

Teaching Children the Structure of Science

Dr. Katy Börner

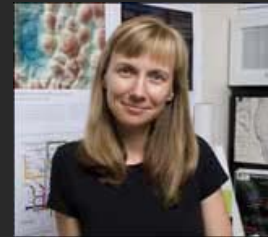
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VDA 2009
Jan 19th, 2009



Teaching Children the Structure of Science

How can children start to understand the complex interplay of the different sciences?

How can they get an intuitive understanding of the importance of math and how much it is needed to succeed in many if not all of the other sciences?

What does it mean for teaching, learning, and job opportunities if the biomedical sciences account for 50% of all sciences?

Can we make them see the central position of computer science and its evolving symbiosis with all other aptly named 'computational X' sciences?

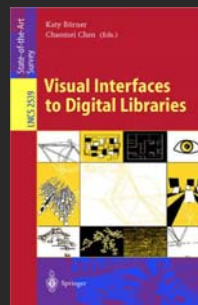
Can we offer them a means to see the emergence and evolution of new sciences, e.g., nano* or neuro*?

How can we empower them to search for a certain expertise in the correct scientific discipline?

How can we teach them to appreciate the very diverse cultures, research approaches, and languages that exist in the different sciences and enable them to 'speak' more than one science in order to collaborate across scientific boundaries?

Last but not least, how can we engage children in the work of real scientists, have them share the excitement of discovery, and allow them to find their own 'place' in science?

Computational Scientometrics: Studying Science by Scientific Means



- Börner, Katy, Chen, Chaomei, and Boyack, Kevin. (2003). *Visualizing Knowledge Domains*. In Blaise Cronin (Ed.), *Annual Review of Information Science & Technology*, Medford, NJ: Information Today, Inc./ American Society for Information Science and Technology, 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/
- Börner, Katy, Sanyal, Soma and Vespignani, Alessandro (2007). *Network Science*. In Blaise Cronin (Ed.), *Annual Review of Information Science & Technology*, Information Today, Inc./ American Society for Information Science and Technology, Medford, NJ, Volume 41, Chapter 12, pp. 537-607. <http://ivl.slis.indiana.edu/km/pub/2007-borner-arist.pdf>
- *Places & Spaces: Mapping Science* exhibit, see also <http://scimaps.org>.

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Process of Analyzing and Mapping Knowledge Domains

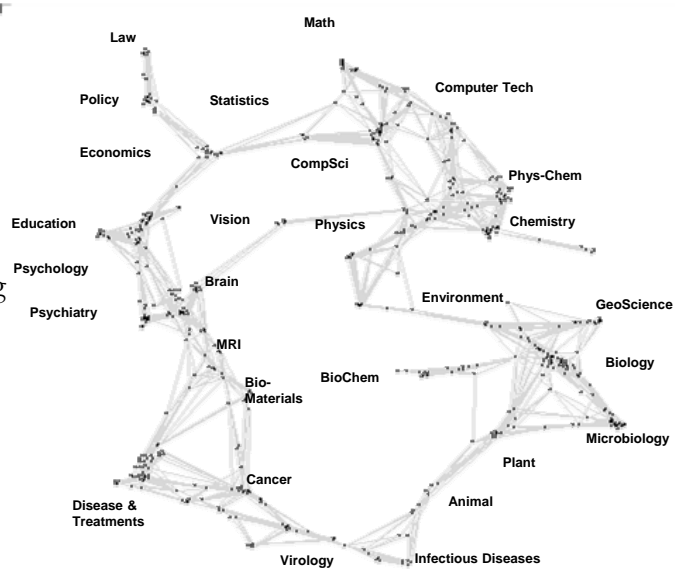
DATA EXTRACTION	UNIT OF ANALYSIS	MEASURES	LAYOUT (often one code does both similarity and ordination steps)		DISPLAY
			SIMILARITY	ORDINATION	
SEARCHES ISI INSPEC Eng Index Medline ResearchIndex Patents etc.	COMMON CHOICES Journal Document Author Term	COUNTS/FREQUENCIES Attributes (e.g. terms) Author citations Co-citations By year THRESHOLDS By counts	SCALAR (unit by unit matrix) Direct citation Co-citation Combined linkage Co-word / co-term Co-classification VECTOR (unit by attribute matrix) Vector space model (words/terms) Latent Semantic Analysis (words/terms) incl. Singular Value Decomposition (SVD) CORRELATION (if desired) Pearson's R on any of above	DIMENSIONALITY REDUCTION Eigenvector/ Eigenvalue solutions Factor Analysis (FA) and Principal Components Analysis (PCA) Multi-dimensional scaling (MDS) LSA, Topics Pathfinder networks (PFNet) Self-organizing maps (SOM) includes SOM, ET-maps, etc.	INTERACTION Browse Pan Zoom Filter Query Detail on demand ANALYSIS
BROADENING By citation By terms				CLUSTER ANALYSIS SCALAR Triangulation Force-directed placement (FDP)	

Börner, Katy, Chen, Chaomei, and Boyack, Kevin. (2003) *Visualizing Knowledge Domains*. In Blaise Cronin (Ed.), [Annual Review of Information Science & Technology, Volume 37](#), Medford, NJ: Information Today, Inc./ American Society for Information Science and Technology, chapter 5, pp. 179-255.

Latest 'Base Map' of Science

Kevin W. Boyack, Katy Börner, & Richard Klavans (2007). *Mapping the Structure and Evolution of Chemistry Research*. 11th International Conference on Scientometrics and Informetrics. pp. 112-123.

