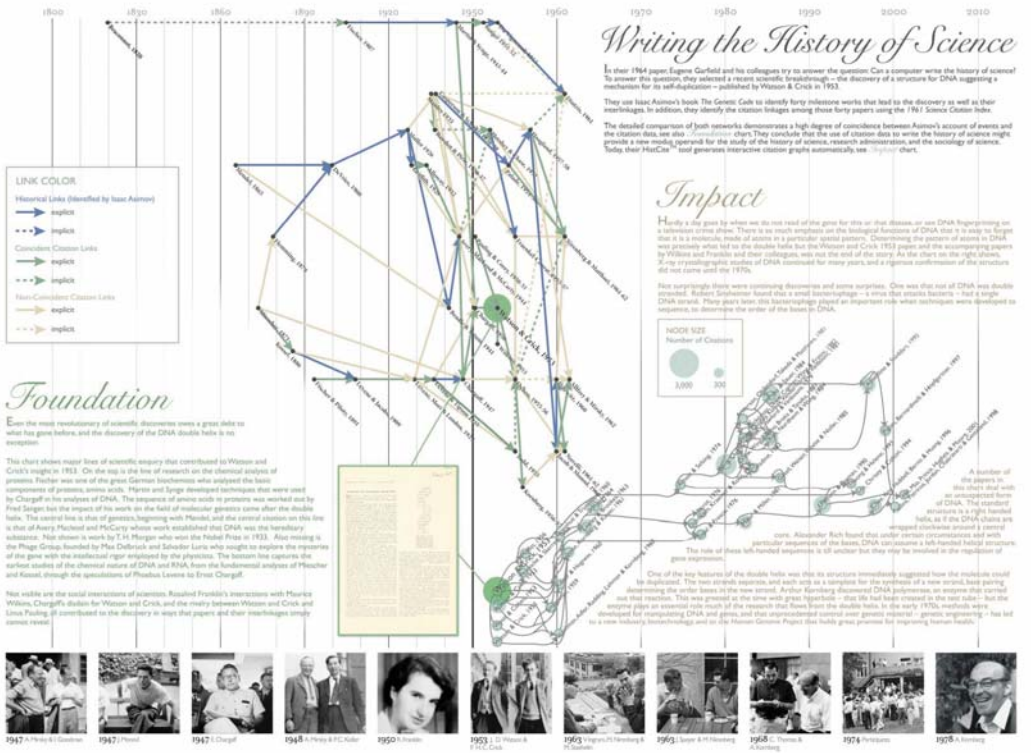
Visual Elements Periodic Table - Murray Robertson, John Emsley - 2005



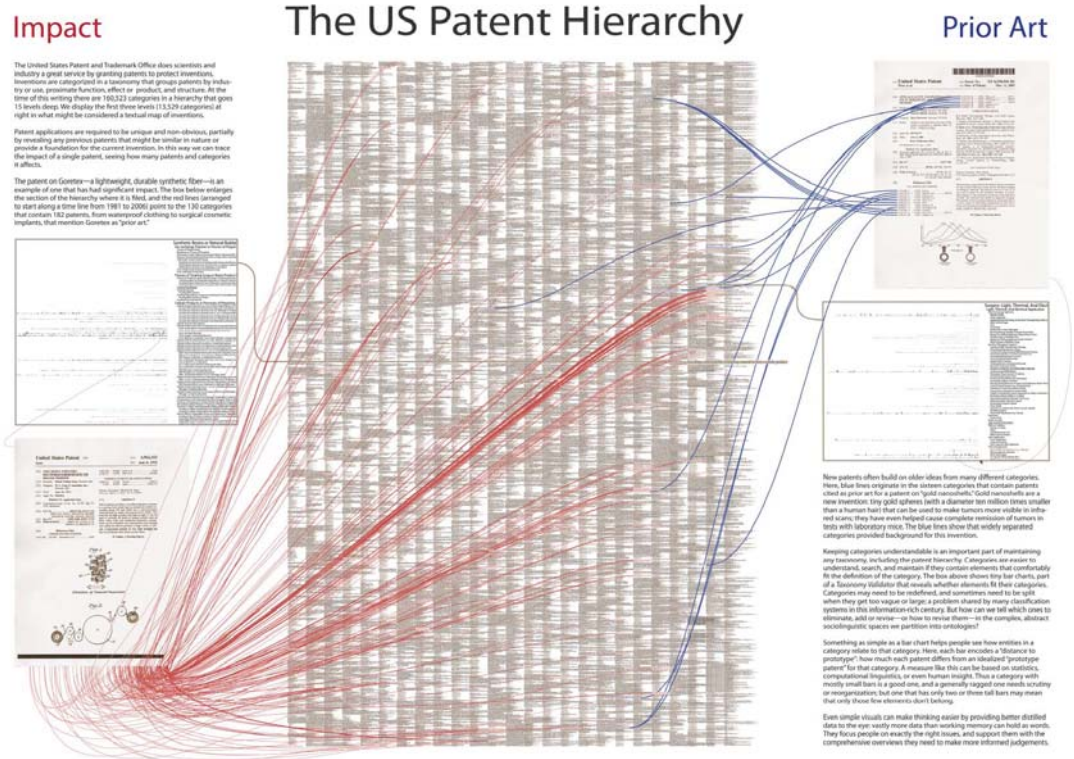
Sky Chart of New York City in April 2006 - Roger W. Sinnott, Interactive Factory - 2006

How would a reference system for all of science look?

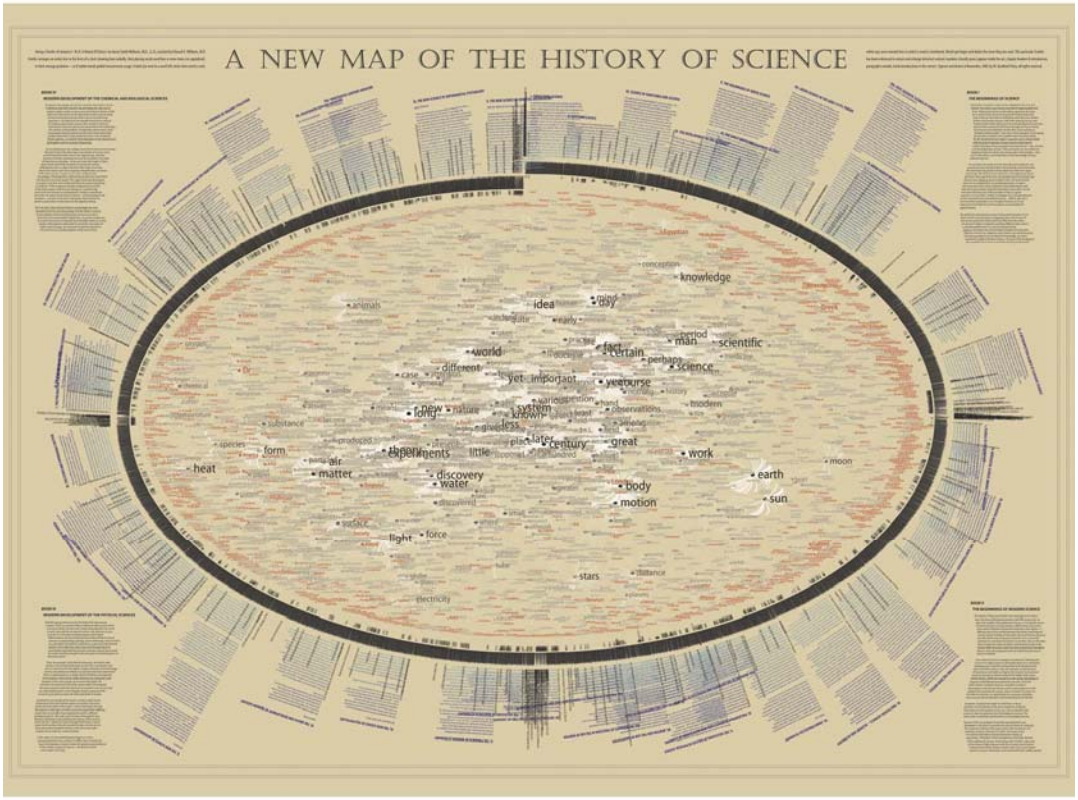
What dimensions would it have?



HistCiteTM Visualization of DNA Development - Eugene Garfield, Elisha Hardy, Katy Börner, Ludmila Pollock, Jan Witkowski - 2006

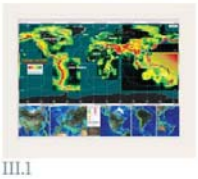


Taxonomy Visualization of Patent Data - Katy Borner, Elisha Hardy, Bruce Herr, Todd Holloway, Bradford Paley - 2006



TexArc Visualization of "The History of Science" - W. Bradford Paley - 2006

The Power of Forecasts 2007


III.1


III.3


III.5


III.7

III.9


III.2


III.4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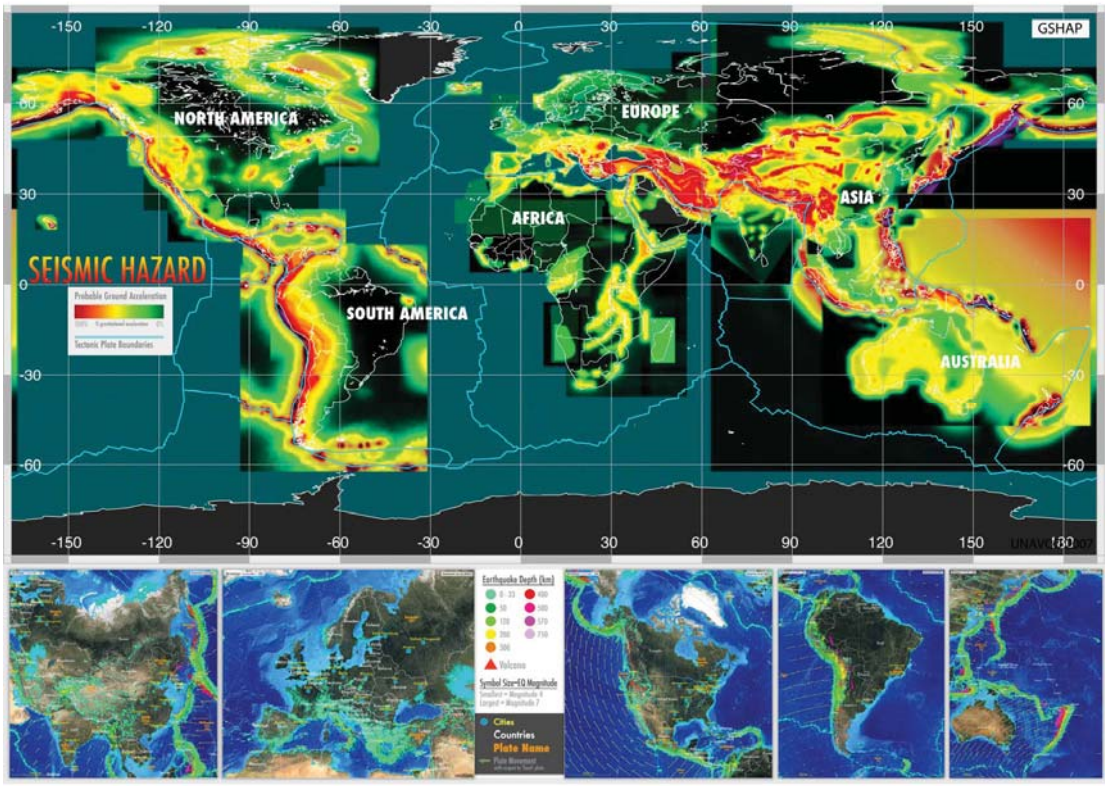
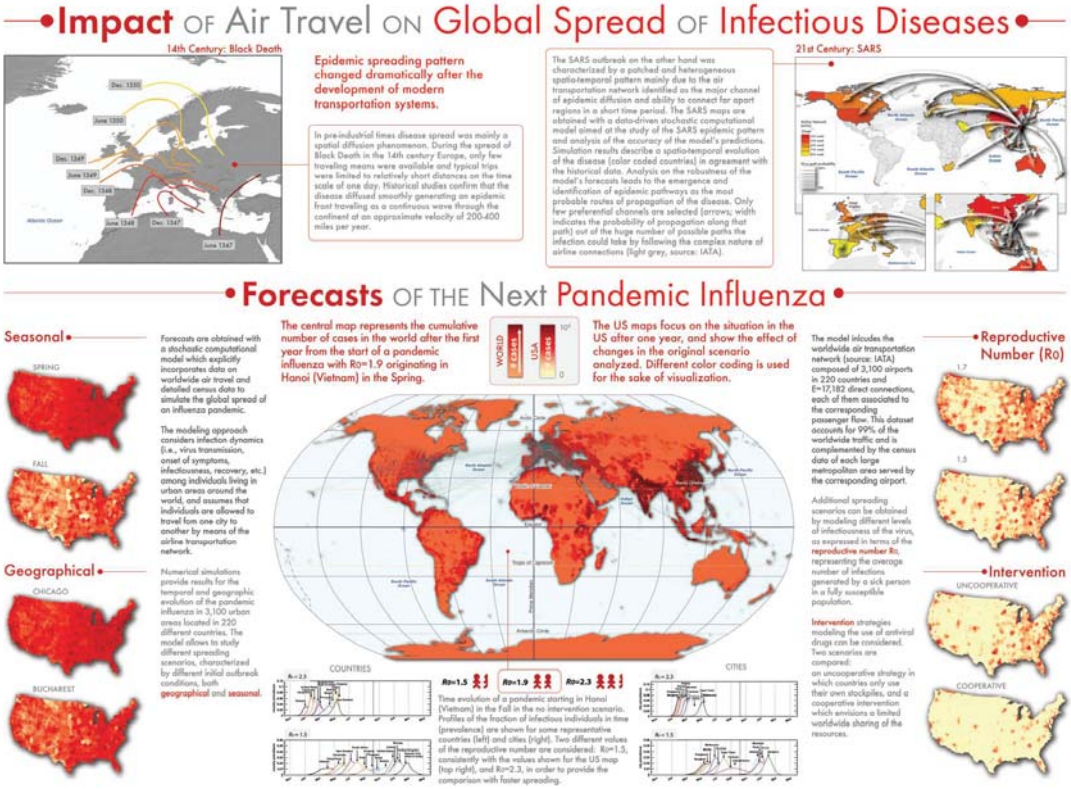
III.8


