



Visual Analytics & Learning Analytics

Katy Börner, Indiana University @katycns

Doktorandenkolloquium "Education & Technology"
Fakultät für Erziehungswissenschaften und Medienzentrum der TU Dresden, Germany

July 5, 2018



Visual Analytics & Learning Analytics

Outline:

Context

Visual Analytics

Learning Analytics



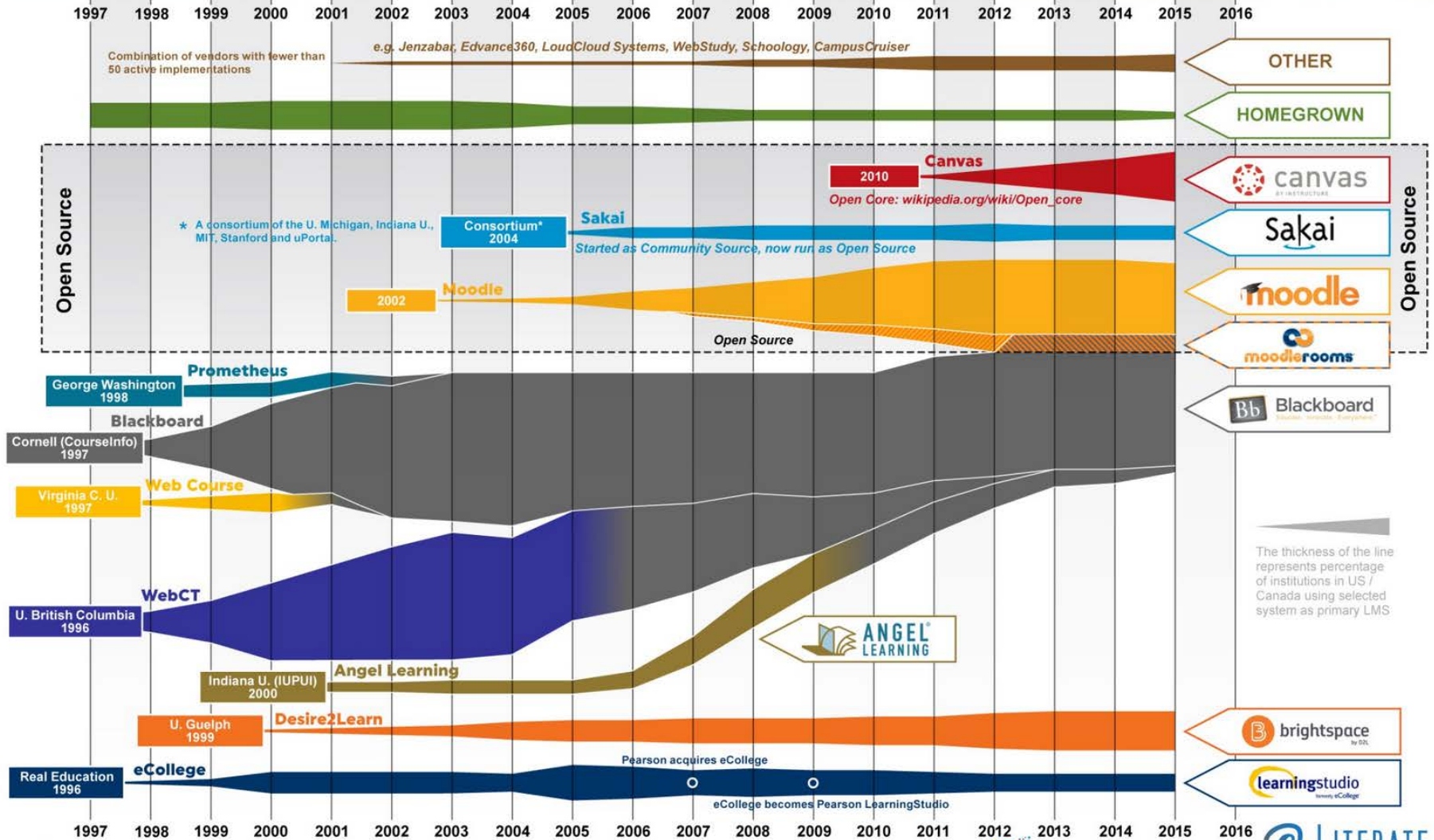
Context

LMS Market Share For US & Canadian Higher Ed Institutions

SPRING 2016
VERSION

LEARNING MANAGEMENT SYSTEM

LEARNING PLATFORM



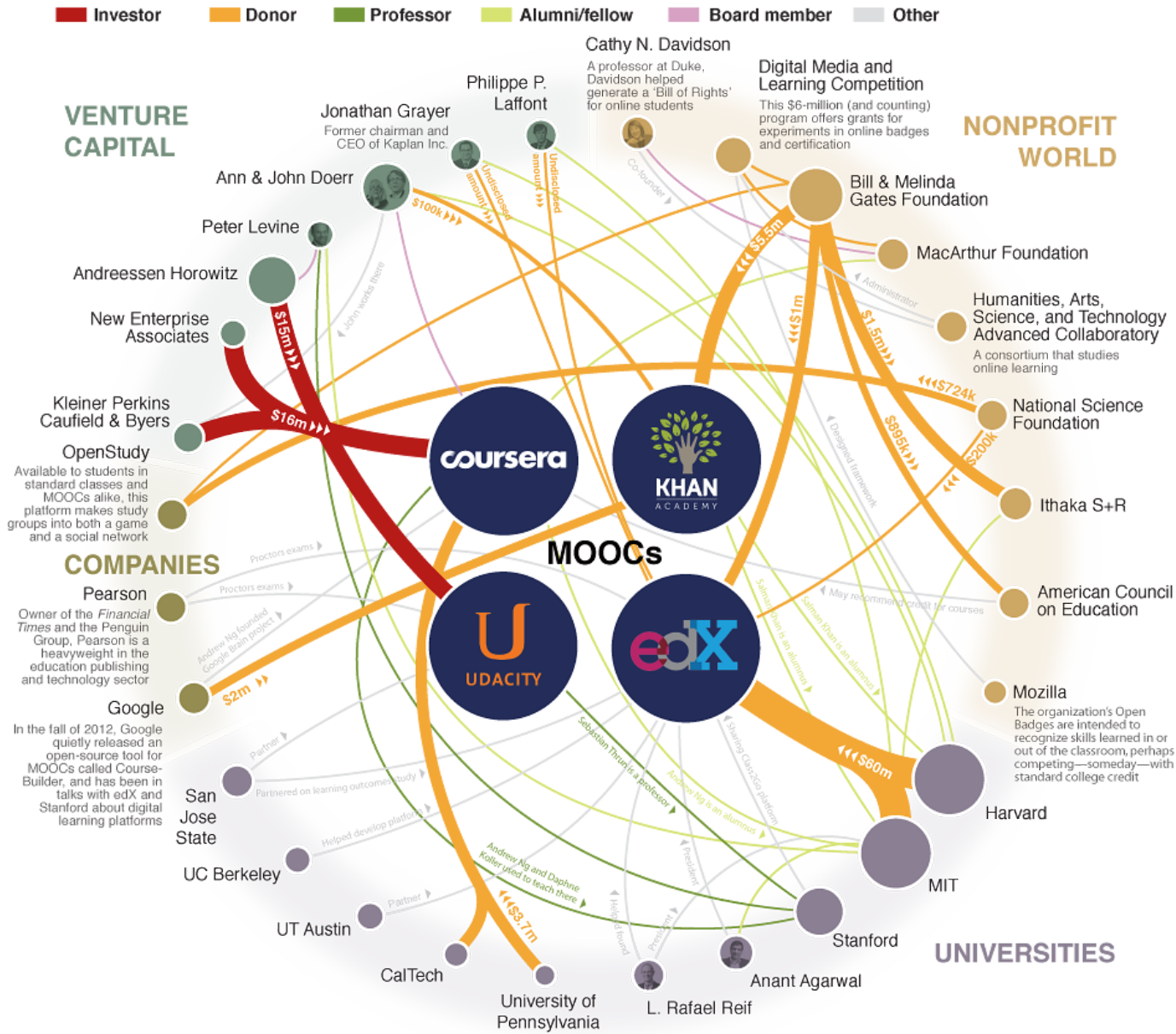
All data from LISTedTECH LMS database under agreement with MindWires Consulting