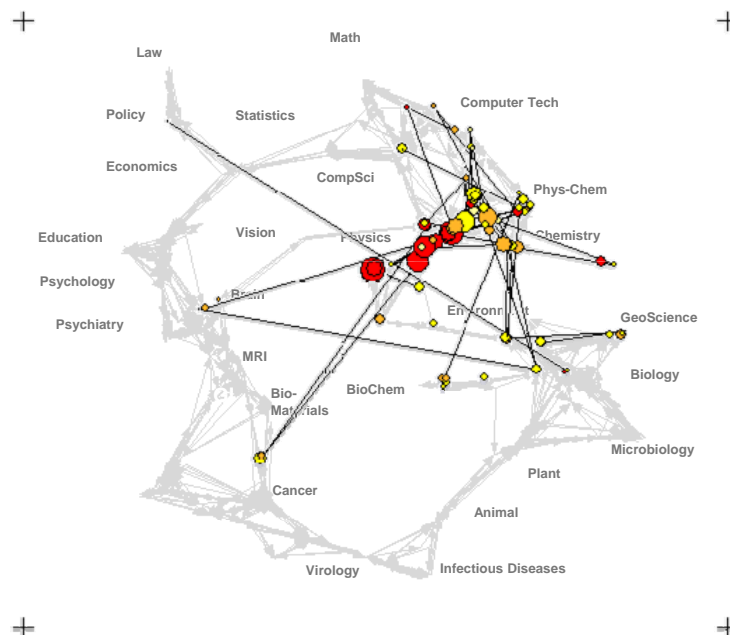
- Uses combined SCI/SSCI from 2002
 - 1.07M papers, 24.5M references, 7,300 journals
 - Bibliographic coupling of papers, aggregated to journals
- Initial ordination and clustering of journals gave 671 clusters
- Coupling counts were reaggregated at the journal cluster level to calculate the
 - (x,y) positions for each journal cluster
 - by association, (x,y) positions for each journal



Science map applications: Identifying core competency

Kevin W. Boyack, Katy Börner, & Richard Klavans (2007).

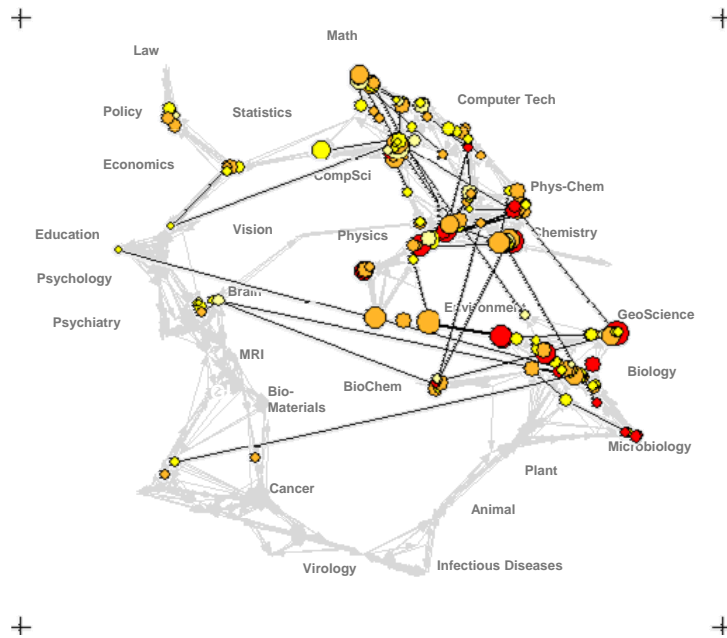
Funding patterns of the US Department of Energy (DOE)



Science map applications: Identifying core competency

Kevin W. Boyack, Katy Börner, & Richard Klavans (2007).

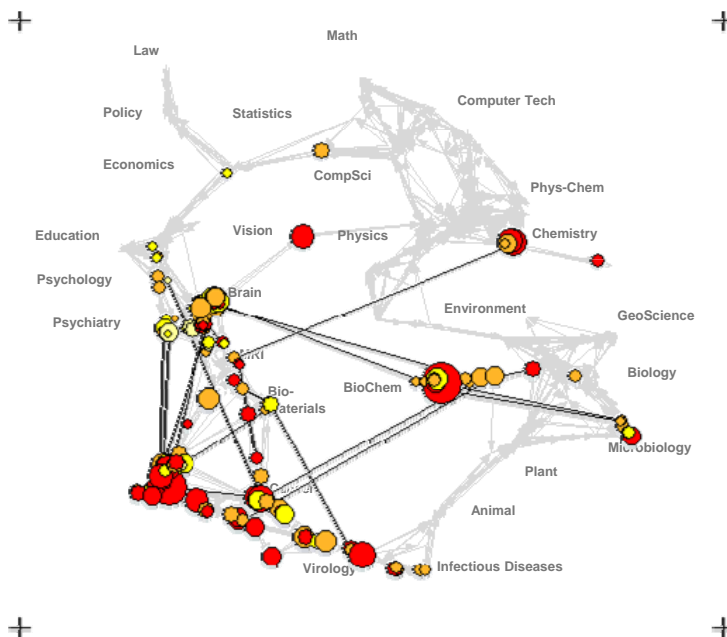
Funding Patterns of the National Science Foundation (NSF)



Science map applications: Identifying core competency

Kevin W. Boyack, Katy Börner, & Richard Klavans (2007).

Funding Patterns of the National Institutes of Health (NIH)





places & spaces

Cartography of the Physical and the Abstract

An exhibition created for the conference "Mapping Humanity's Knowledge and Expertise in the Digital Domain" at the 2005 Meeting of the American Association of Geographers that is updated regularly with new maps and explanations.

Home
Browse Maps
Compare & Contrast Maps
Connect

Home







Exhibit Purpose and Goals

The Places & Spaces exhibit has been created to demonstrate the power of maps.

An initial theme of this exhibit is to compare and contrast first maps of our entire planet with the first maps of all of science as we know it.

Come see with your own eyes the extent to which maps can be employed to help make sense of the flood of information we are confronted with and how domain maps can be used to locate complex and beautiful information.

This online part of the exhibit provides links to a selected series of maps and their makers along with detailed explanations of why these maps work. The physical counterpart supports the close inspection of high quality reproductions for display at conferences and education centers. It is meant to inspire cross-disciplinary discussion on how to best track and communicate human activity and scientific progress on a global scale.