III.10



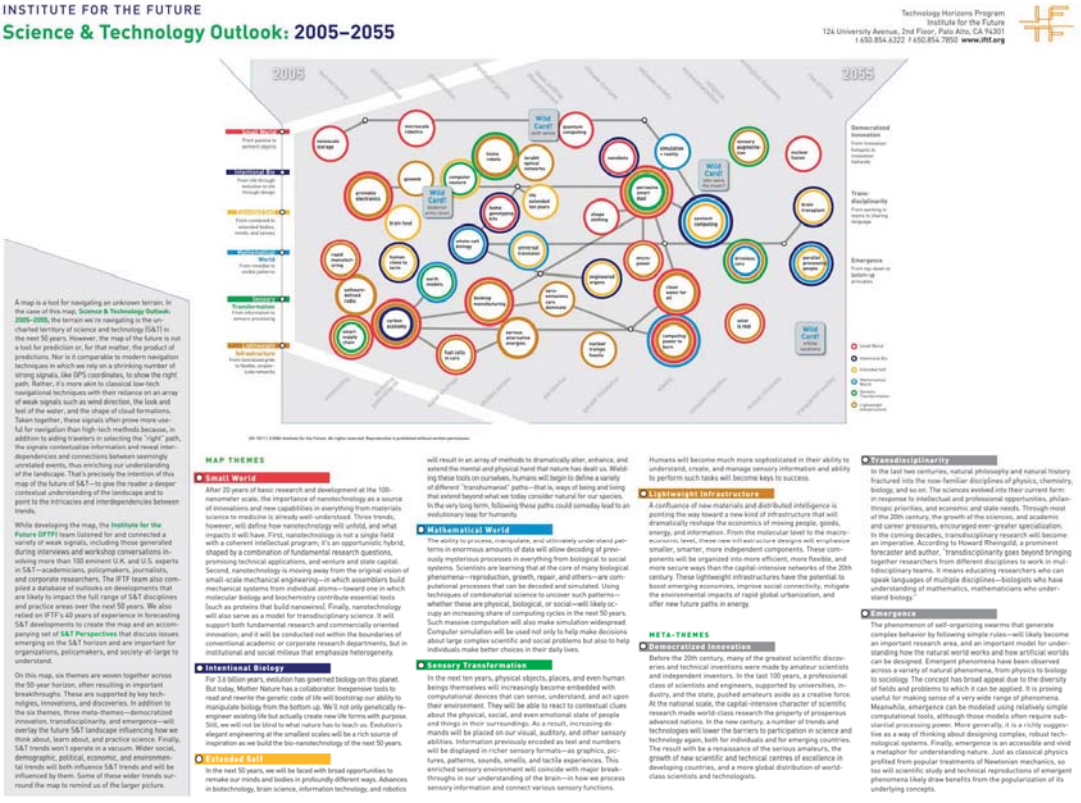
Tectonic Movements and Earthquake Hazard Predictions - Martin W. Hamburger, Lou Estey, Chuck Meertens, Elisha Hardy - 2005



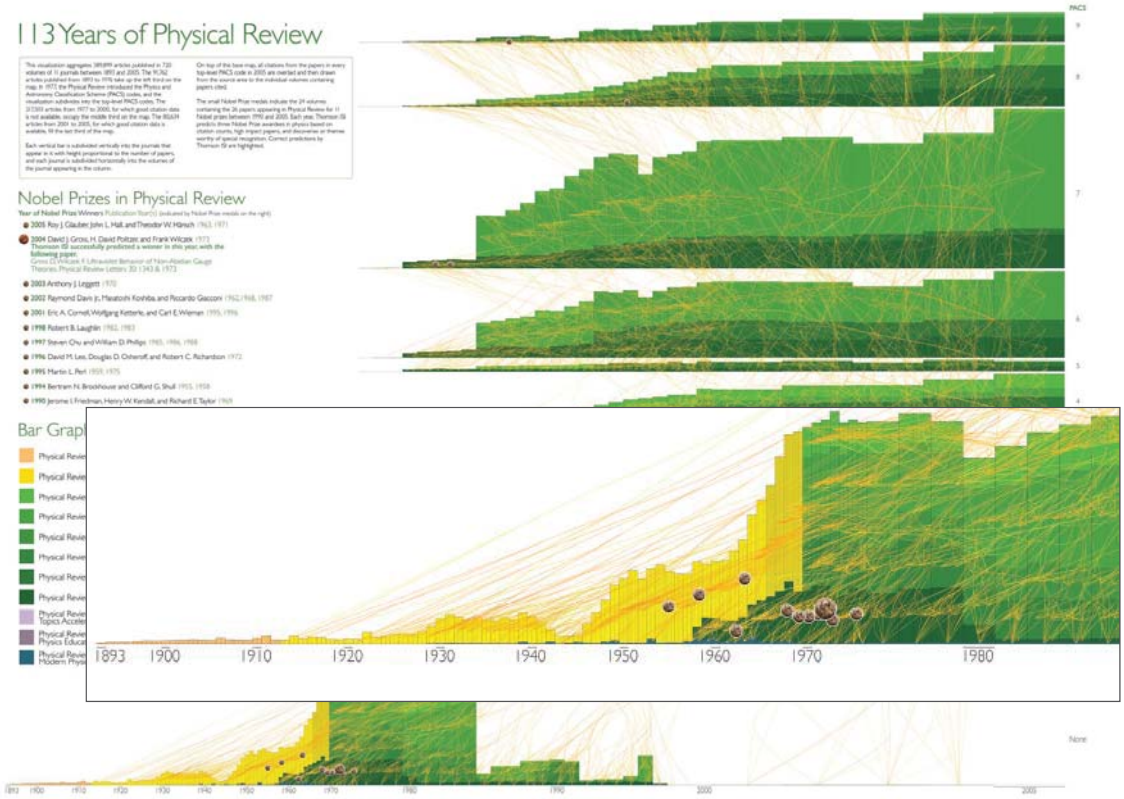
Impact of Air Travel on Global Spread of Infectious Diseases - Vittoria Colizza, Alessandro Vespignani - 2007

Can one forecast science?

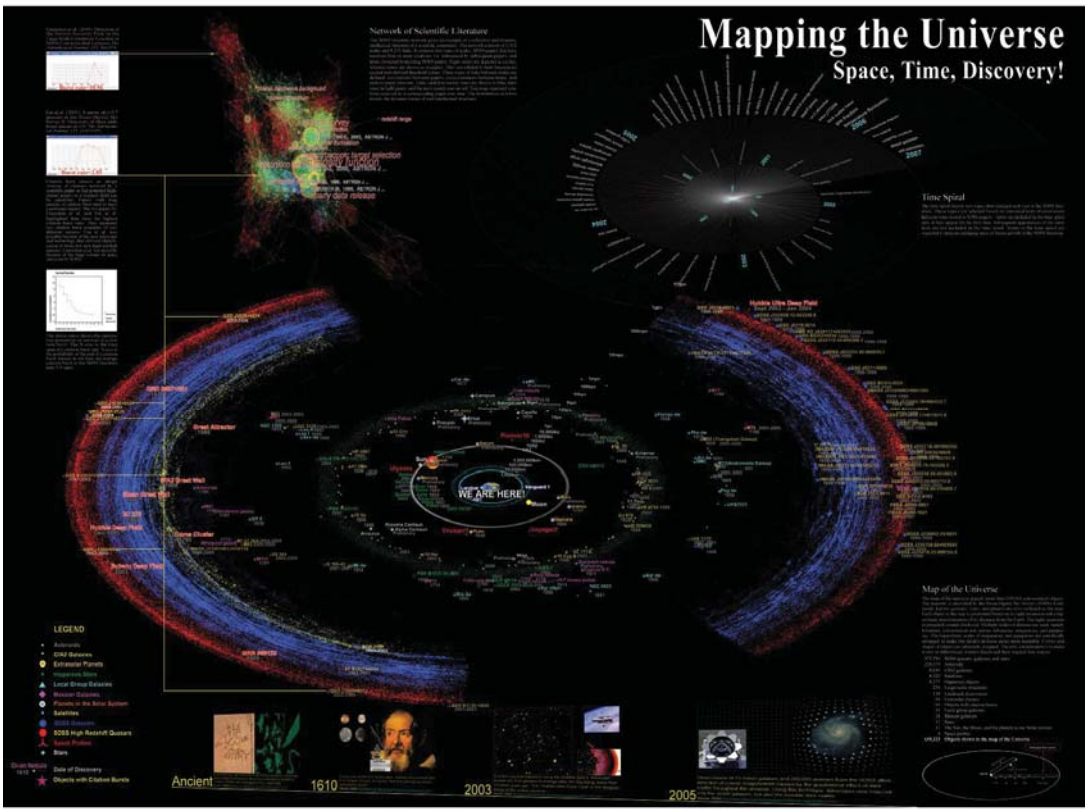
What 'science forecast language' will work to communicate results?



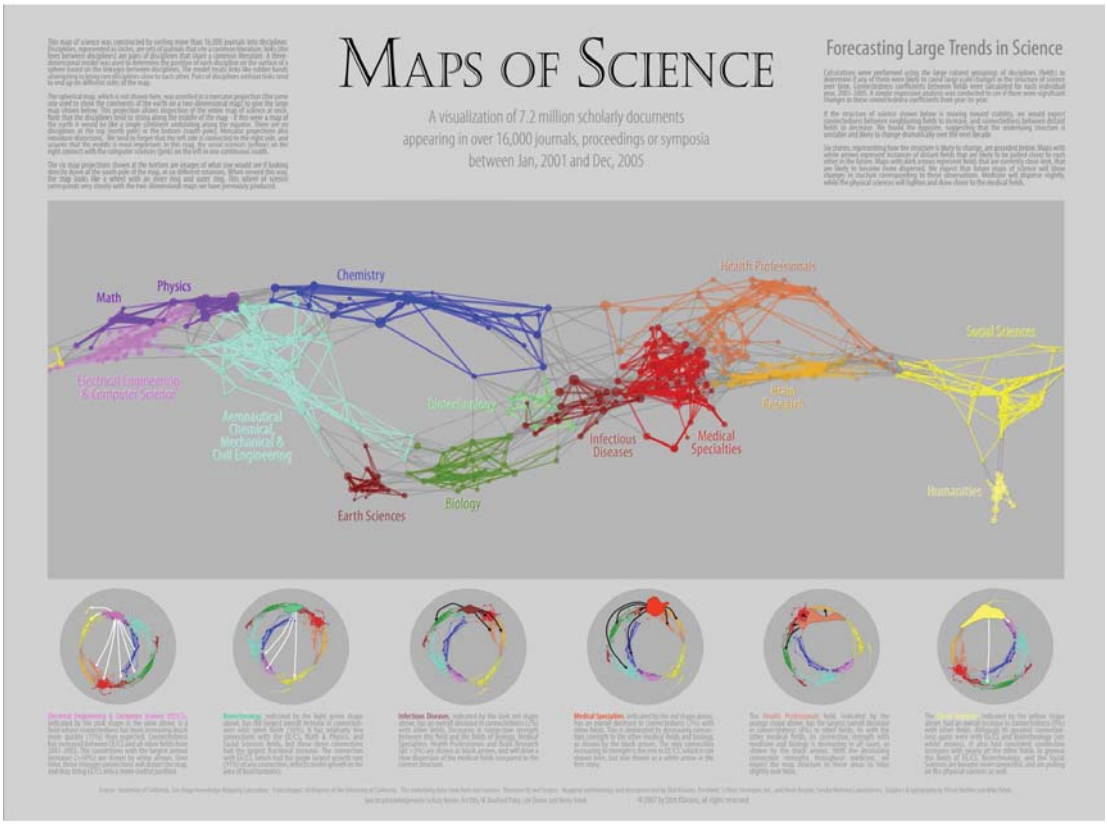
Science & Technology Outlook: 2005-2055 - Alex Soojung-Kim Pang, David Pescovitz, Marina Gorbis, Jean Hagan - 2006



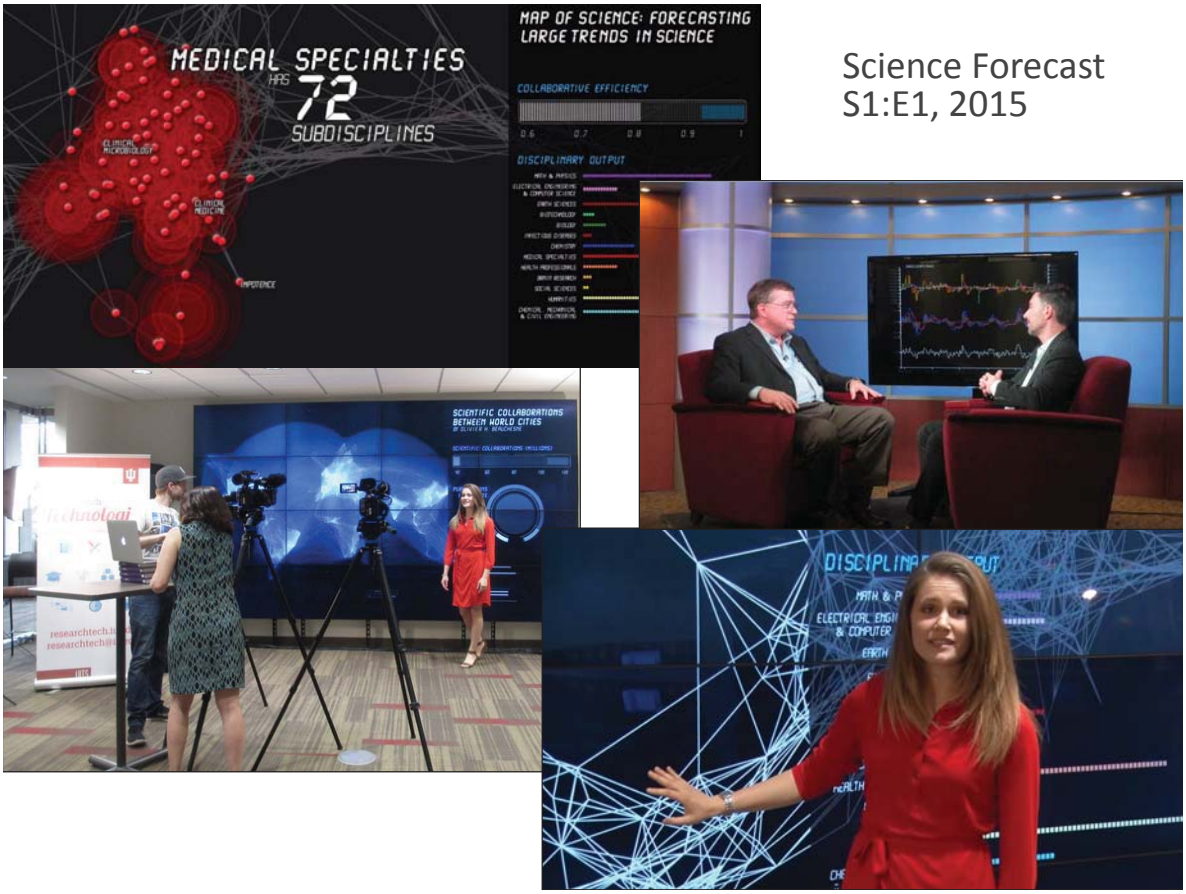
114 Years of Physical Review - Bruce W. Herr II, Russell Duhon, Katy Borner, Elisha Hardy, Shashikant Penumarthy - 2007