LISTedTECH

delta initiative

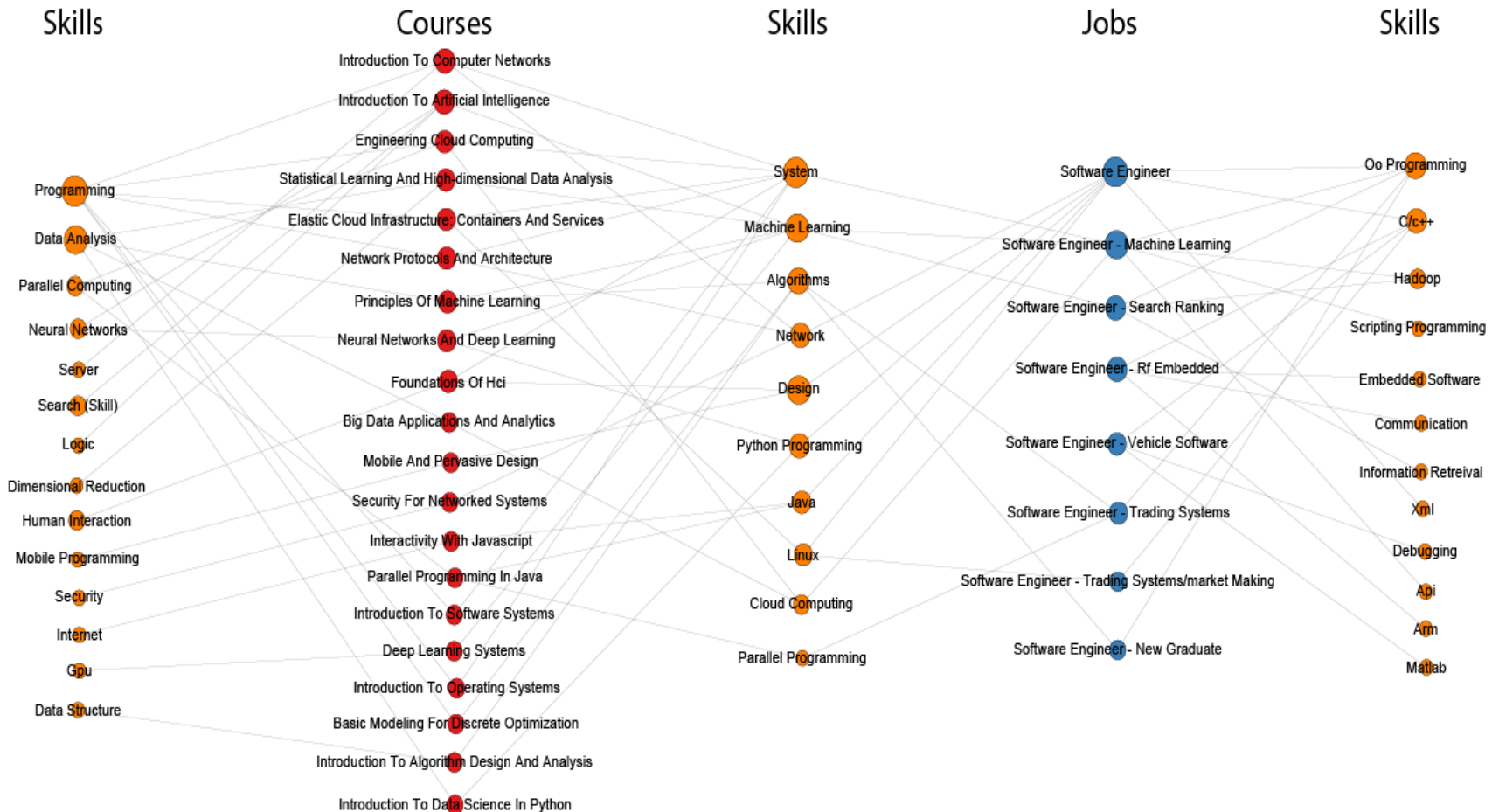
@-LITERATE
mfeldstein.com

<https://mfeldstein.com/state-higher-ed-lms-market-spring-2016>



IU Data Science Program: Courses, Skills & Jobs

Katy Börner, Michael Ginda & Xiaozhong Liu, Indiana University

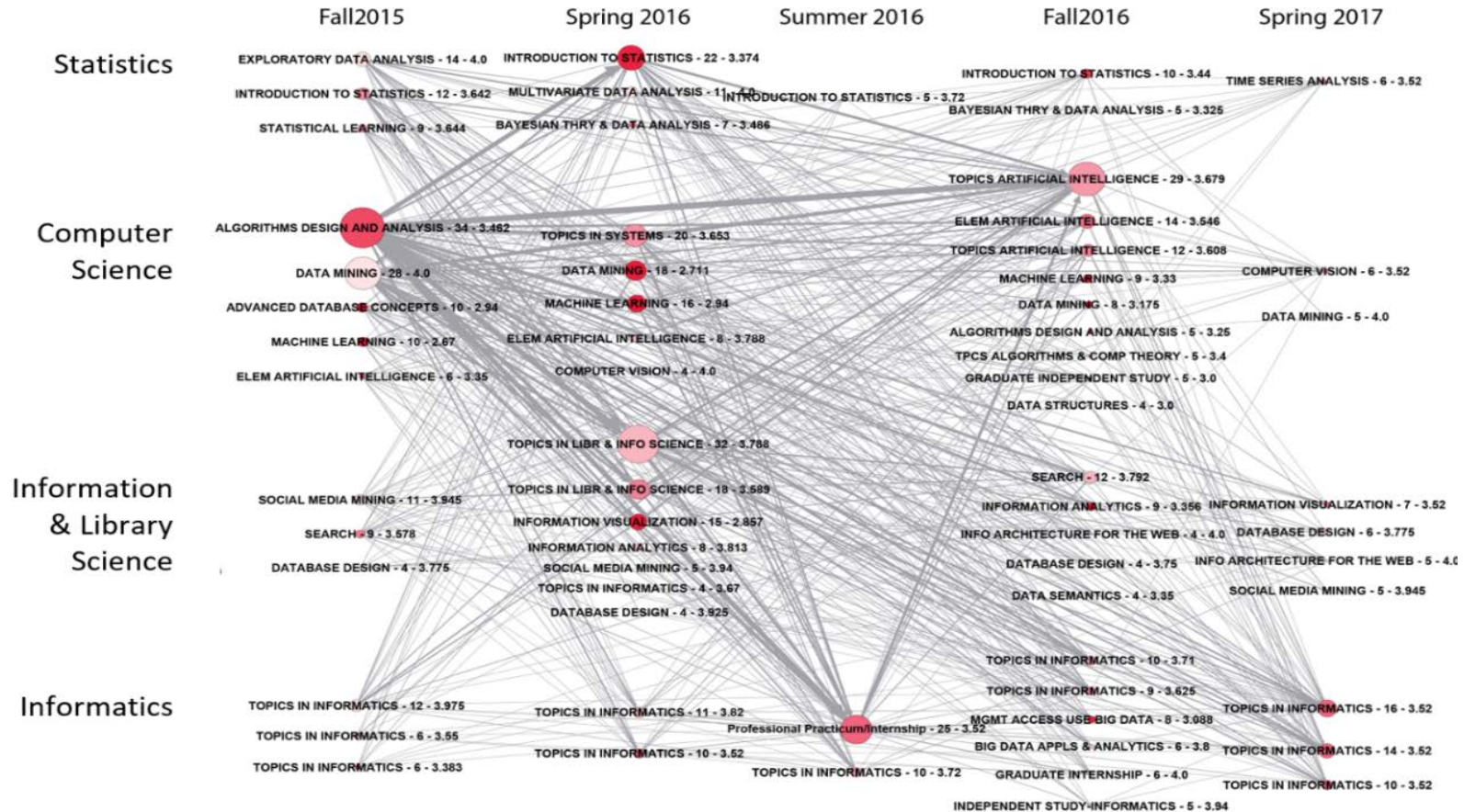


Exemplary set of IU Data Science courses, ‘Software Engineering’ jobs, and associated skills.