Places & Spaces: Mapping Science
a science exhibit that introduces people to maps of sciences, their makers and users.
<http://scimaps.org>

Exhibit Curators: Dr. Katy Börner & Elisha F. Hardy



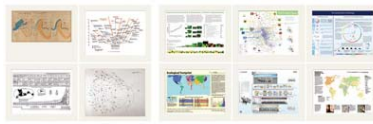


Mapping Science Exhibit – 10 Iterations in 10 years

The Power of Maps (2005)



Science Maps for Economic Decision Makers (2008)



The Power of Reference Systems (2006)



Science Maps for Science Policy Makers (2009)

Science Maps for Scholars (2010)

Science Maps as Visual Interfaces to Digital Libraries (2011)

Science Maps for Kids (2012)

Science Forecasts (2013)

How to Lie with Science Maps (2014)

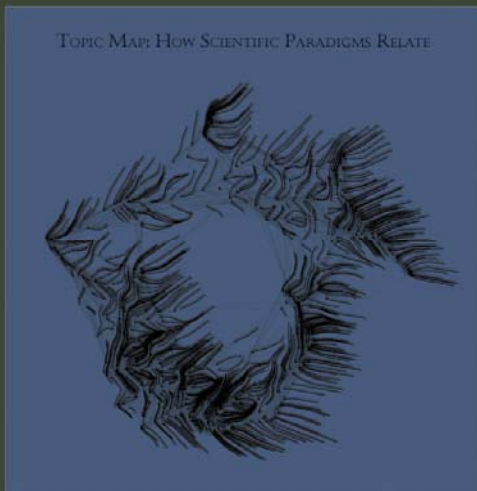
scimaps.org

The Power of Forecasts (2007)



Illuminated Diagram Display

W. Bradford Paley, Kevin W. Boyack, Richard Kalvans, and Katy Börner (2007) Mapping, Illuminating, and Interacting with Science. SIGGRAPH 2007, San Diego, CA.



You may run your finger over each of these maps to control the lighting on the other: touching a place on the world map will light up topics studied in that place; touching a paradigm on the topic map will light up the places that study that topic.

Nanotechnology

This overlay shows the distribution of nanotechnology within the paradigms of science. The majority of current work in nanotechnology takes place in physics, chemistry, and materials science, at the upper right portion of the map. However, an increasing amount of nanotechnology is being applied in the biological and medical sciences, at the lower right.

All Topics

Sweep through all 276 scientific paradigms

Sustainability

The science behind our long-term hopes

Nanotechnology

Science on the tiny scale of molecules

Biology & Chemistry

The interface between these two vital fields

Francis H. C. CRICK

Co-discovered DNA's double helix

Joshua LEDERBERG

Pioneer in bacterial genetic mechanisms

Albert EINSTEIN

Revitalized physics with Relativity theories

Derek J. de Solla PRICE

Known as the "Father of Scientometrics"

Michael E. FISHER

Models critical phase transitions of matter

Richard N. ZARE

Uses laser chemistry in molecular dynamics

Susan T. FISKE

Connects perception and stereotypes

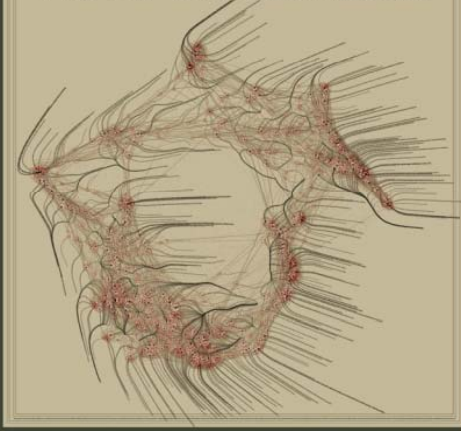
About this display

People & organizations that helped create it

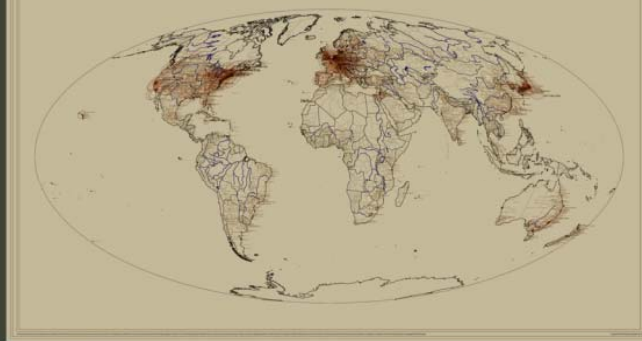
We sweep slowly through adjoining related topics, lighting up the places in the world that study each topic. You may select a subset of the topics that deal with these three interesting subjects by touching it.

A single person's spreading influence is shown as a series of four snapshots. First, we light only topics and places relating to that person's papers—papers that are still highly cited today. The second lights everything that cites that original work. Note that this first-generation impact extends to far more topics than did the original work. The third snapshot lights science that cites the second, and the fourth lights science that cites the third.

学科分布图：科学学科是怎样相互关联的



世界地图：科学研究在哪里进行着



你可以通过触摸屏在地图上随意指点来改变所到之处的光亮强度。当你触摸世界地图的某一点时，在那个地理位置上的所有研究机构会被点亮。同时在这些研究机构工作的学者的论文所属的学科会在学科分布图上被点亮。而当你触摸学科分布图的某一点时，在那个位置上的科学学科会被点亮，同时从事这些学科研究的研究机构在世界地图上的分布会被点亮。

纳米技术

这里显示所有和纳米技术相关的科学学科。纳米技术和科学研究人类在无形的空间里改造世界的的能力。这些空间存在于极其微小以至单个原子的结构中。目前大部分有关纳米的研究主要集中在物理、化学和材料科学领域。它们主要位于学科分布图上半部分的右面。不过，纳米技术在生物学和医药学研究里的应用也越来越多。生物学和医药学位于学科分布图下半部分的右面。



探索科学学科的相互关联性

所有科学学科 显示所有776种科学学科	纳米技术 有关微观粒子的科学
可持续性 一些与人类寄予长期希望相关的科学	化学和生物 化学和生物科学的交叉部分

光标缓慢的扫过所有相互关联的科学学科，每一个学科以及从事这方面科学研究的研究机构在世界地图上的位置会被逐一点亮。首先，显示屏会点亮那些产出论文最多、最活跃的科学学科，然后那些小学科或冷门学科会被逐一点亮。