Mapping the Universe: Space, Time, Discovery! Chaomei Chen, Jian Zhang, Michael S. Vogeley, J. Richard Gott III, Mario Juric, Lisa Kershner - 2007

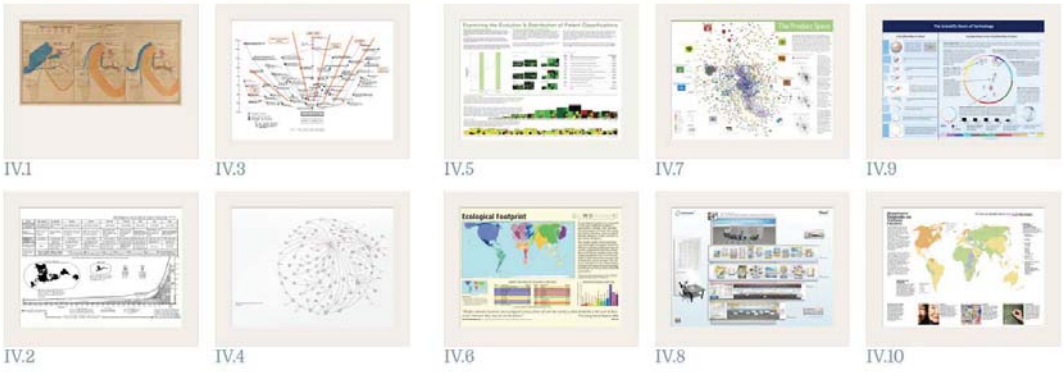


Maps of Science: Forecasting Large Trends in Science - Richard Klavans, Kevin Boyack - 2007



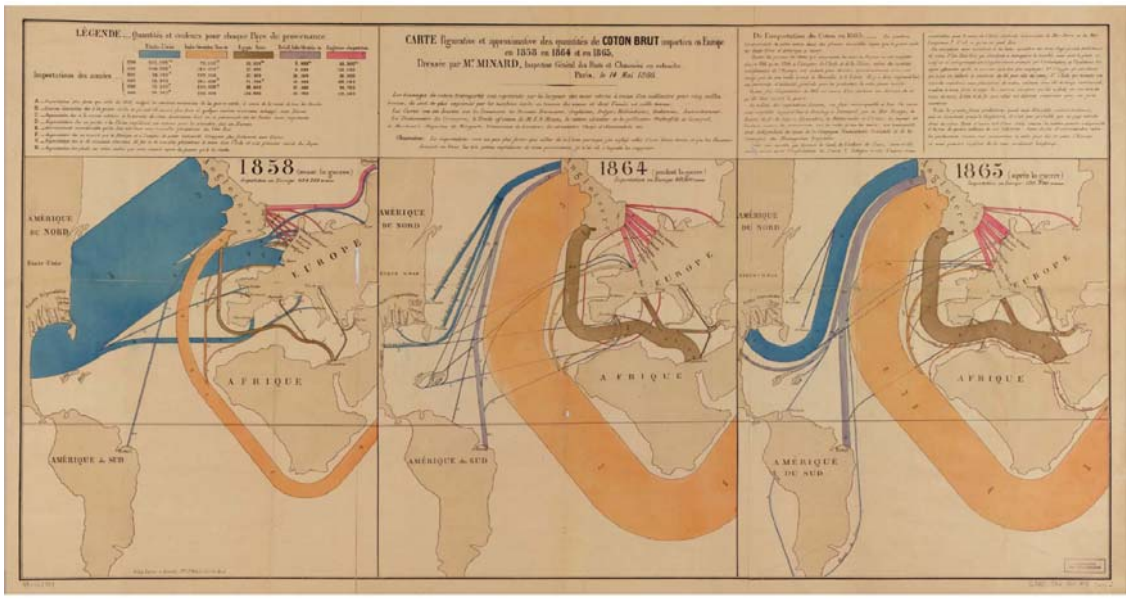
Science Forecast
S1:E1, 2015

Science Maps for Economic Decision Makers 2008



What insight needs to economic decision makers have?

What data views are most useful?



Europe Raw Cotton Imports in 1858, 1864 and 1865 - Charles Joseph Minard - 1866

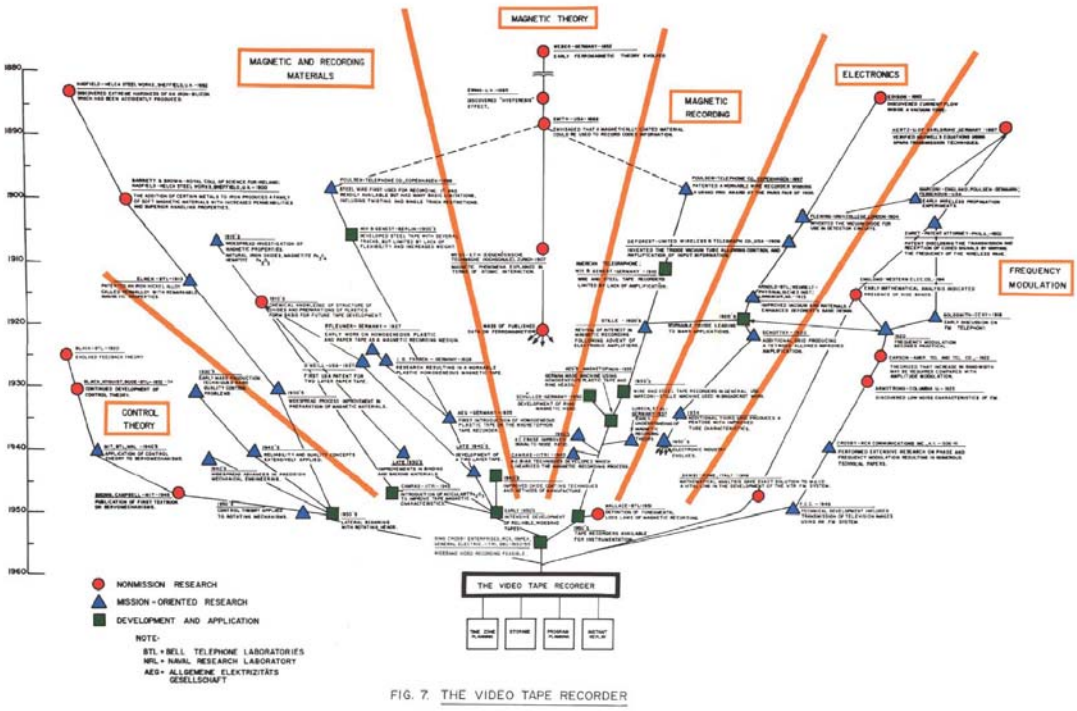
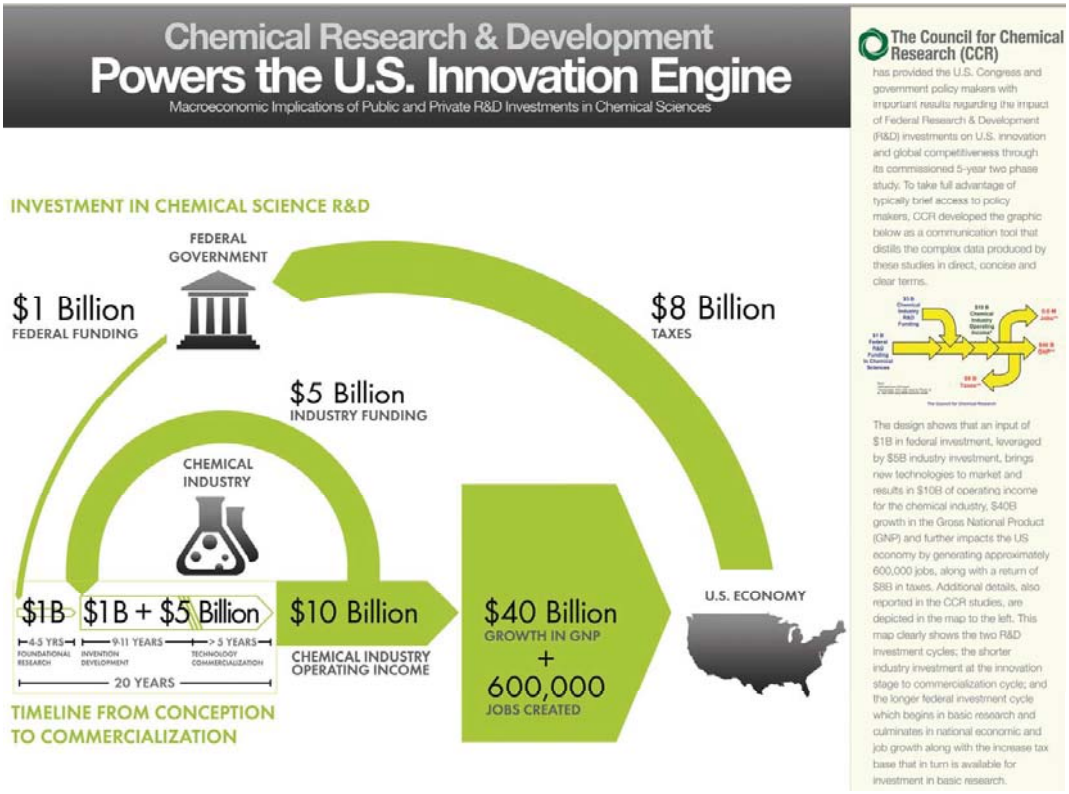
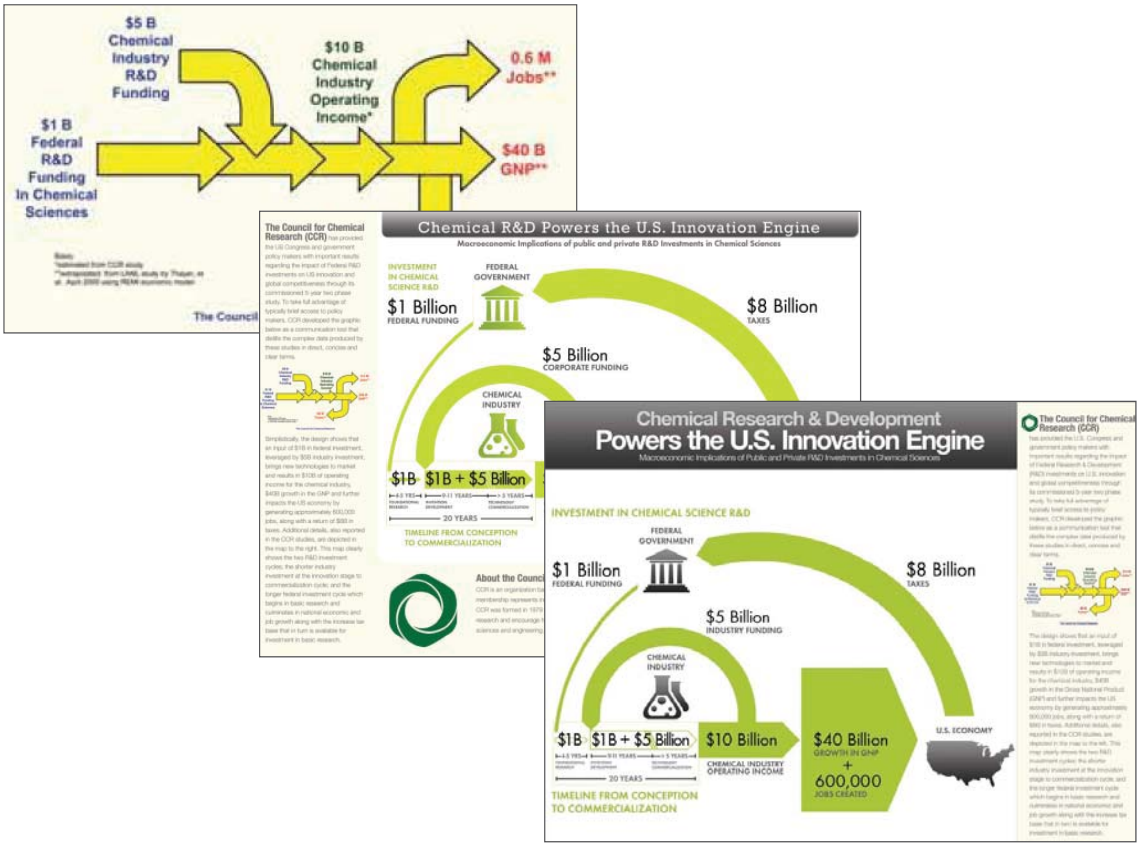