Job data was retrieved from LinkedIn and CareerBuilder and course data come from the IU course list. As can be seen, there are many skills (in orange) that are exclusively associated with courses or jobs; however, the skills in the middle interlink courses (in red) to jobs (in blue).

IU Data Science Program: Student Course Transition Network

Michael Ginda, Kayla Scroggins & Katy Börner, Indiana University



Empower students, teachers, and curriculum committee members to understand and discuss current and desirable student cohorts, key course trajectories, or the (gatekeeper) role that specific courses play. Vertically, courses are arranged into four groups based on the department offering the course. Within each vertical grouping, the nodes are sorted by the total enrollment for the course with highest values on top. Node size encodes number of students enrolled; node color denotes overall GPA for the course.

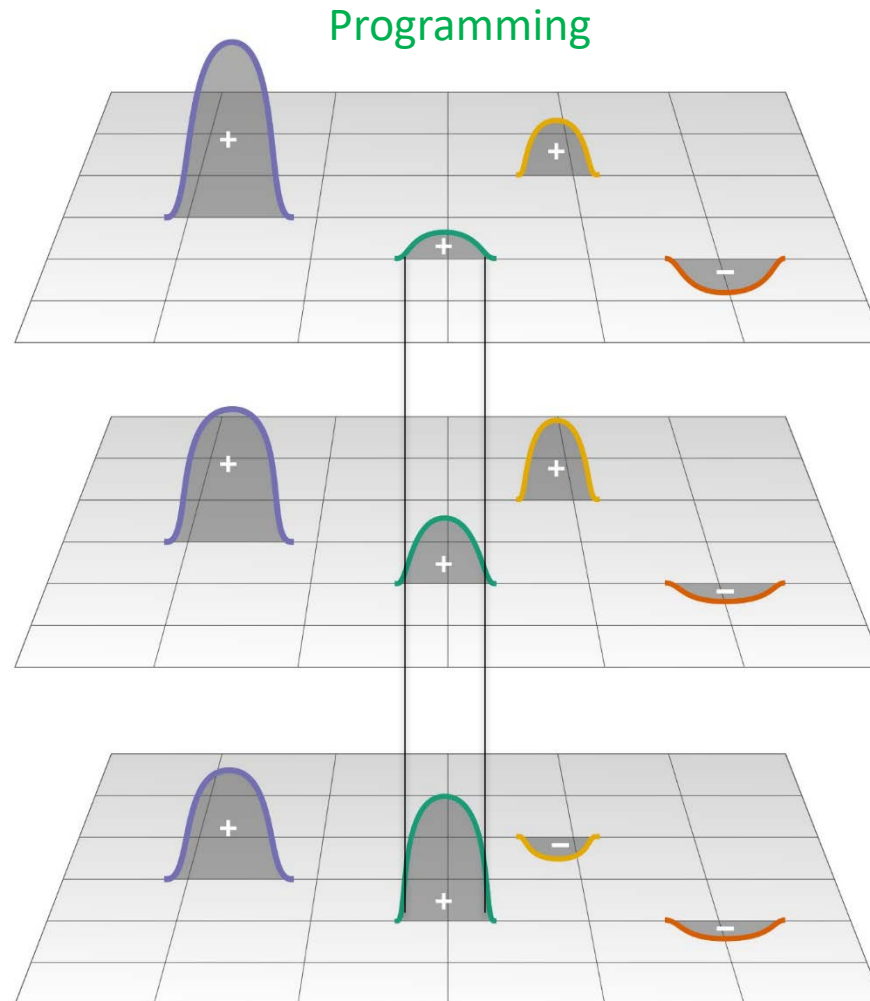
Science & Technology vs. Education/Training vs. Jobs

Katy Börner, Olga Scrivner, Mike Gallant, Shutian Ma, Xiaozhong Liu, Keith Chewning, Lingfei Wu and James A. Evans

Need to study the **(mis)match** and **temporal dynamics** of S&T progress, education and workforce development options, and job requirements.

Challenges:

- Rapid change of STEM knowledge
- Increase in tools, AI
- Social skills (project management, team leadership)
- Increasing team size