探索某个学者的科学著作的影响力的传播

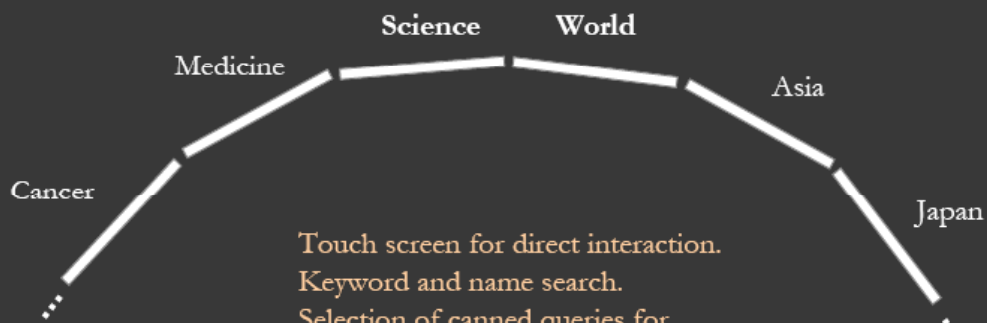
弗郎西·科里克 DNA双螺旋结构的发现者之一	阿尔伯特·爱因斯坦 用相对论重新激活了物理学	迈克尔·费舍尔 发现了物质转变模式的关键步骤	苏珊·费斯克 研究人的认知是如何产生偏见的
约舒亚·雷德伯格 细菌遗传机制研究先驱	德里克·德索拉·普里斯 著名的“科学计量学之父”	理查德·扎尔 采用激光化学技术研究分子动态分布	关于本次展览 与此展览相关人员和机构

显示屏通过四步来展示某个学者对科学的贡献以及影响力的传播。首先，显示屏点亮该学者所发表的论文所属的学科在学科分布图上的位置以及该学者从事这项研究时的研究机构在世界地图上的位置。到目前为止，所有这些论文的引用率仍然很高。第二步，显示屏点亮所有引用在第一步中被点亮的原始论文的论文在学科分布图上的位置以及它们在世界地图上的位置。第三步，显示屏点亮所有引用了在第二步中被点亮的论文的论文在学科分布图上的位置以及它们在世界地图上的位置。第四步，显示屏点亮所有引用了在第三步中被点亮的论文的论文在学科分布图上的位置以及它们在世界地图上的位置。

Re-implementation of Illuminated Diagram Software

by Advanced Visualization Lab, Indiana University

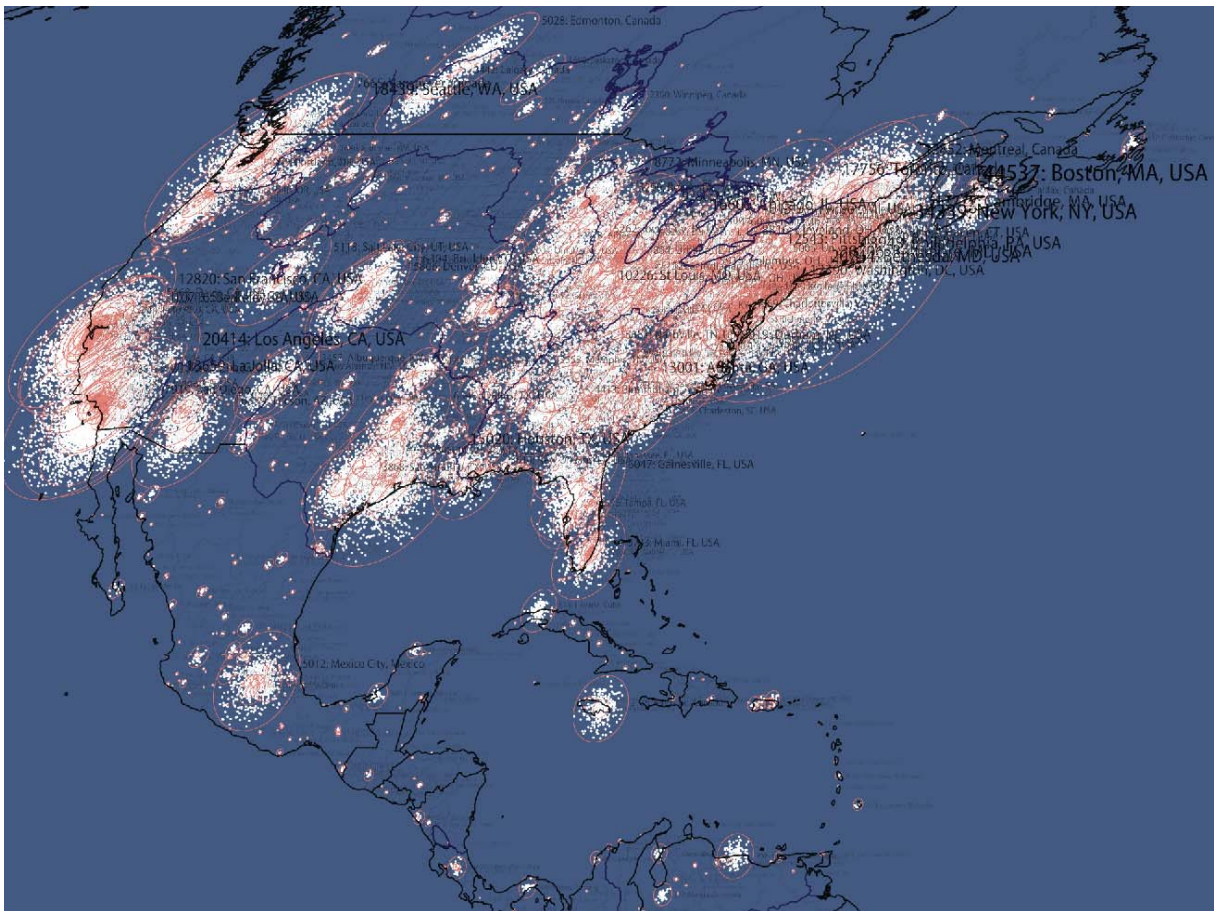
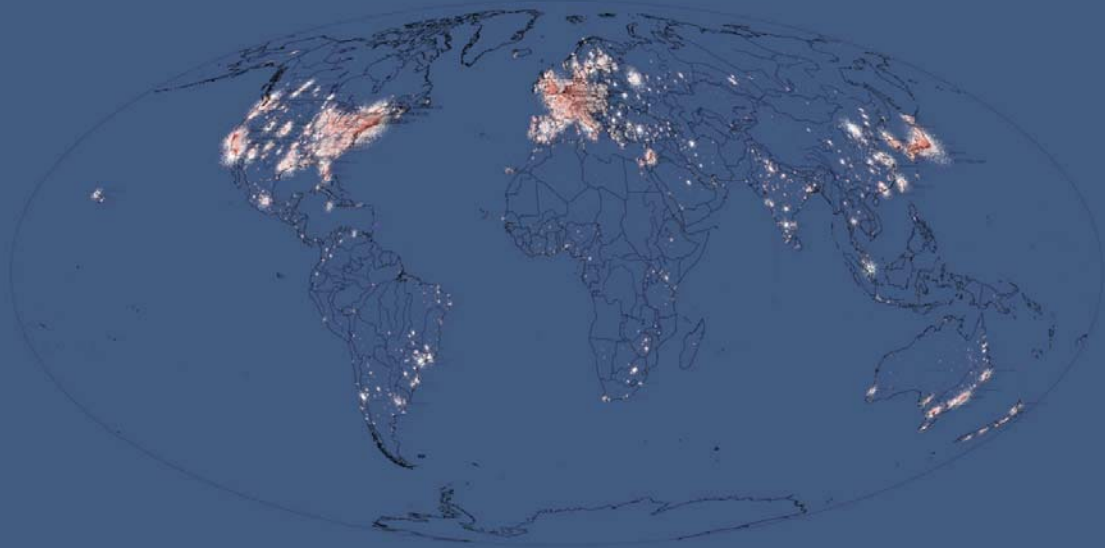
Drives unlimited number of ID screens.