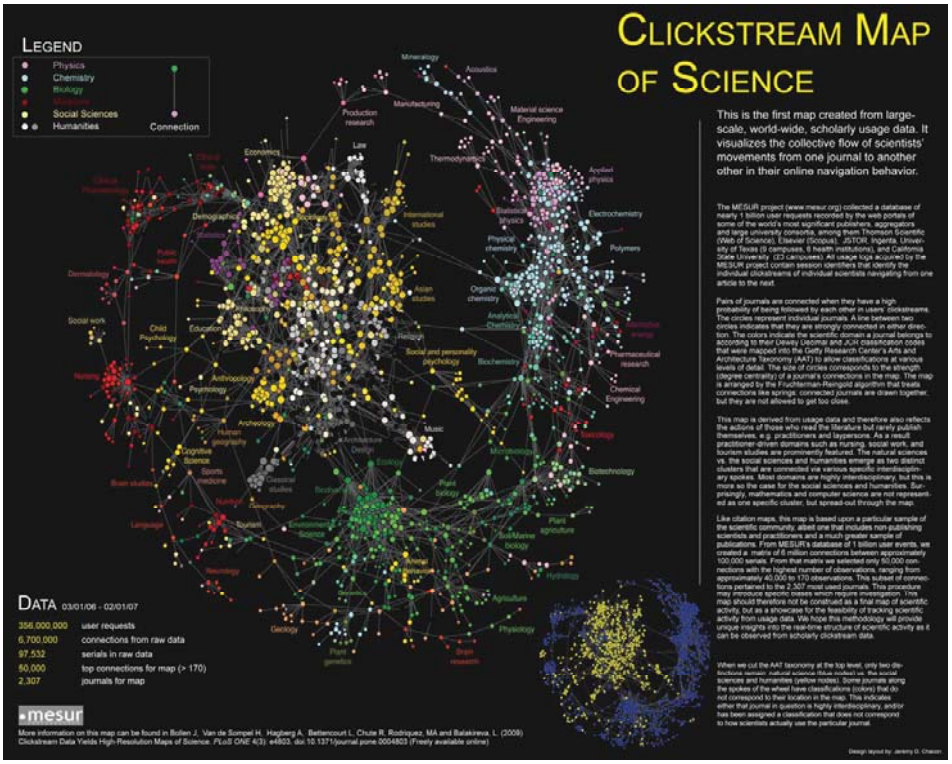
FIG. 7. THE VIDEO TAPE RECORDER

Tracing of Key Events in the Development of the Video Tape Recorder - Mr. G. Benn, Francis Narin - 1968

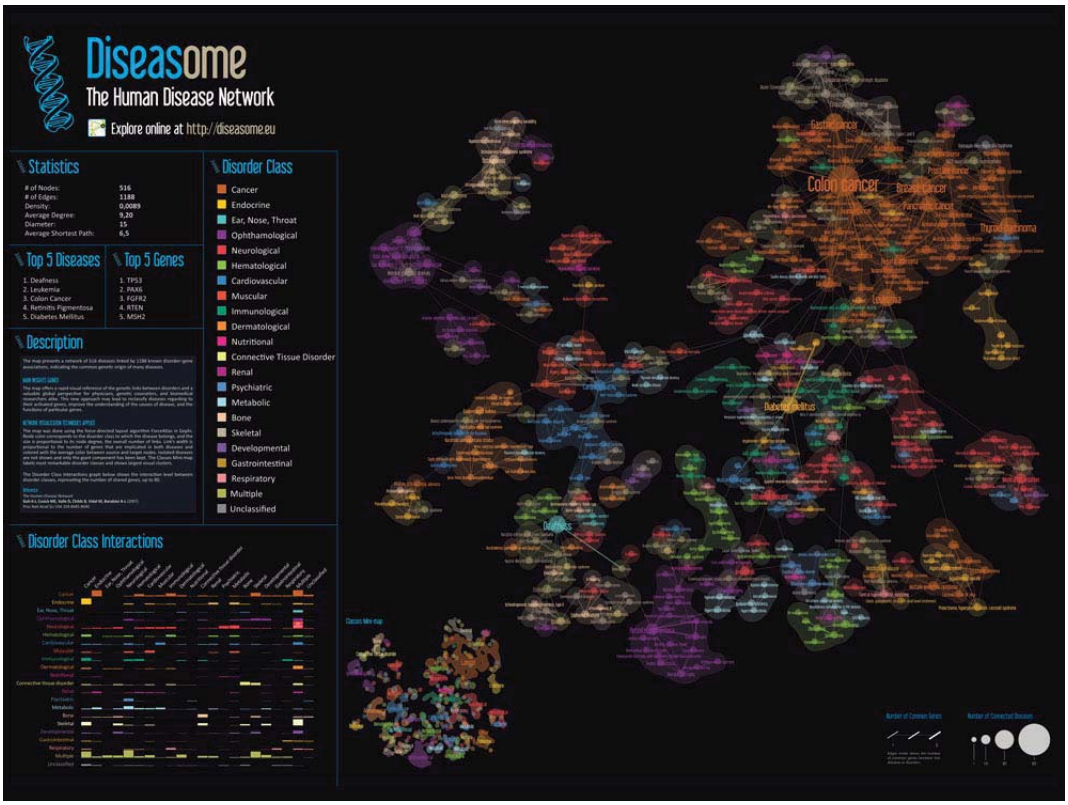


Chemical R&D Powers the U.S. Innovation Engine - The Council for Chemical Research - 2009

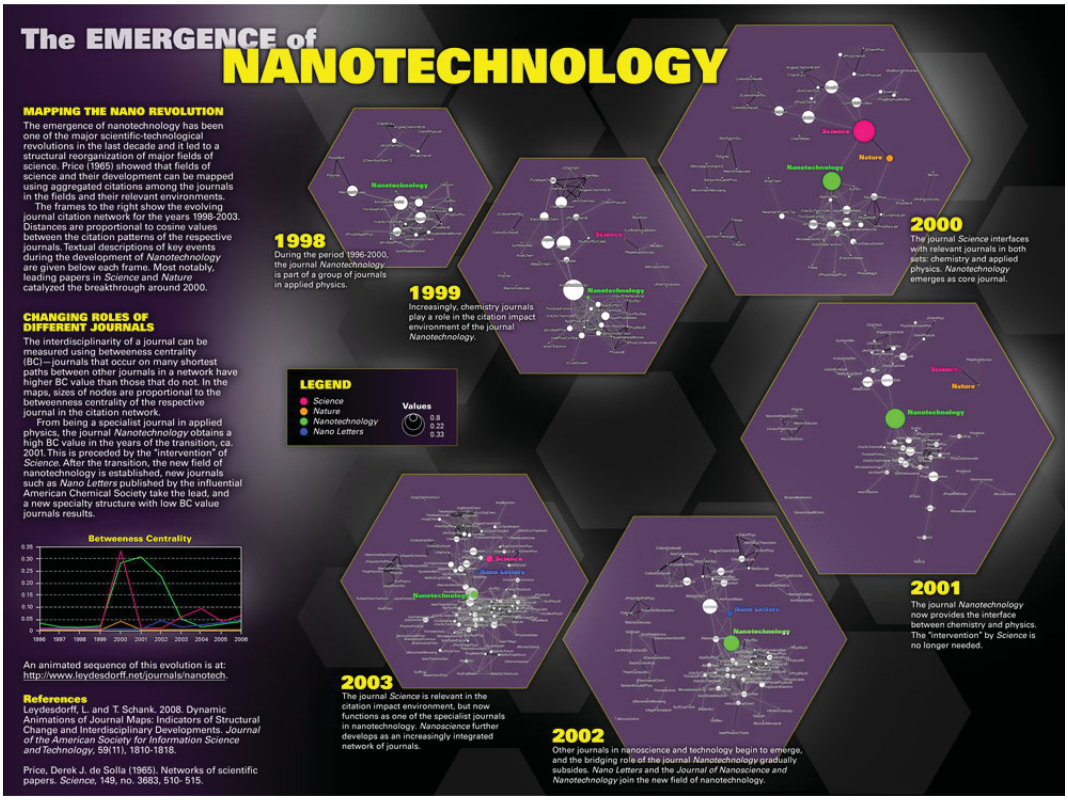




A Clickstream Map of Science. Johan Bollen, Herbert Van de Sompel, Aric Hagberg, Luís M. A. Bettencourt, Ryan Chute, Marko A. Rodriguez, and Lyudmila Balakireva - 2008

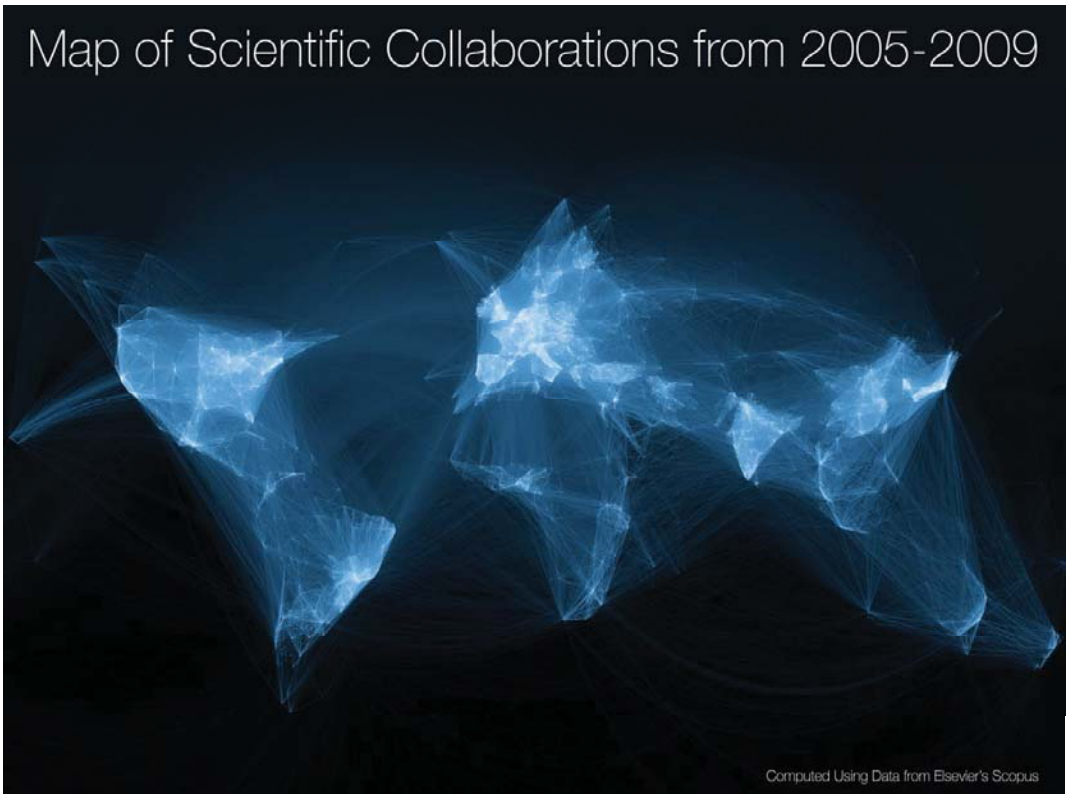


Diseasome - Mathieu Bastian & Sebastien Heymann - 2009

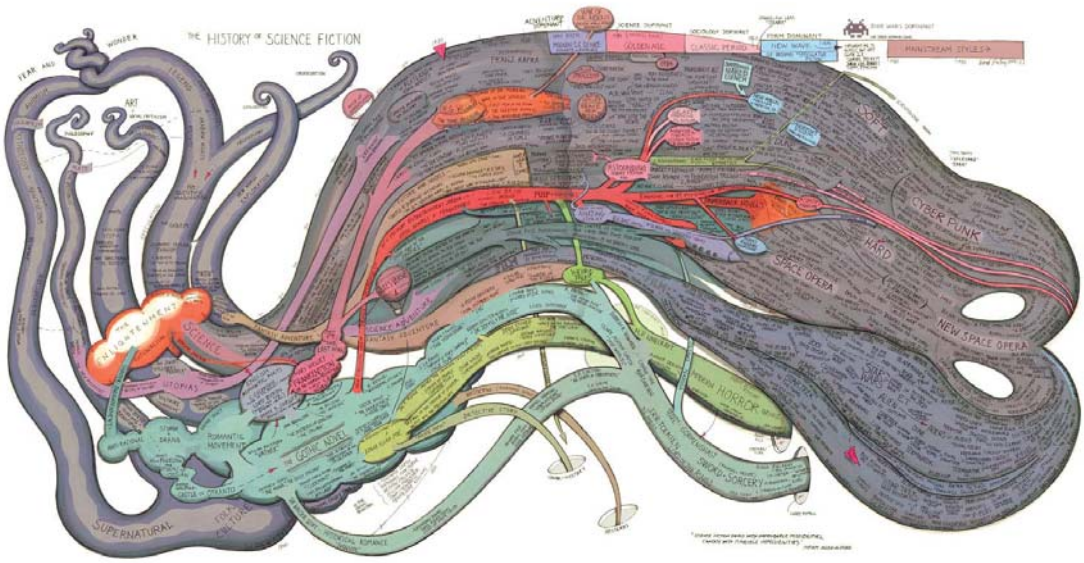


The Emergence of Nanoscience & Technology - Loet Leydesdorff - 2010

Science Maps as Visual Interfaces to Digital Libraries 2011



Stream of Scientific Collaborations between World Cities - Olivier H. Beauchesne - 2012



History of Science Fiction - Ward Shelley - 2011

Check out our Zoom Maps online!

VII.10
History of Science Fiction, by Ward S

Visit scimaps.org and check out all our maps in stunning detail!