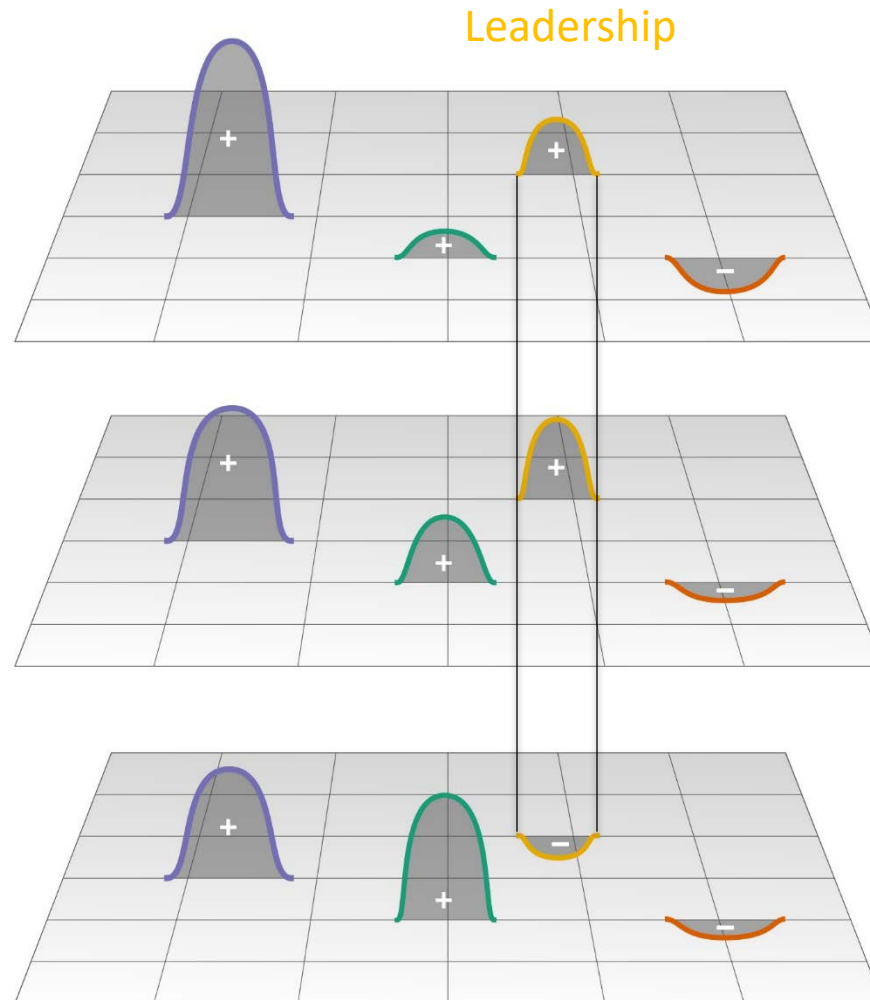
Science & Technology vs. Education/Training vs. Jobs

Katy Börner, Olga Scrivner, Mike Gallant, Shutian Ma, Xiaozhong Liu, Keith Chewning, Lingfei Wu and James A. Evans

Need to study the **(mis)match** and **temporal dynamics** of S&T progress, education and workforce development options, and job requirements.

Challenges:

- Rapid change of STEM knowledge
- Increase in tools, AI
- Social skills (project management, team leadership)
- Increasing team size

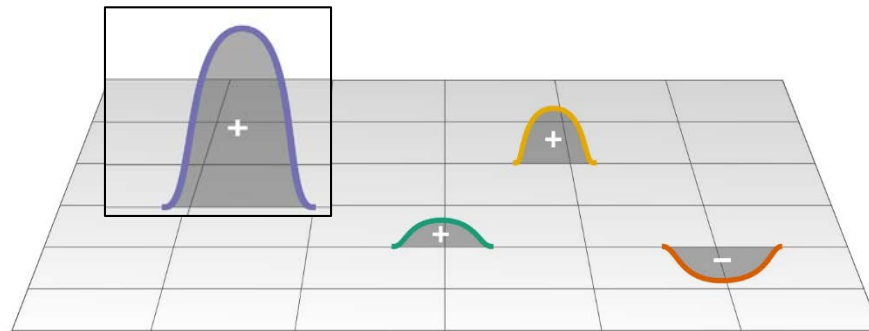


Science & Technology vs. Education/Training vs. Jobs

Katy Börner, Olga Scrivner, Mike Gallant, Shutian Ma, Xiaozhong Liu, Keith Chewning, Lingfei Wu and James A. Evans

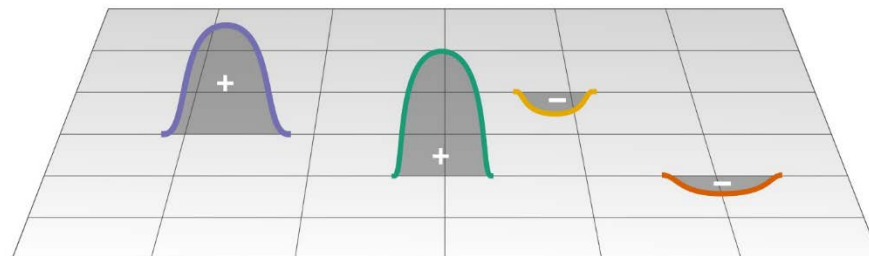
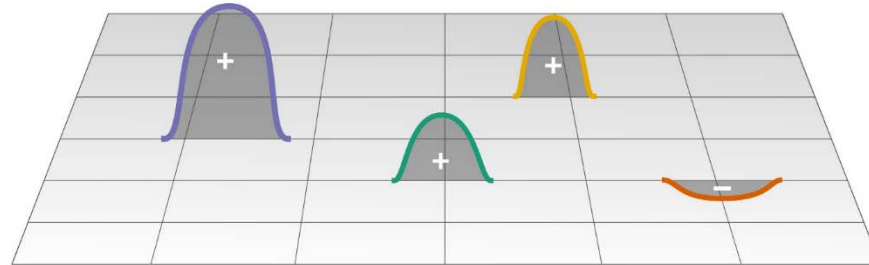
Need to study the **(mis)match** and **temporal dynamics** of S&T progress, education and workforce development options, and job requirements.