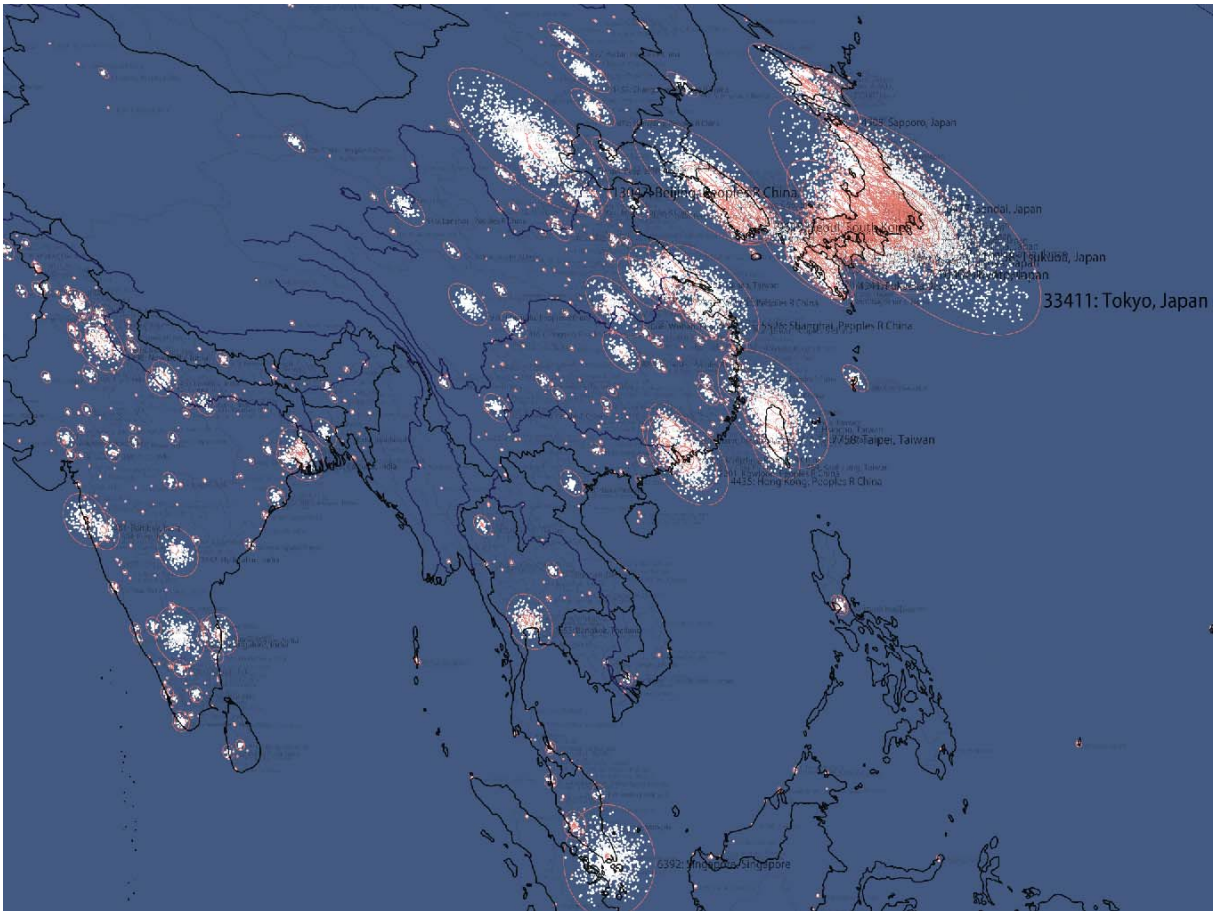
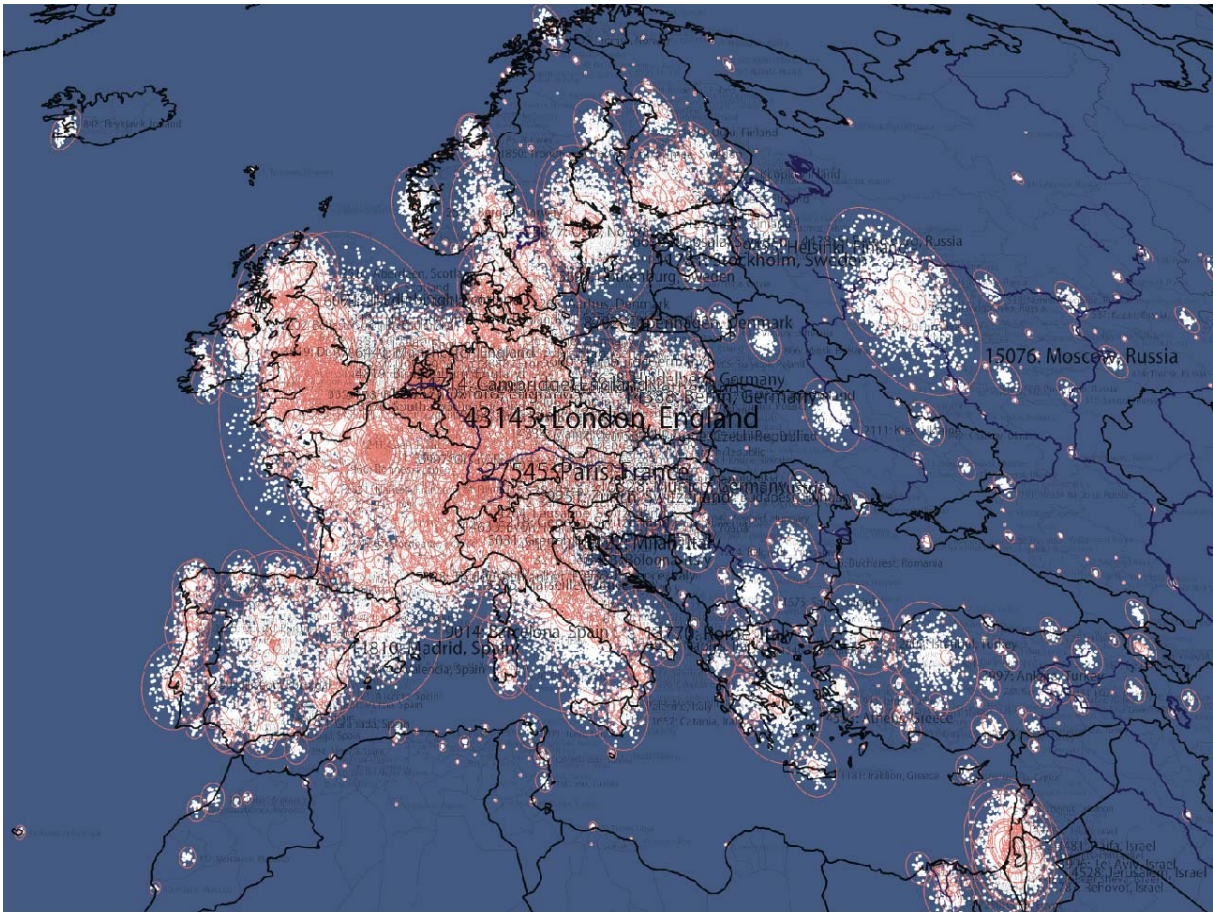