Science Maps for Kids 2012


VIII.1


VIII.3


VIII.5


VIII.7


VIII.9

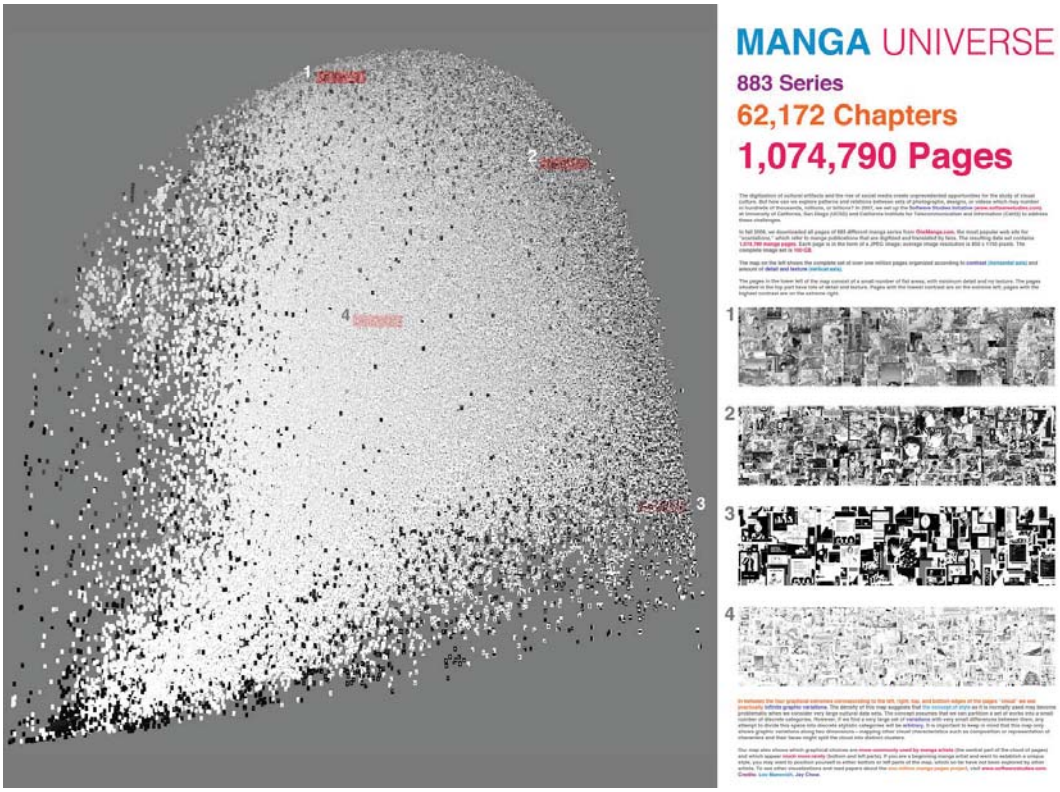

VIII.2


VIII.4

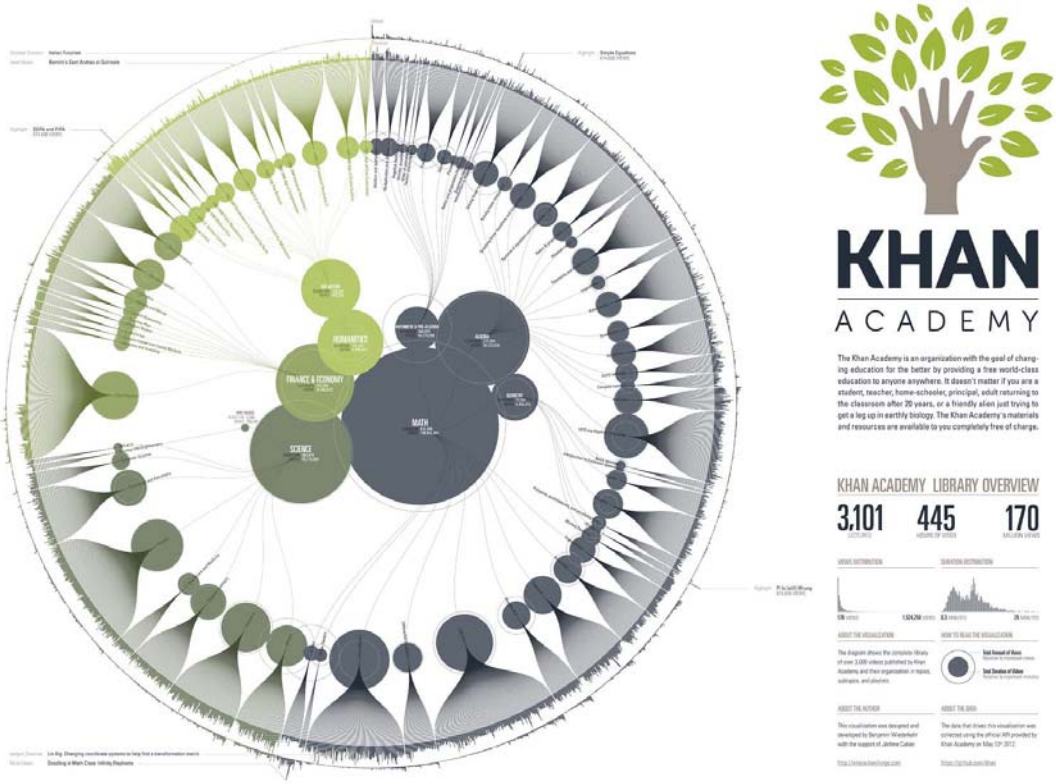

VIII.6


VIII.8

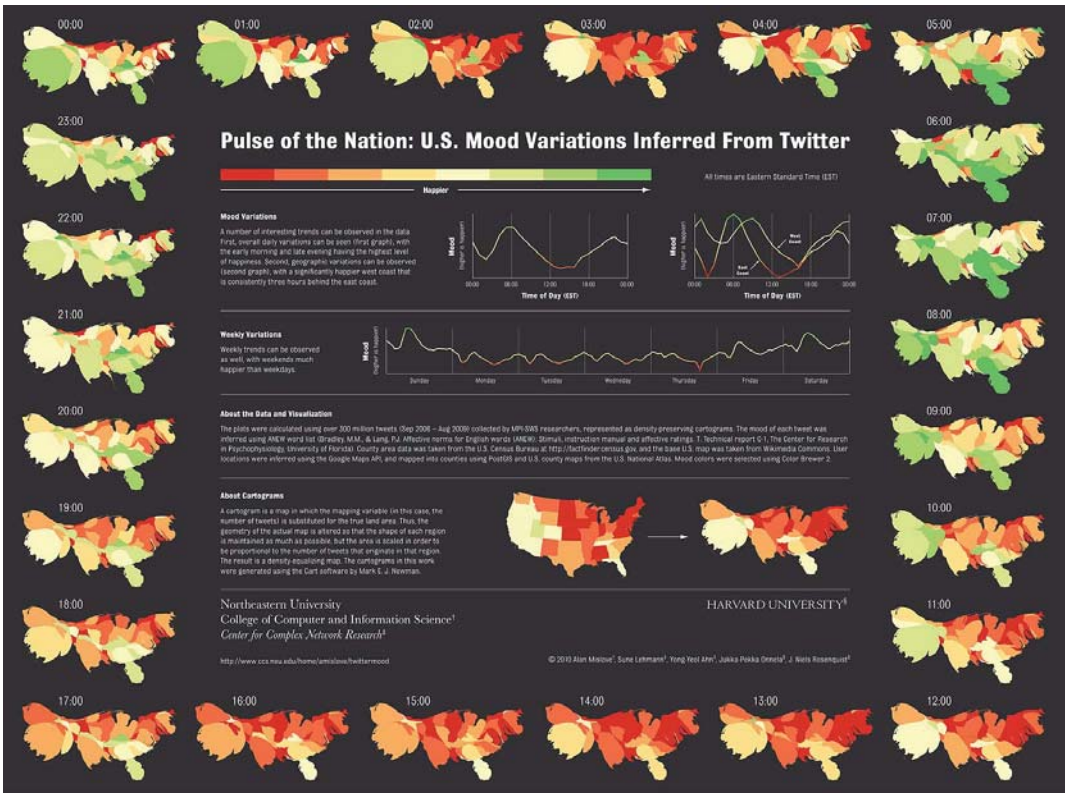
VIII.10



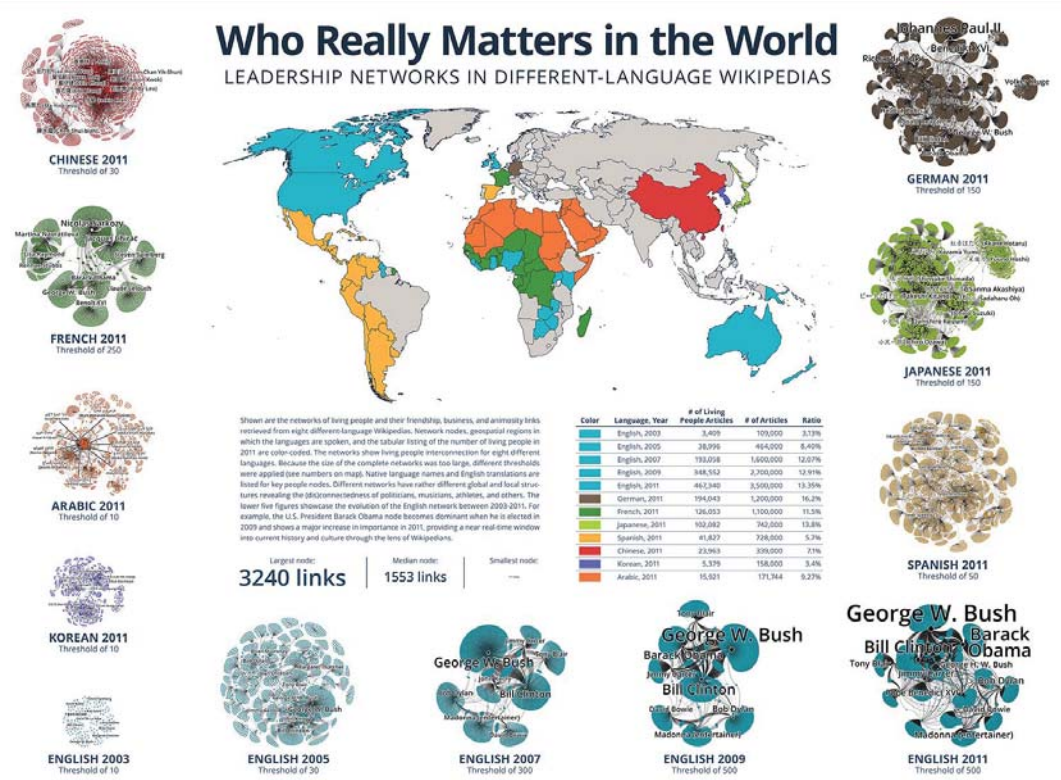
Manga Universe - Lev Manovich and Jay Chow - 2012



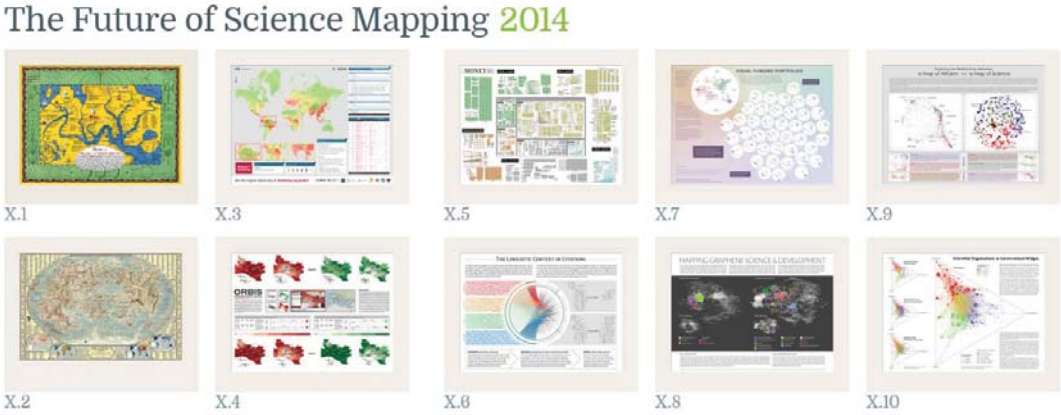
Khan Academy Library Overview - Benjamin Wiederkehr and Jérôme Cukier - 2012

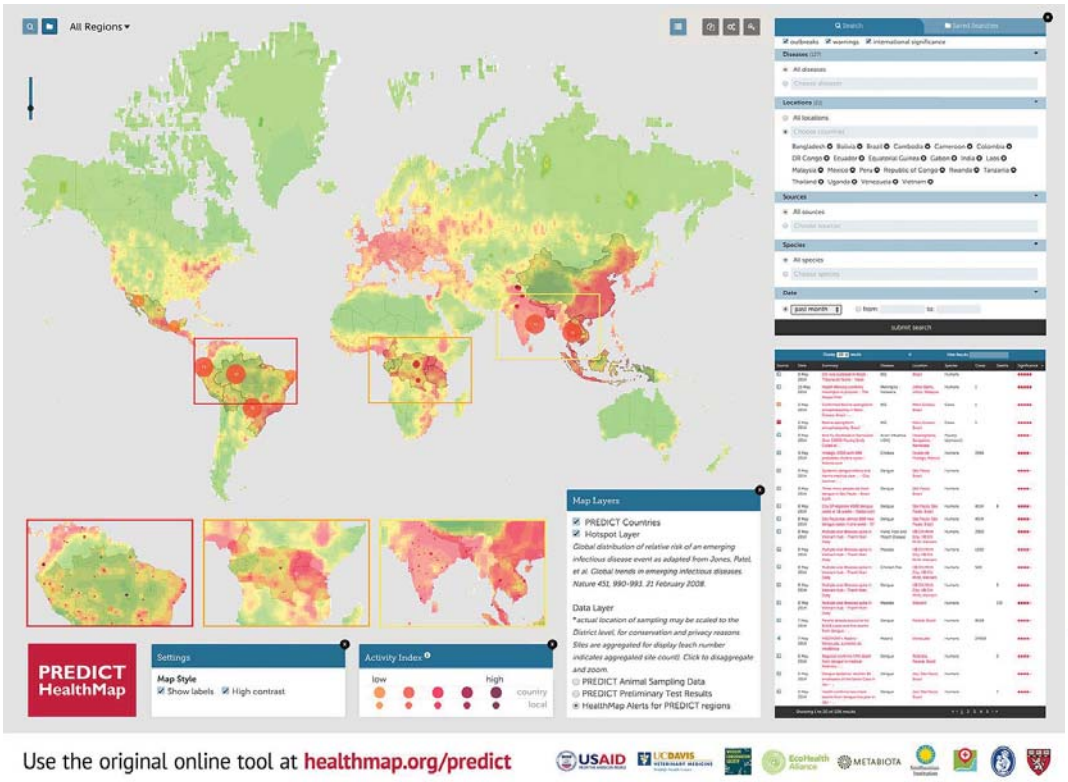


Pulse of the Nation - Alan Mislove, Sune Lehmann, Yong-Yeol Ahn, Jukka-Pekka Onnela, and James Niels Rosenquist - 2010