Data Science



Challenges:

- Rapid change of STEM knowledge
- Increase in tools, AI
- Social skills (project management, team leadership)
- Increasing team size



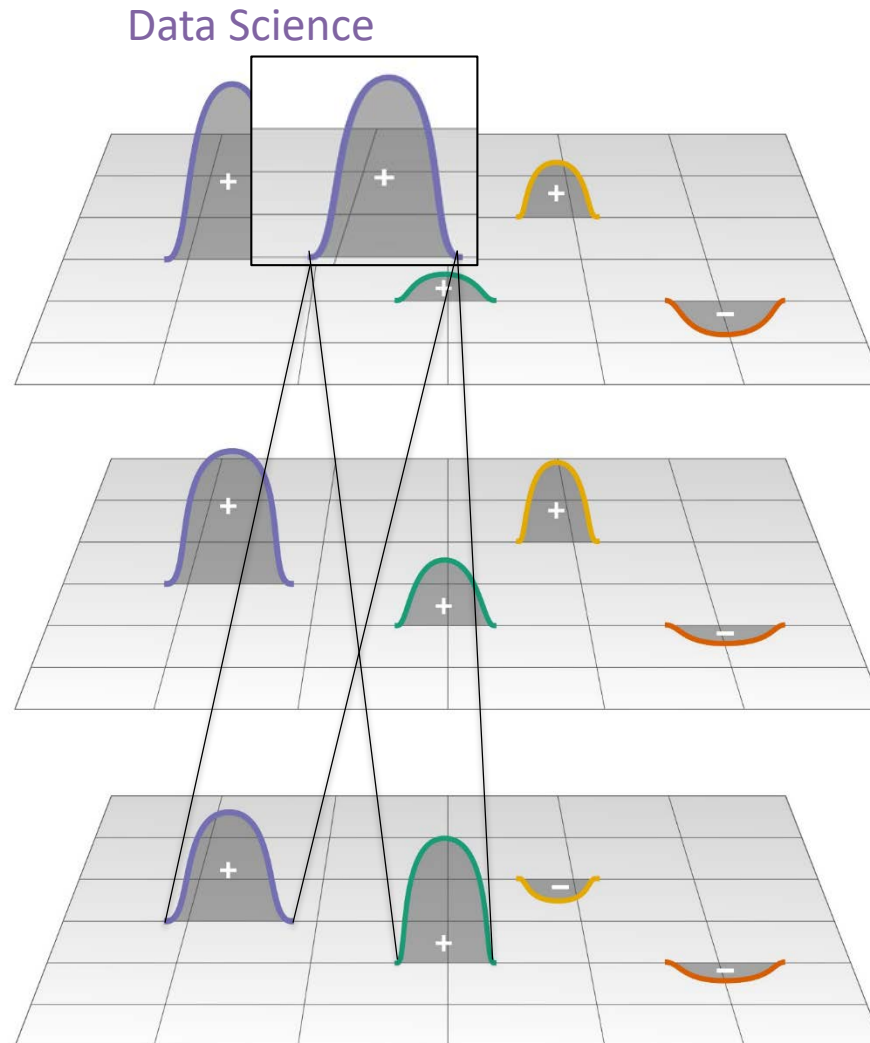
Science & Technology vs. Education/Training vs. Jobs

Katy Börner, Olga Scrivner, Mike Gallant, Shutian Ma, Xiaozhong Liu, Keith Chewning, Lingfei Wu and James A. Evans

Need to study the **(mis)match** and **temporal dynamics** of S&T progress, education and workforce development options, and job requirements.

Challenges:

- Rapid change of STEM knowledge
- Increase in tools, AI
- Social skills (project management, team leadership)
- Increasing team size

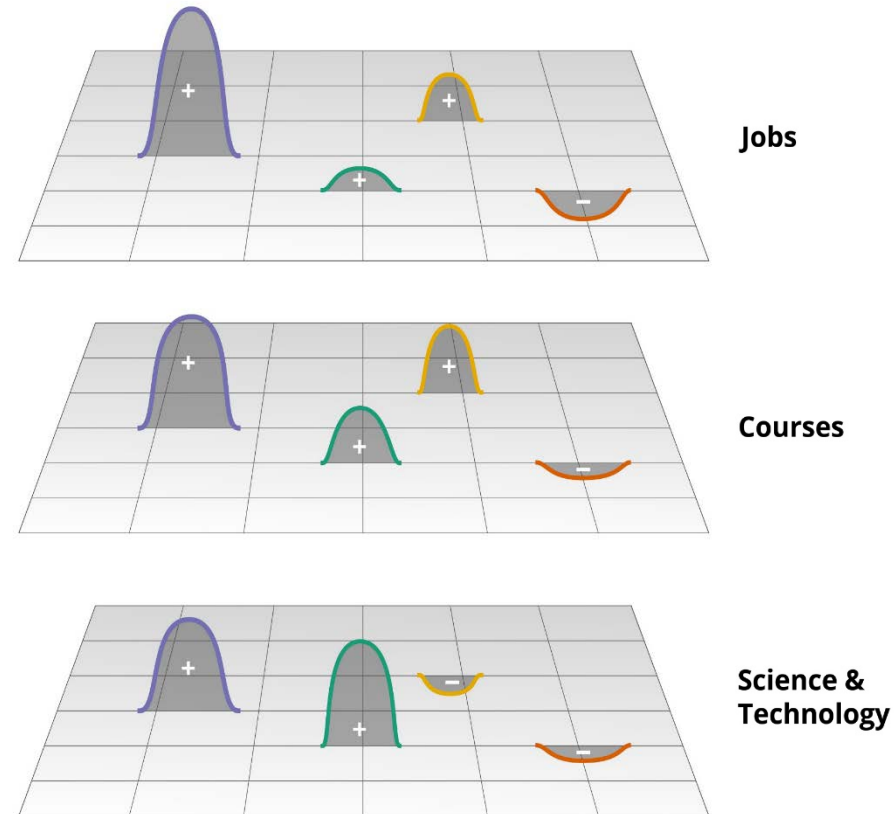


Science & Technology vs. Education/Training vs. Jobs

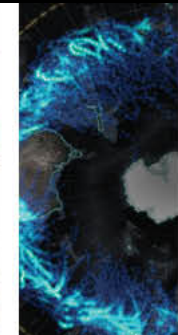
Katy Börner, Olga Scrivner, Mike Gallant, Shutian Ma, Xiaozhong Liu, Keith Chewning, Lingfei Wu and James A. Evans