- Touch screen for direct interaction.
 Keyword and name search.
 Selection of canned queries for
- interdisciplinary research areas
 - famous people
 - activity patterns, e.g., bursts, trends, etc.

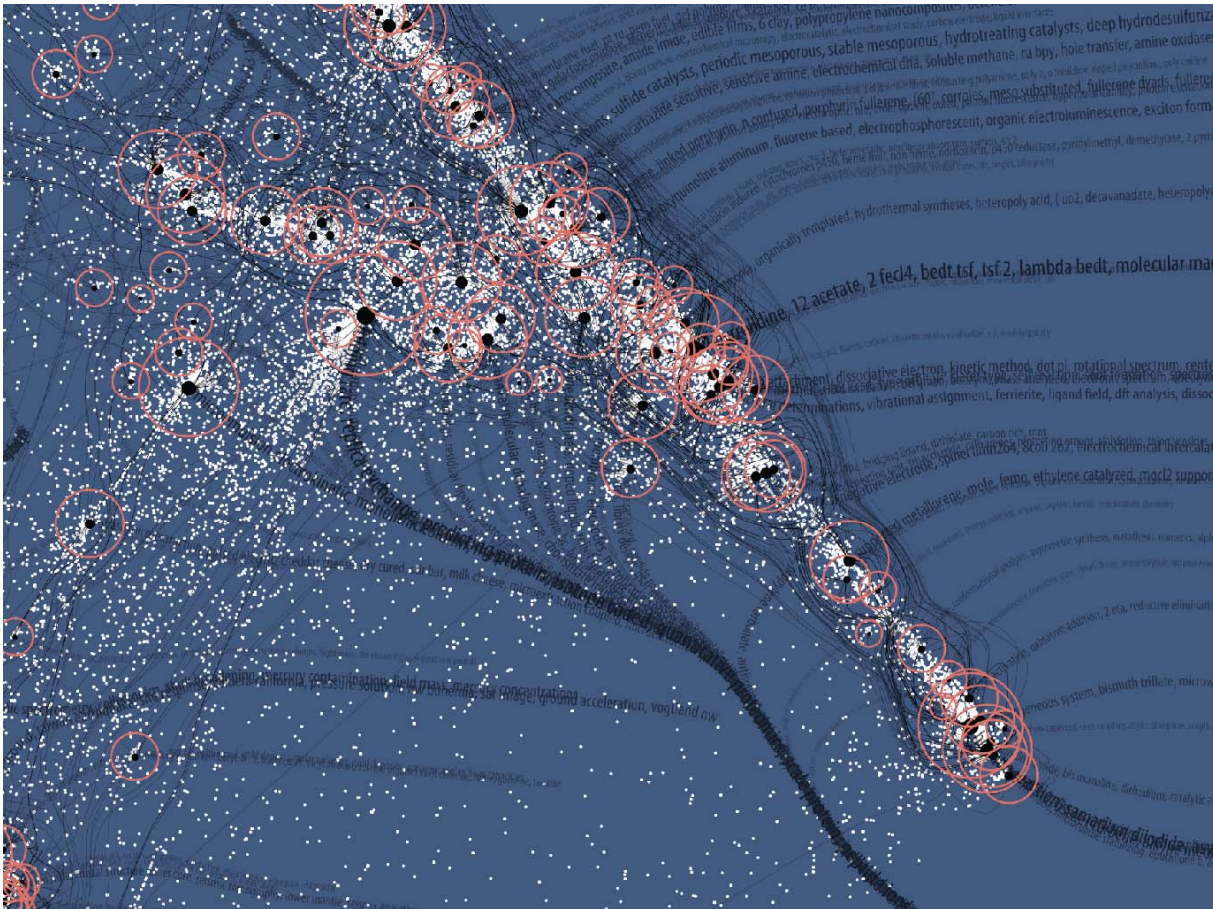


GEOGRAPHIC MAP: WHERE SCIENCE GETS DONE

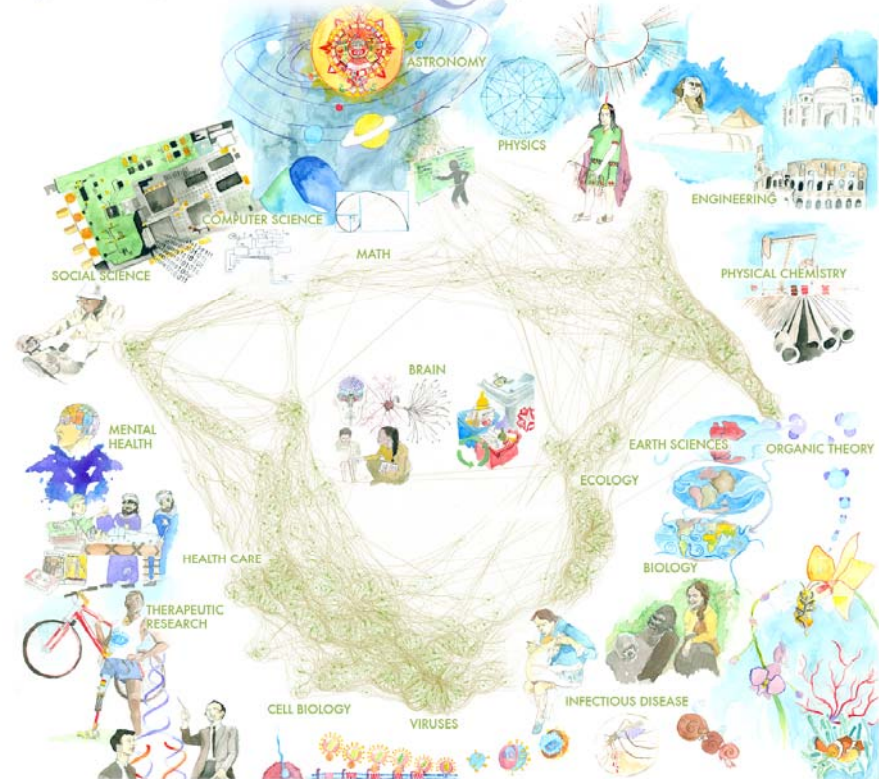




TOPIC MAP: HOW SCIENTIFIC PARADIGMS RELATE

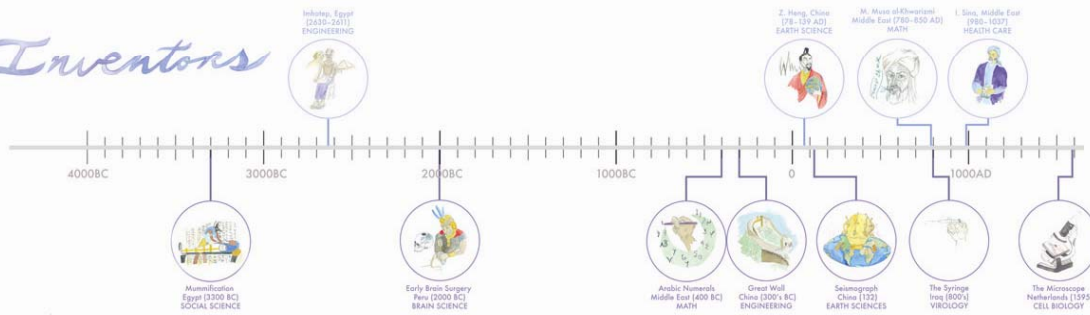


Inventors & Inventions

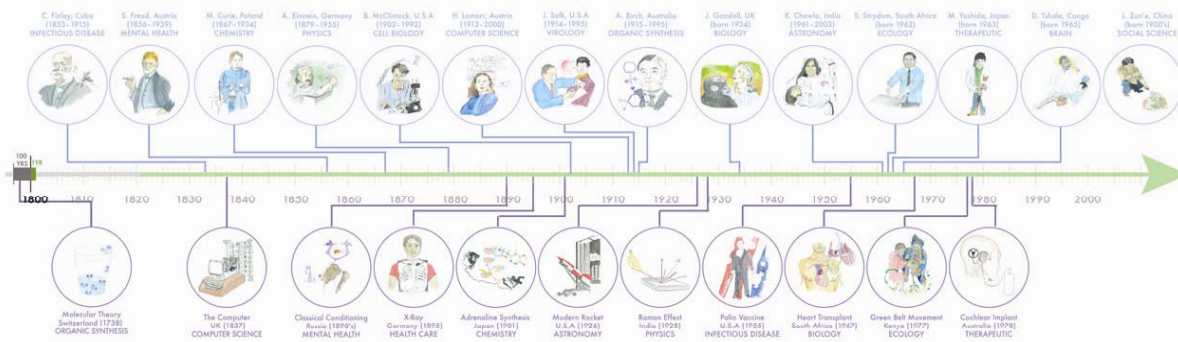


Hands-On Science Maps for Kids, by Flavia Palmer (Paintings), Julie Smith (Data Acquisition), Elaha Hardy and Kory Blinner (Graphic Design), BEDDINGTON, IN 2004. Courtesy of Indiana University. Learn more at www.science.org. This map plots the locations where scientific papers were published; each light green dot represents 10 or fewer papers; they are scattered around the exact location for visibility, within a labeled green circle whose size is proportional to the number of papers published in that place. The base map is part of the "illuminated diagram" software which uses a computer and two projectors, projecting spots of light on the arena to highlight different kinds of scientific research (e.g. a biology map of a genetic paradigm) and the areas in the world where such research is conducted (e.g. a map of research on the brain). For more information, visit www.science.org.

Inventors



Inventions

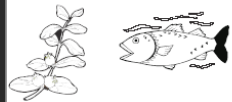






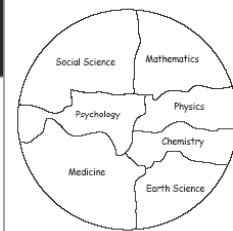
My Science Story

By _____



For more information about the map of science for kids or this exercise, please contact Katy Borvan (katy@indiana.edu) or Nikki Roberg (nroberg@indiana.edu) at the School of Library and Information Science, Indiana University. These materials were compiled by Nikki Roberg in 2006.