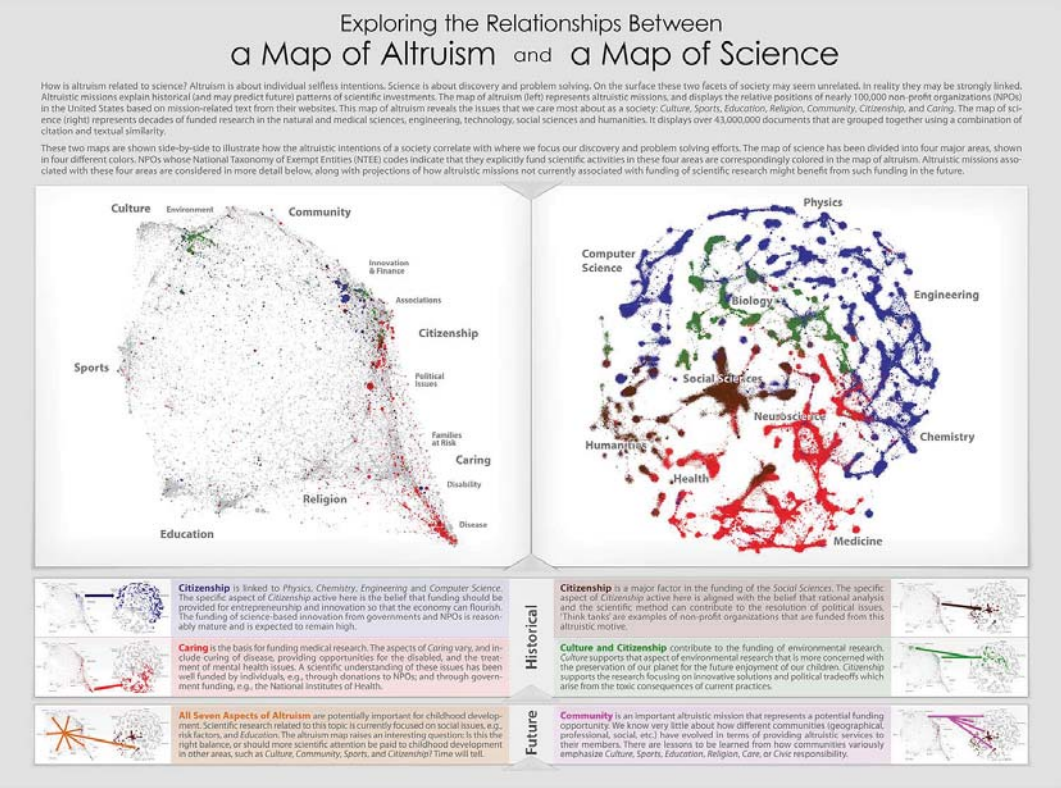
Who Really Matters in the World—Leadership Networks in Different-Language Wikipedias
Peter A. Gloor, Keiichi Nemoto, Samuel T. Mills, and David E. Polley - 2013





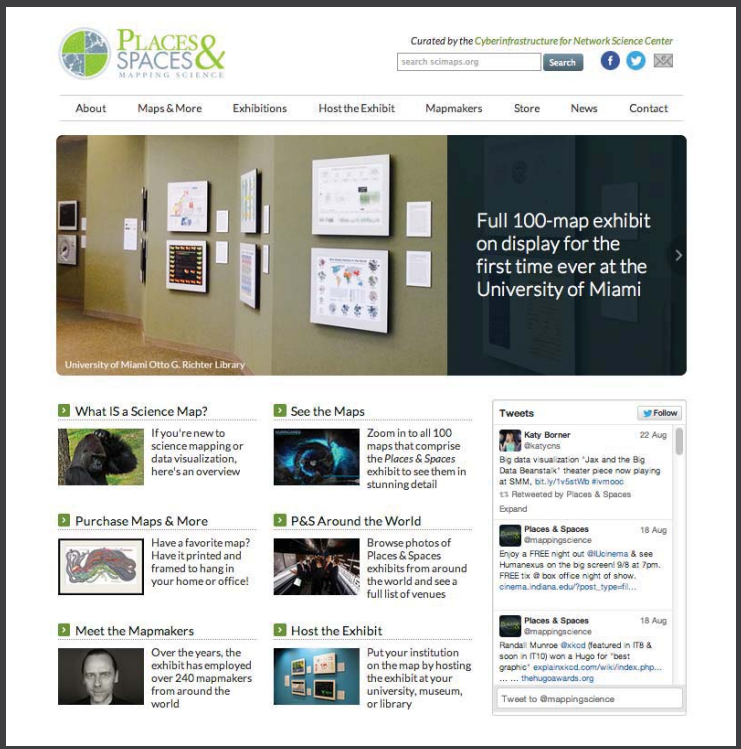
PREDICT: HealthMap - John Brownstein, Damien Joly, William Karesh, Peter Daszak, Nathan Wolfe, Tracey Goldstein, Susan Aman, Clark Freifeld, Sumiko Mekaru, Tammie O'Rourke, Stephen Morse, Christine Kreuder Johnson, Jonna Mazet, and the PREDICT Consortium - 2014

Map of the Internet - Martin Vargic - 2014



Exploring the Relationships between a Map of Altruism and a Map of Science - Richard Klavans and Kevin W. Boyack - 2014

Explore the maps and background information at http://scimaps.org



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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 Macroscope Tools for the *Places & Spaces: Mapping Science* Exhibit (2016) http://scimaps.org/call

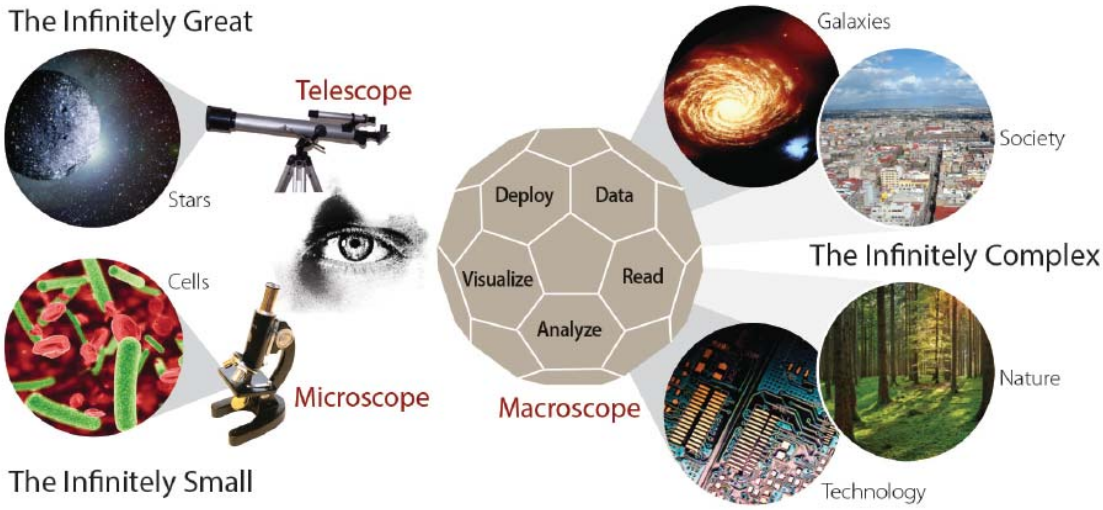
Background and Goals

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

Microscopes, Telescopes, Macroscopes Plug-and-Play Macroscopes



MACROSCOPES FOR INTERACTING WITH SCIENCE

http://scimaps.org/iteration/11

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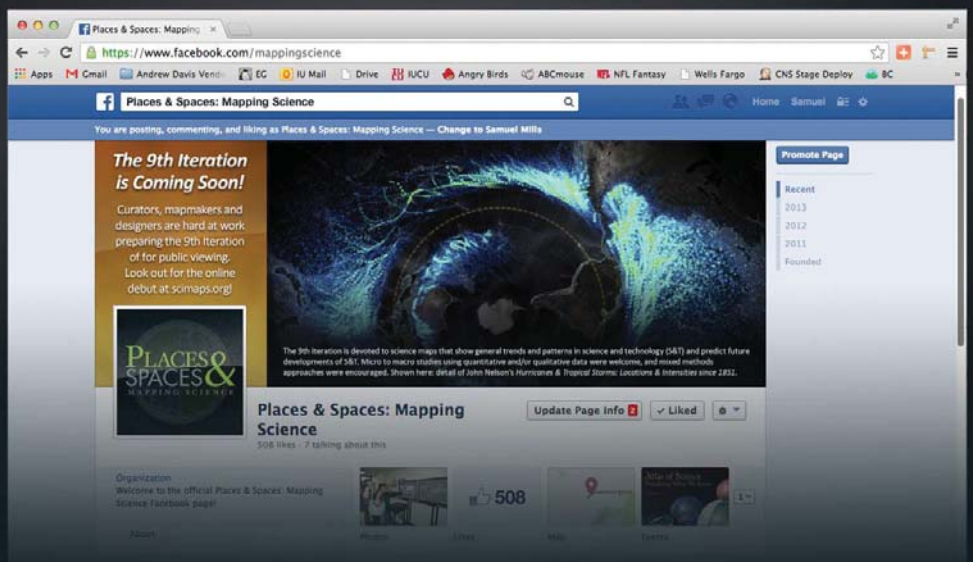

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Data Visualizations: Drawing Actionable Insights From Data

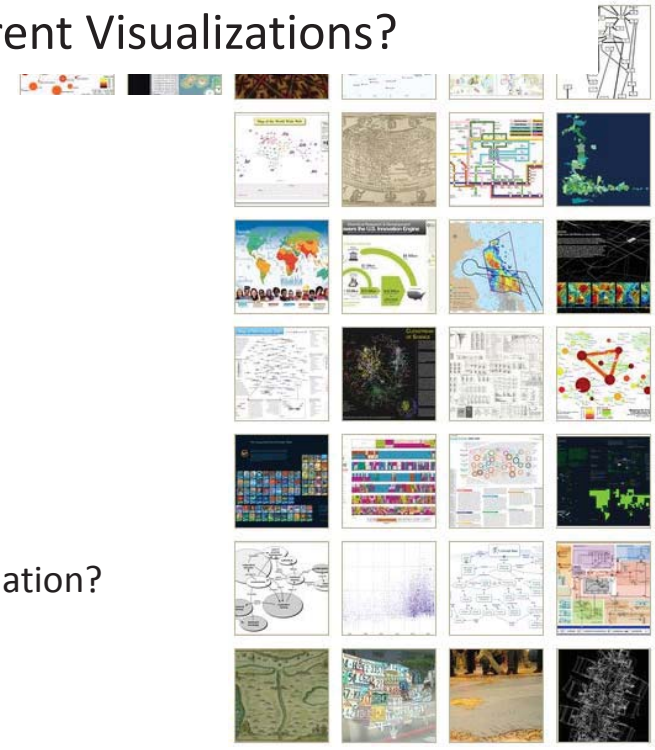
Katy Börner

Victor H. Yngve Professor of Information Science
Director, Cyberinfrastructure for Network Science Center
School of Informatics and Computing and
Indiana University Network Science Institute
Indiana University, USA

Inaugural Lecture
Auditorium A, CDC Tom Harkin Global Comm. Center, Atlanta, GA

February 4, 2016

How to Classify Different Visualizations?



By

- User insight needs?
- User task types?

- Data to be visualized?
- Data transformation?

- Visualization technique?
- Visual mapping transformation?
- Interaction techniques?

- Or ?

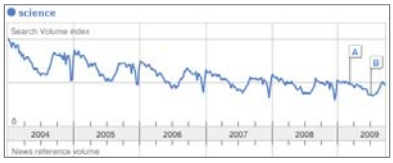
Different Question Types

Terabytes of data

Descriptive & Predictive Models

Find your way

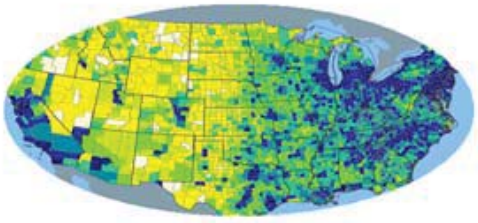
Find collaborators, friends



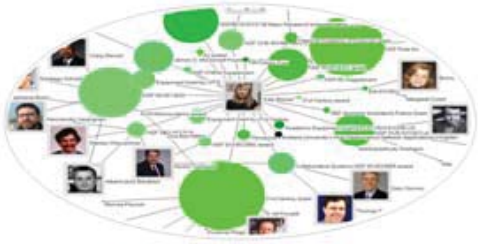
Identify trends

Different Levels of Abstraction/Analysis

Macro/Global
Population Level



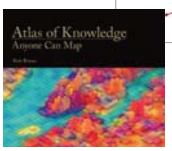
Meso/Local
Group Level



Micro
Individual Level

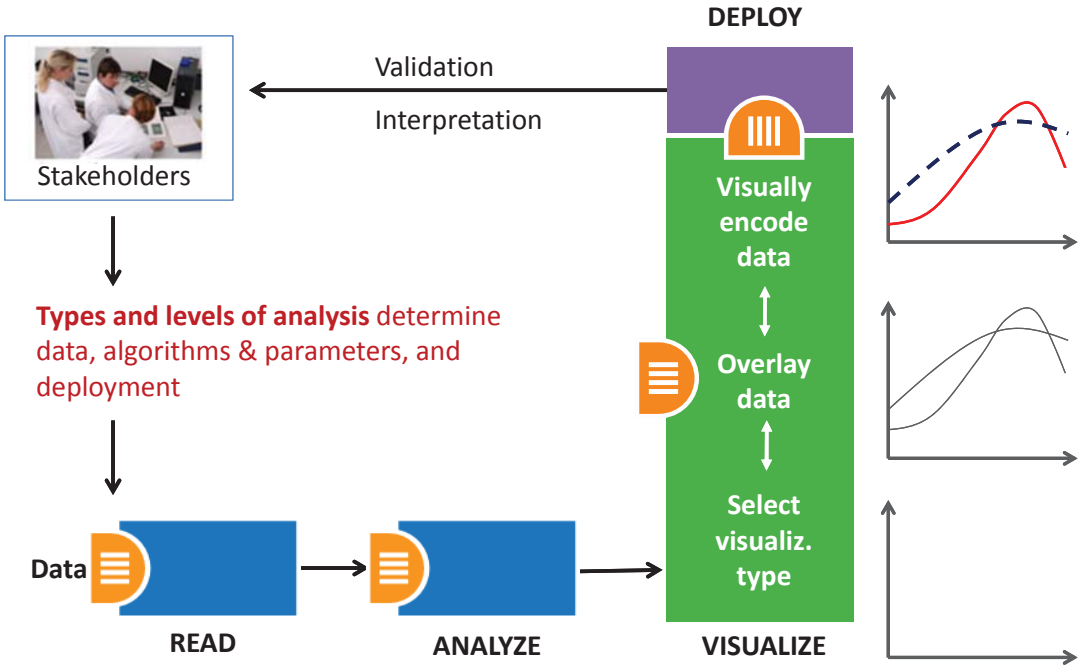
Tasks

TYPES	LEVELS		
	MICRO: Individual Level about 1–1,000 records page 6	MESO: Local Level about 1,001–100,000 records page 8	MACRO: Global Level more than 100,000 records page 10
Statistical Analysis page 44	Knowledge Cartography page 135	Productivity of Russian life sciences research teams page 105	Number of scientists versus population and R&D costs versus GNP. page 103
WHEN: Temporal Analysis page 48	Visualizing decision-making processes page 95	Key events in the development of the video tape recorder page 85	Increased travel and communication speeds page 83
WHERE: Geospatial Analysis page 52	Cell phone usage in Milan, Italy page 109	Victorian poetry in Europe page 137	Ecological footprint of countries page 99
WHAT: Topical Analysis page 56	Evolving patent holdings of Apple Computer, Inc. and Jerome Lemelson page 89	Evolving journal networks in nanotechnology page 139	Product space showing co-export patterns of countries page 93
WITH WHOM: Network Analysis page 60	World Finance Corporation network page 87	Electronic and new media art networks page 133	World-wide scholarly collaboration networks page 157