Study results are needed by:

- **Students:** What jobs will exist in 1-4 years? What program/learning trajectory is best to get/keep my dream job?
- **Teachers:** What course updates are needed? What curriculum design is best? What is my competition doing? How much timely knowledge (to get a job) vs. forever knowledge (to be prepared for 80 productive years) should I teach? How to innovate in teaching and get tenure?
- **Employers:** What skills are needed next year, in 5 years? Who trains the best? What skills does my competition list in job advertisements? How to hire/train productive teams?



What is ROI of my time, money, compassion?



Modeling and Visualizing Science and Technology Developments

National Academy of Sciences Sackler Colloquium, December 4-5, 2017, Irvine, CA

Rankings and the Efficiency of Institutions

H. Eugene Stanley | Albert-László Barabási | Lada Adamic | Marta González | Kaye Husbands Fealing | Brian Uzzi | John V. Lombardi

Higher Education and the Science & Technology Job Market

Katy Börner | Wendy L. Martinez | Michael Richey | William Rouse | Stasa Milojevic | Rob Rubin | David Krakauer

Innovation Diffusion and Technology Adoption

William Rouse | Donna Cox | Jeff Alstott | Ben Shneiderman | Rahul C. Basole | Scott Stern | Cesar Hidalgo

Modeling Needs, Infrastructures, Standards

Paul Trunfio | Sallie Keller | Andrew L. Russell | Guru Madhavan | Azer Bestavros | Jason Owen-Smith



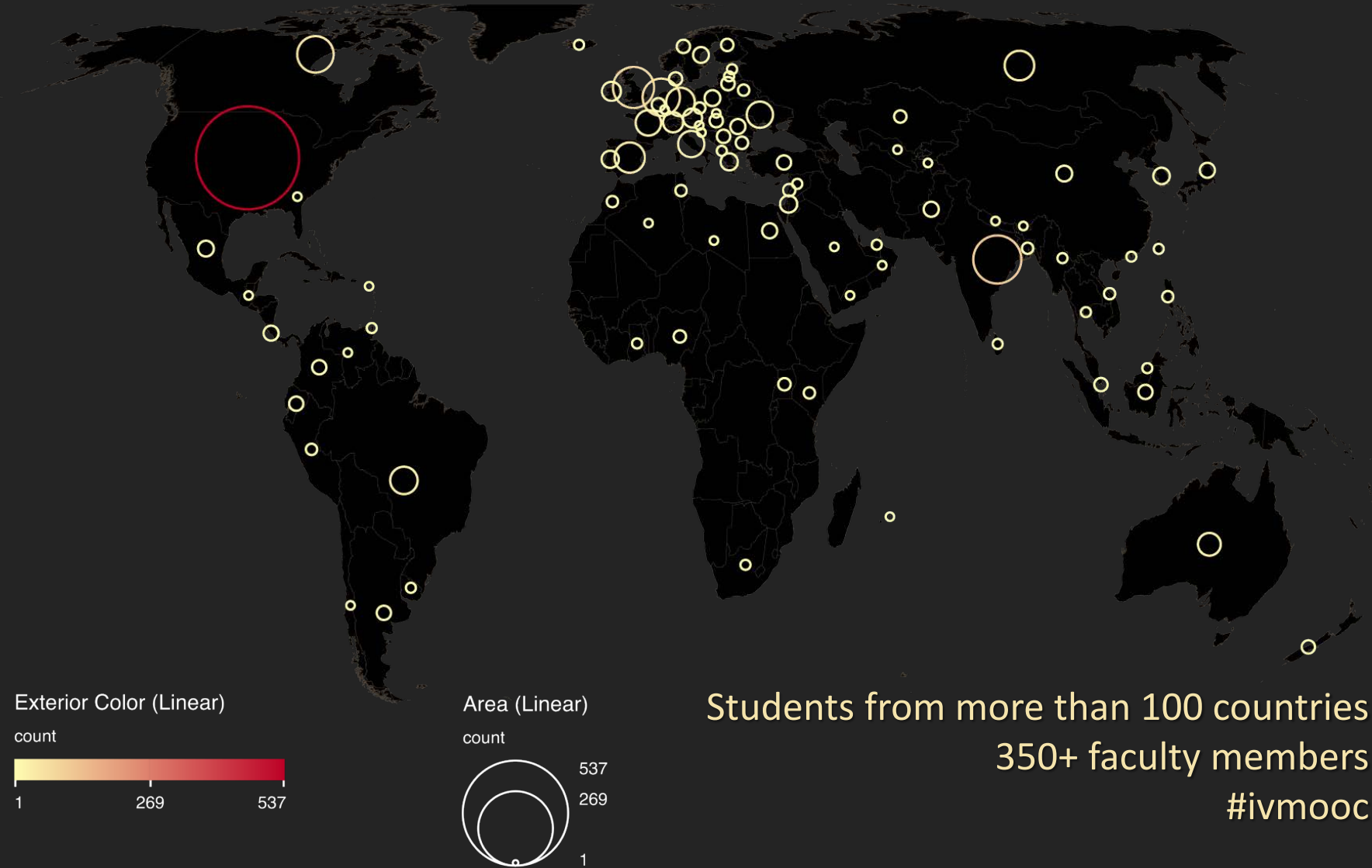
Visual Analytics - IVMOOC



Register for free: <http://ivmooc.cns.iu.edu>

The Information Visualization MOOC

ivmooc.cns.iu.edu



Data Visualization Literacy

Data visualization literacy (ability to read, make, and explain data visualizations) requires