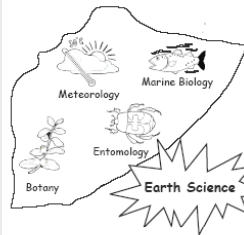
There are seven main fields of science. They are...



social science, mathematics, physics, chemistry, earth science, medicine, and psychology. I like to study earth science.

Color earth science green.

Earth scientists study the weather, plants and trees, marine life, insects, and much more.

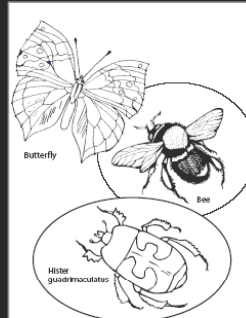


I like insects. They are interesting to look at and study.

Color in the insect.

Activities:

- Solve the puzzle.
- Navigate to 'Earth Science'.
- Identify major inventions.
- Place major inventors.
- Find your dream job on the map.
- Why is mathematics important?



There are many types of insects in the world. Bees, butterflies, and beetles are just a few.



I want to be an entomologist when I grow up. Then I can study insects all the time.

What is Science? KIDS DRAWING CONTEST

WHAT

What is Science? Who does Science? What is Science to you? Design a picture of your favorite scientist or science experiment and tell us about it!

WHEN

October 1st - 30th: Submit entries
November 5th: Winners notified
November 5th - 30th: Winning entries and Top 50 on display at the American Museum of Science and Energy.

Judging Criteria

- 25% Appropriateness of contest theme
- 25% Creativity and quality of drawing
- 25% Originality of the story
- 25% Sensitivity of drawing and story

Requirements

Kids ages 4-15 are invited to submit their hand-drawn illustrations on 8.5 x 11 paper with a typed story of 25-100 words explaining their drawing and discussing their favorite scientist or experiment.

PRIZES

1 year family membership & Science Kit from AMSE

Science Kit from the AMSE Discovery Shop

Science Book from the AMSE Discovery Shop

Bring in your contest submission and get into AMSE for FREE

Consent

Required: Parental signature granting consent for child to enter contest and agreement that the submitted material will not be returned and will become the property of the Places & Spaces-Museum Science exhibit.

Submitting

Mail submissions to: The American Museum of Science and Energy, 600 S. Tulane Ave., Oak Ridge, TN 37830. You may also bring in your submission to The American Museum of Science and Energy.

QUESTIONS? Ask Kim Poyes (kimpoyes@amse.org) | Phone 865-574-9584

Please attach this form to the back of submission



Artist's Name _____ Age _____ Parent's Name _____ Phone Number _____

My Favorite Scientist



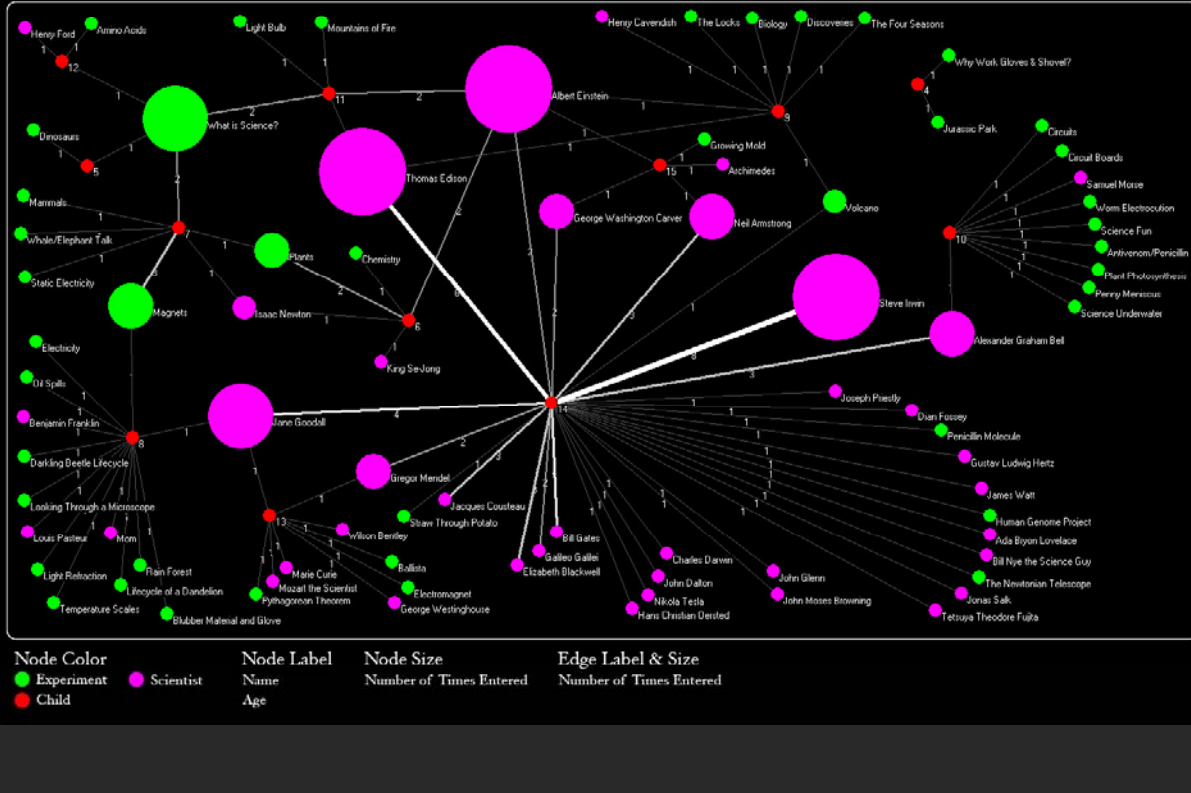
Observe
Discover
Understand
Learn
Science
Explore
Hypothesis
Experiment
Win or Lose

Winners @ AMSE

JoHanna Sanders, age 12, a picture of someone enjoying nature and a theme that science is all around us.
Sascha Richey, age 8, drew a picture of her mother and explained why her mother is her favorite scientist.

Places & Spaces: Mapping Science

Kids Contest Entries for Monroe County Public Library and American Museum of Science & Energy in 2007



cyberinfrastructure for NETWORK SCIENCE CENTER
 School of Library and Information Science | Indiana University Bloomington

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Funding

Visiting Artists

<http://cns.slis.indiana.edu>