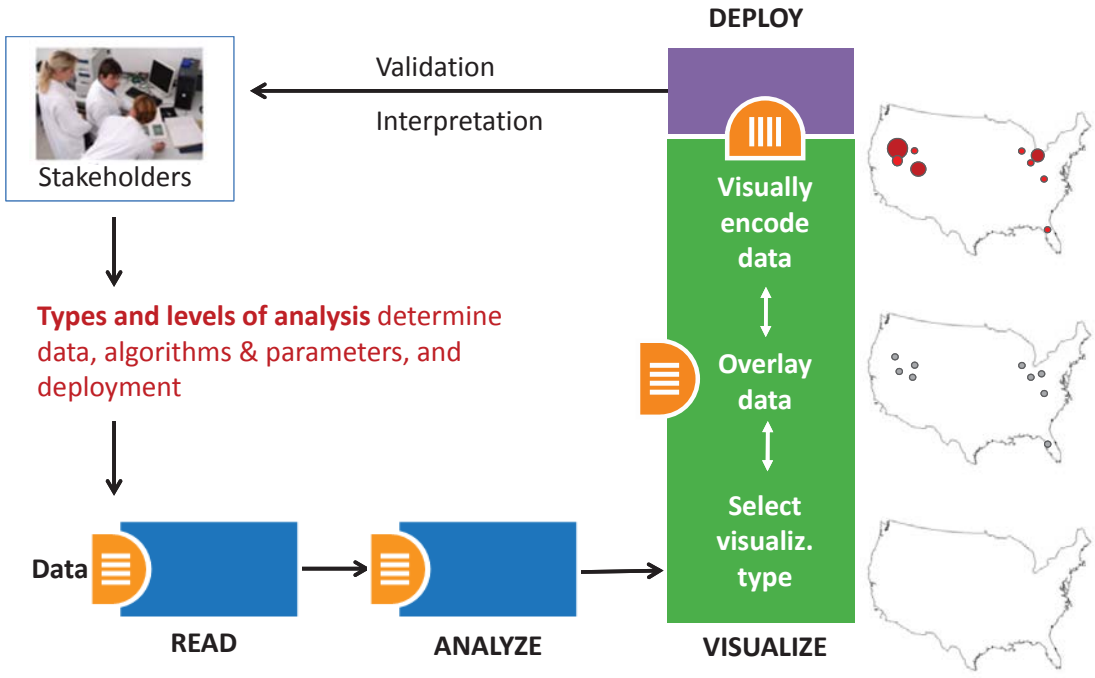


See page 5

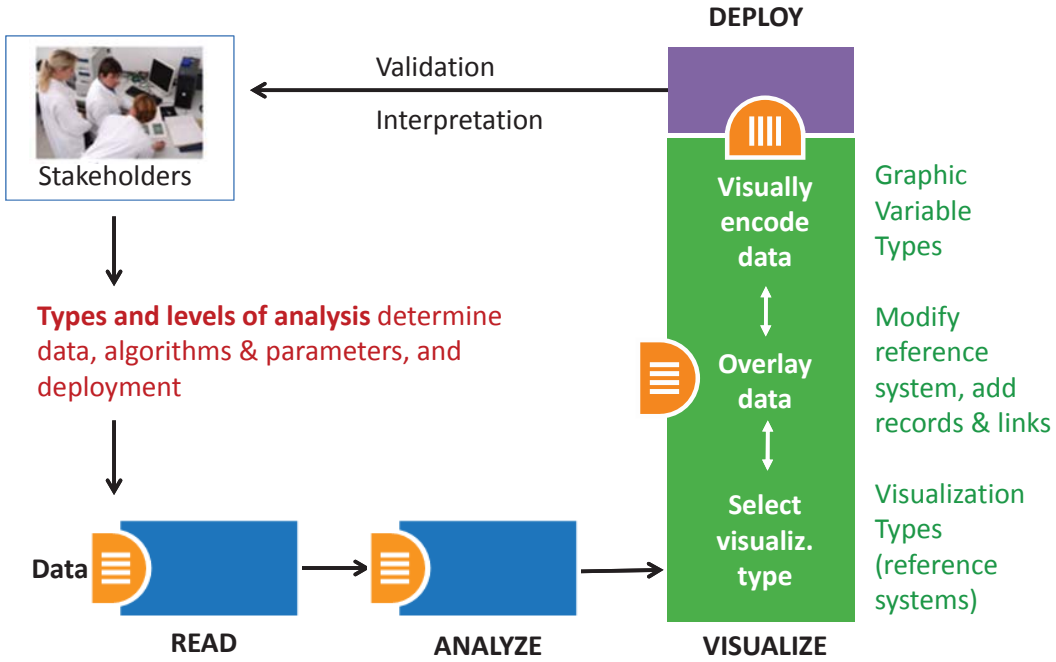
Needs-Driven Workflow Design



Needs-Driven Workflow Design



Needs-Driven Workflow Design

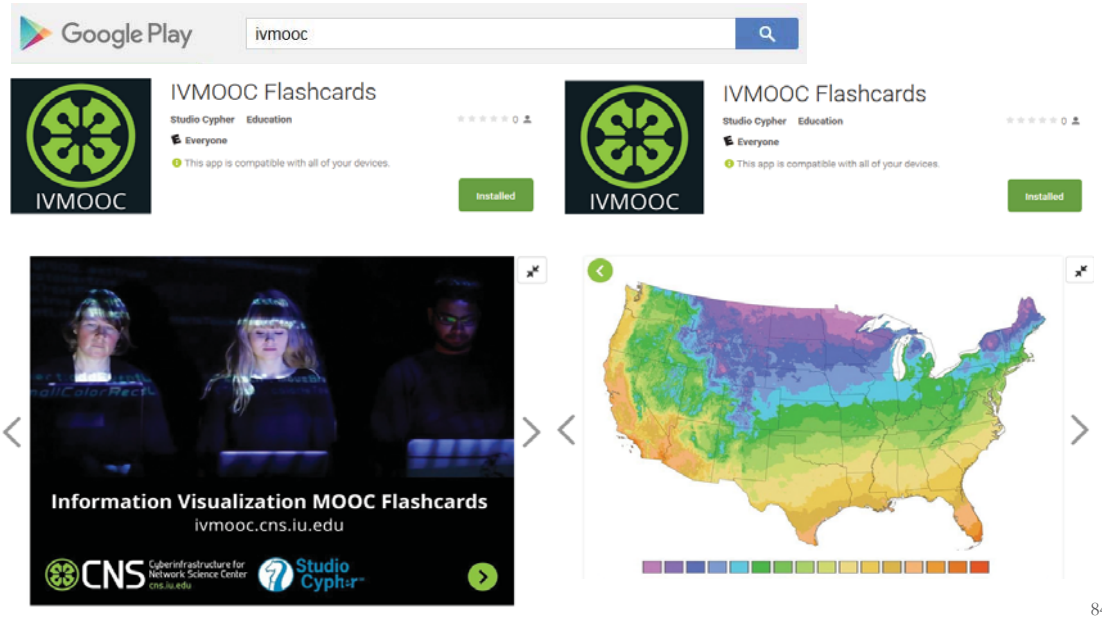


Visualization Types (Reference Systems)

1. **Charts:** No reference system—e.g., Wordle.com, pie charts
2. **Tables:** Categorical axes that can be selected, reordered; cells can be color coded and might contain proportional symbols. Special kind of graph.
3. **Graphs:** Quantitative or qualitative (categorical) axes. Timelines, bar graphs, scatter plots.
4. **Geospatial maps:** Use latitude and longitude reference system. World or city maps.
5. **Network graphs:** Node position might depends on node attributes or node similarity. **Tree graphs:** hierarchies, taxonomies, genealogies. **Networks:** social networks, migration flows.

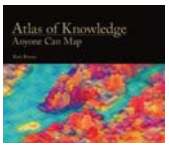
IVMOOC App – More than 60 visualizations

The “IVMOOC Flashcards” app can be downloaded from Google Play and Apple iOS stores.



Visualization Framework

Insight Need Types page 26	Data Scale Types page 28	Visualization Types page 30	Graphic Symbol Types page 32	Graphic Variable Types page 34	Interaction Types page 26
• categorize/cluster • order/rank/sort • distributions (also outliers, gaps) • comparisons • trends (process and time) • geospatial • compositions (also of text) • correlations/relationships	• nominal • ordinal • interval • ratio	• table • chart • graph • map • network layout	• geometric symbols point line area surface volume • linguistic symbols text numerals punctuation marks • pictorial symbols images icons statistical glyphs	• spatial position • retinal form color optics motion	• overview • zoom • search and locate • filter • details-on-demand • history • extract • link and brush • projection • distortion



See page 24

Visualization Framework

Basic Task Types								
Bertin, 1967	Wehrend & Lewis, 1996	Few, 2004	Yau, 2011	Rendgen & Wiedemann, 2012	Frankel, 2012	Tool: Many Eyes	Tool: Chart Chooser	Börner, 2014
selection	categorize			category				categorize/ cluster
order	rank	ranking					table	order/rank/ sort
	distribution	distribution					distribution	distributions (also outliers, gaps)
	compare	nominal comparison & deviation	differences		compare and contrast	compare data values	comparison	comparisons
		time series	patterns over time	time	process and time	track rises and falls over time	trend	trends (process and time)
		geospatial	spatial relations	location		generate maps		geospatial
quantity		part-to-whole	proportions		form and structure	see parts of whole, analyze text	composition	compositions (also of text)
association	correlate	correlation	relationships	hierarchy		relations between data points	relationship	correlations/ relationships

Visualization Framework

Insight Need Types page 26	Data Scale Types page 28	Visualization Types page 30	Graphic Symbol Types page 32	Graphic Variable Types page 34	Interaction Types page 26
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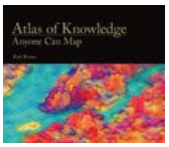
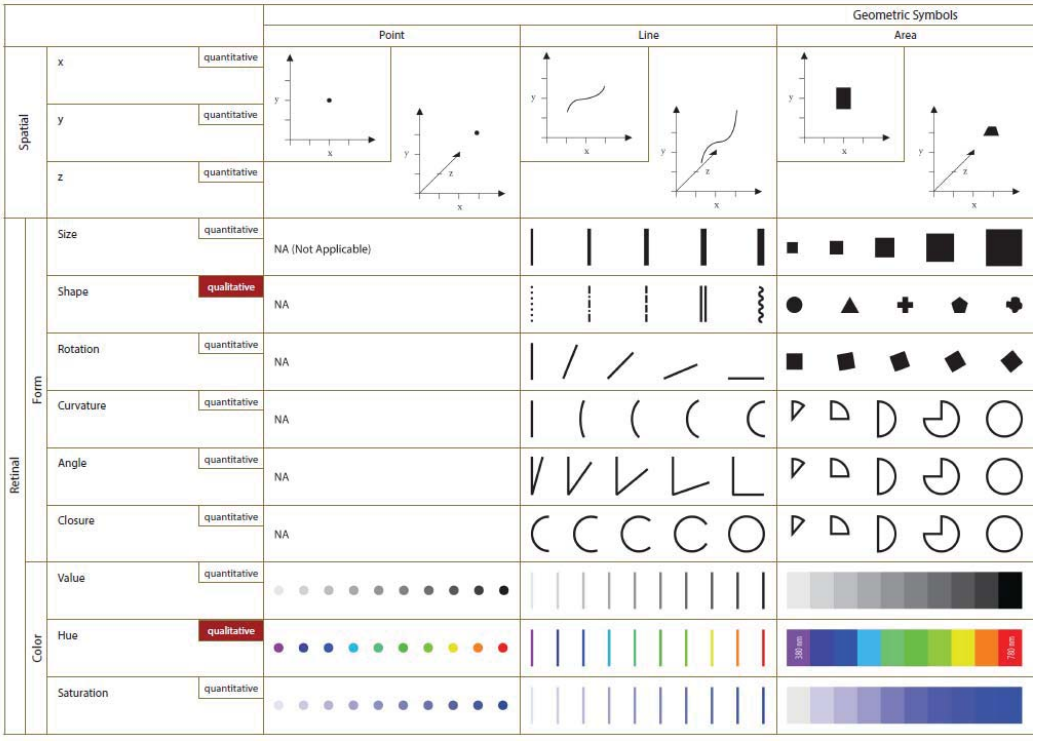
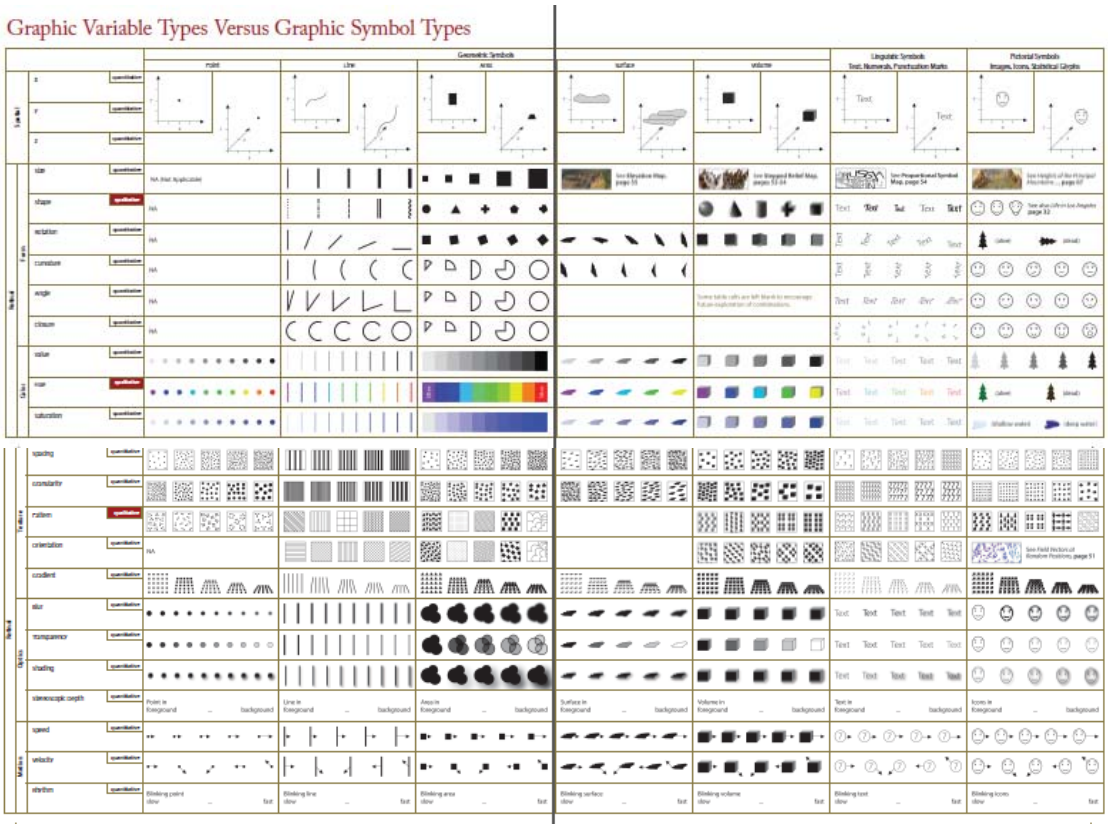


See page 24

Graphic Variable Types Versus Graphic Symbol Types





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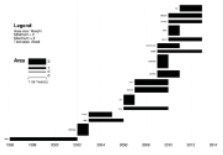
Load **One** File and Run **Many** Analyses and Visualizations

Times Cited	Publication Year	City of Publisher	Country	Journal Title (Full)	Title	Subject Category	Authors
12	2011	NEW YORK	USA	COMMUNICATIONS OF THE ACM	Plug-and-Play Macroscopes	Computer Science	Borner, K
18	2010	MALDEN	USA	CTS-CLINICAL AND TRANSLATIONAL SCIENCE	Advancing the Science of Team Science	Research & Experimental Medicine	Falk-Krzesinski, HJ|Borner, K|Contractor, N|Fiore, SM|Hall, KL|Keyton, J|Spring, B|Stokols, D|Trochim, W|Uzzi, B
13	2010	WASHINGTON	USA	SCIENCE TRANSLATIONAL MEDICINE	A Multi-Level Systems Perspective for the Science of Team Science	Cell Biology |Research & Experimental Medicine	Borner, K|Contractor, N|Falk-Krzesinski, HJ|Fiore, SM|Hall, KL|Keyton, J|Spring, B|Stokols, D|Trochim, W|Uzzi, B

Statistical Analysis–p. 44

Location	*Count*	*# Citations*
Netherlands	13	292
United States	9	318
Germany	11	36
United Kingdom	1	2

Temporal Burst Analysis–p. 48



Geospatial Analysis–p. 52

Geospatial Analysis–p. 52

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Load **One** File and Run **Many** Analyses and Visualizations

Times Cited	Publication Year	City of Publisher	Country	Journal Title (Full)	Title	Subject Category	Authors
12	2011	NEW YORK	USA	COMMUNICATIONS OF THE ACM	Plug-and-Play Macroscopes	Computer Science	Borner, K
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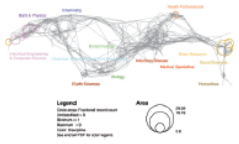
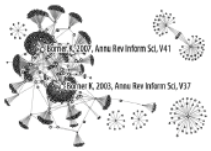
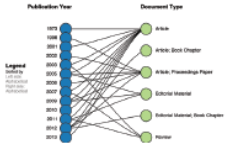
Topical Analysis–p. 56



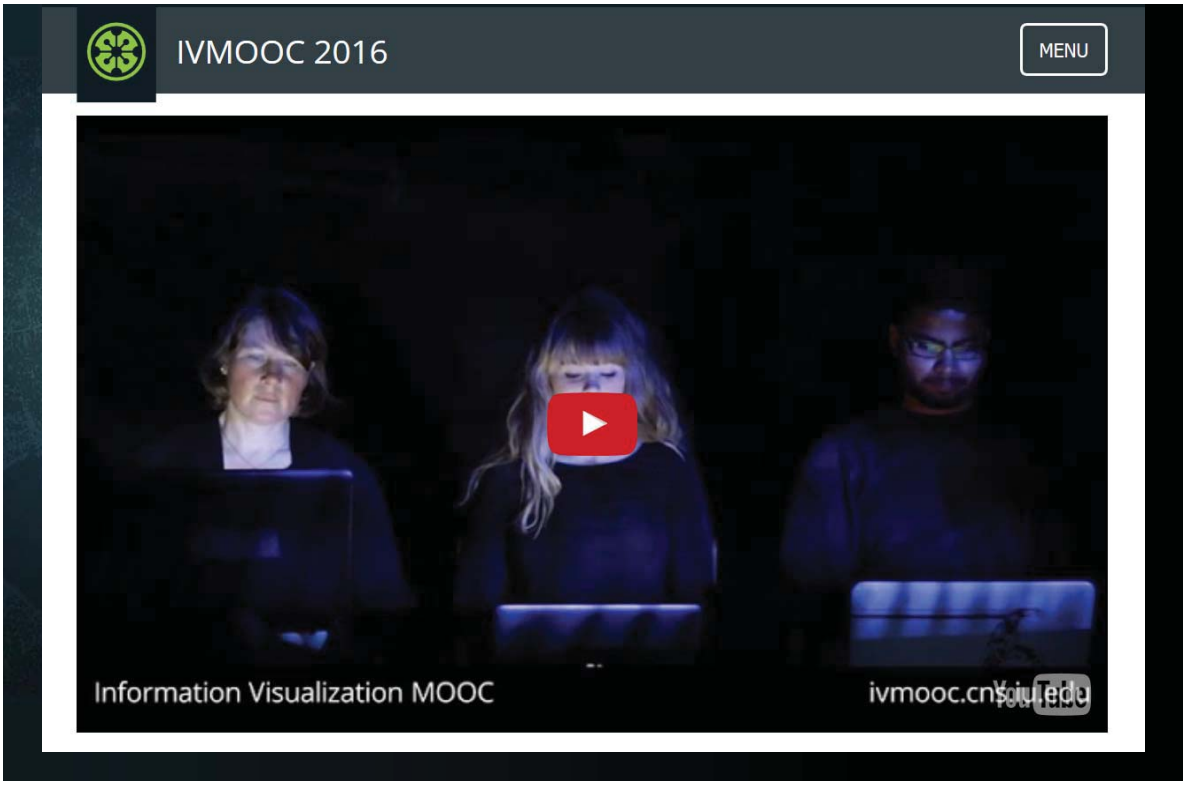
Paper Citation Network–p. 60



Bi-Modal Network–p. 60



Co-author and many other bi-modal networks.



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

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

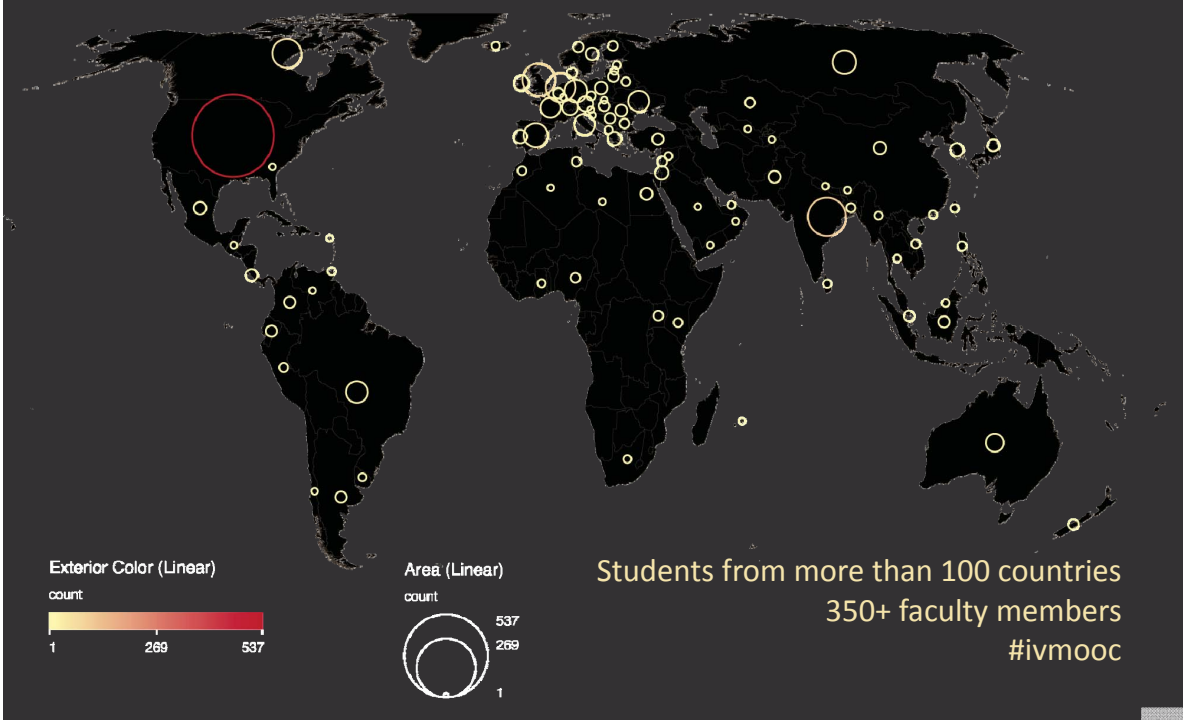
- **Session 5** – "With Whom:" Trees
- **Session 6** – "With Whom:" Networks
- **Session 7** – Dynamic Visualizations and Deployment

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%).

The Information Visualization MOOC
ivmooc.cns.iu.edu

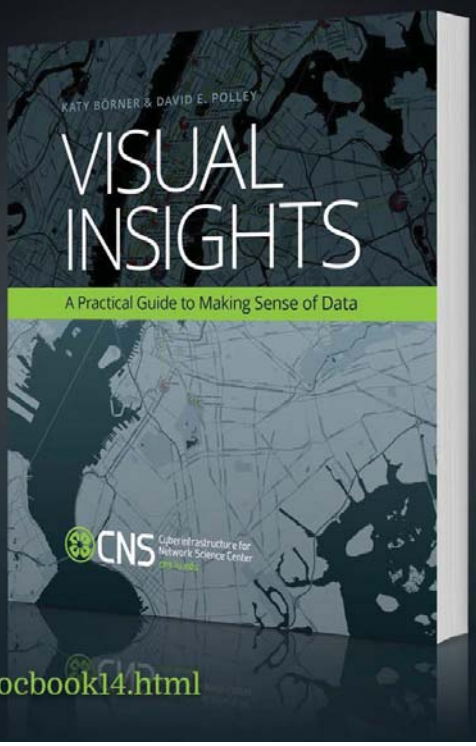


Students from more than 100 countries
350+ faculty members
#ivmooc

The IVMOOC Companion Textbook

This textbook offers a gentle introduction to the design of insightful visualizations. It seamlessly blends theory and practice, giving readers both the theoretical foundation and the practical skills necessary to render data into insights.

The book accompanies the Information Visualization MOOC that attracted students, scholars, and practitioners from many fields of science and more than 100 different countries.



cns.iu.edu/ivmoocbook14.html

CNS Cyberinfrastructure for Network Science Center

CDC Tutorial on Friday Feb 5, 2016, 8:30-11:30am

Title: Open Source Tools for Data Analysis and Visualization
Speaker: Prof. Katy Börner, Indiana University

Abstract: This tutorial is designed for researchers and practitioners interested to use advanced data mining algorithms and visualizations in their research and daily decision making. It introduces the open source Science of Science (Sci2) Tool that supports temporal, geospatial, topical, and network analysis and visualization of scholarly datasets at the micro (individual), meso (local), and macro (global) levels. Open data from different government agencies will be used to demonstrate different analysis and visualization workflows.

The tutorial provides “hands-on” training. Please bring your laptop and pre-install the Sci2 (v 1.1 beta) tool prior to the workshop.

Additional theory and hands-on lectures are available in the Information Visualization MOOC (IVMOOC) (http://ivmooc.cns.iu.edu) that is taught each Spring for students from 100+ countries.

This conference is funded by the NSF Science of Science and Innovation Policy (SciSIP) program and aims at facilitating the generation and execution of a new Roadmap for the Science of Science Policy community and a strategic plan for SciSIP program, see details at http://modsti.cns.iu.edu.

OECD Blue Sky Forum on Science and Innovation Indicators

Every 10 years the OECD Blue Sky Forum engages the policy community, data users and providers into an open dialogue to review and develop its long-term agenda on science, technology and innovation (STI) data and indicators, see details at http://www.oecd.org/science/blue-sky.htm

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

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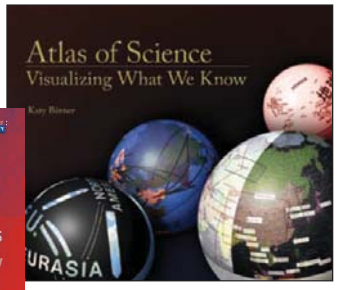
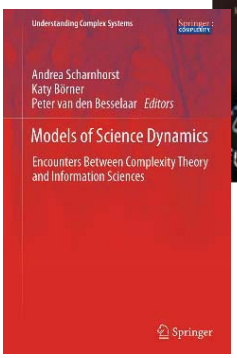
Scharnhorst, Andrea, Börner, Katy, van den Besselaar, Peter (2012) **Models of Science Dynamics**. Springer Verlag.

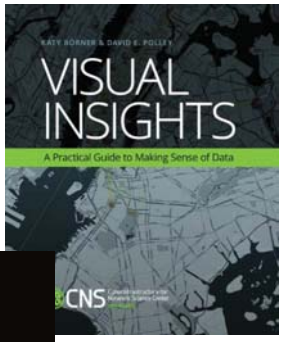
Katy Börner, Michael Conlon, Jon Corson-Rikert, Cornell, Ying Ding (2012) **VIVO: A Semantic Approach to Scholarly Networking and Discovery**. Morgan & Claypool.

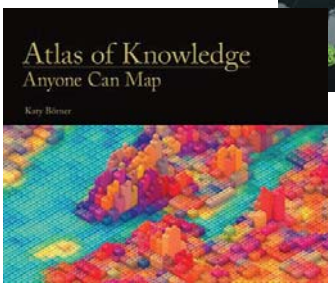
Katy Börner and David E Polley (2014) **Visual Insights: A Practical Guide to Making Sense of Data**. The MIT Press.

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









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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