- *literacy* (ability to read and write text, e.g., in titles, axis labels, legend),
- *visual literacy* (ability to find, interpret, evaluate, use, and create images and visual media), and
- *data literacy* (ability to read, create, and communicate data).

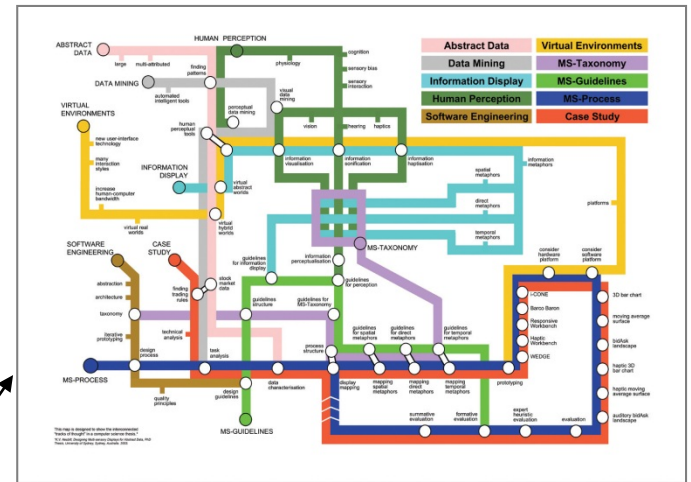
Being able to “read and write” data visualizations is becoming as important as being able to read and write text. Understanding, measuring, and improving data and visualization literacy is important for understanding STEAM developments and to strategically approach global issues.

Different Question Types



Terabytes of data

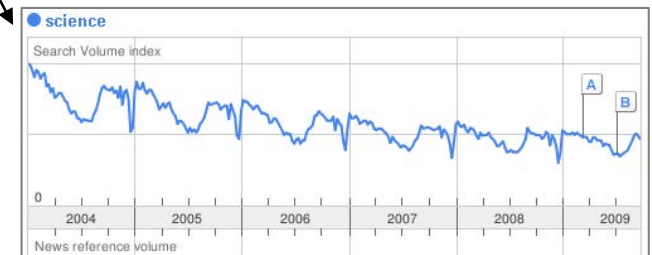
Descriptive & Predictive Models



Find your way



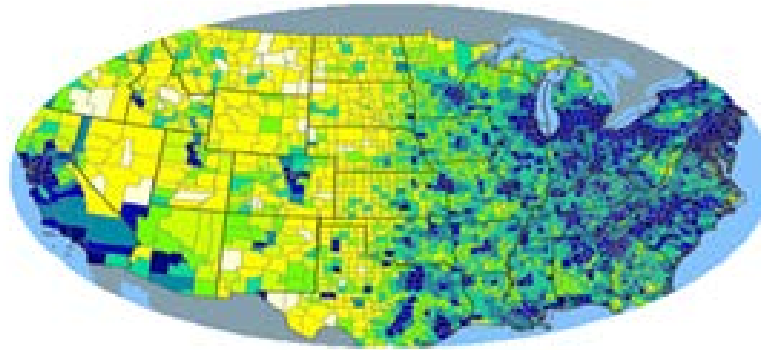
Find collaborators, friends



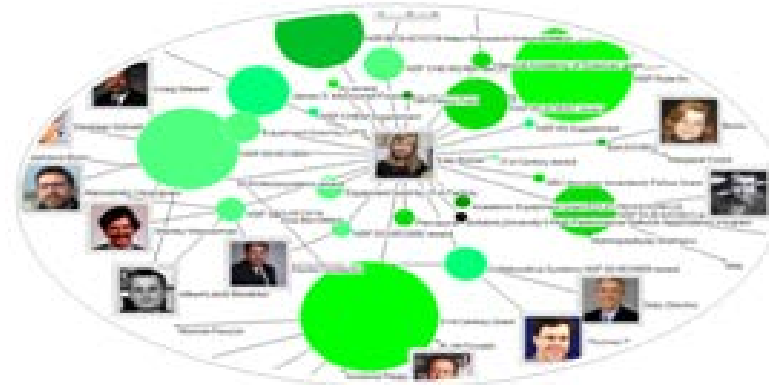
Identify trends

Different Levels of Abstraction/Analysis

Macro/Global
Population Level



Meso/Local
Group Level



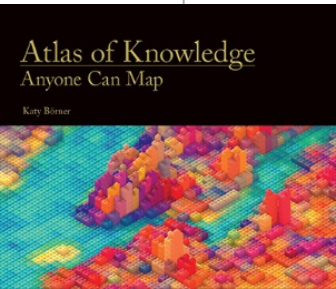
Micro
Individual Level



Tasks

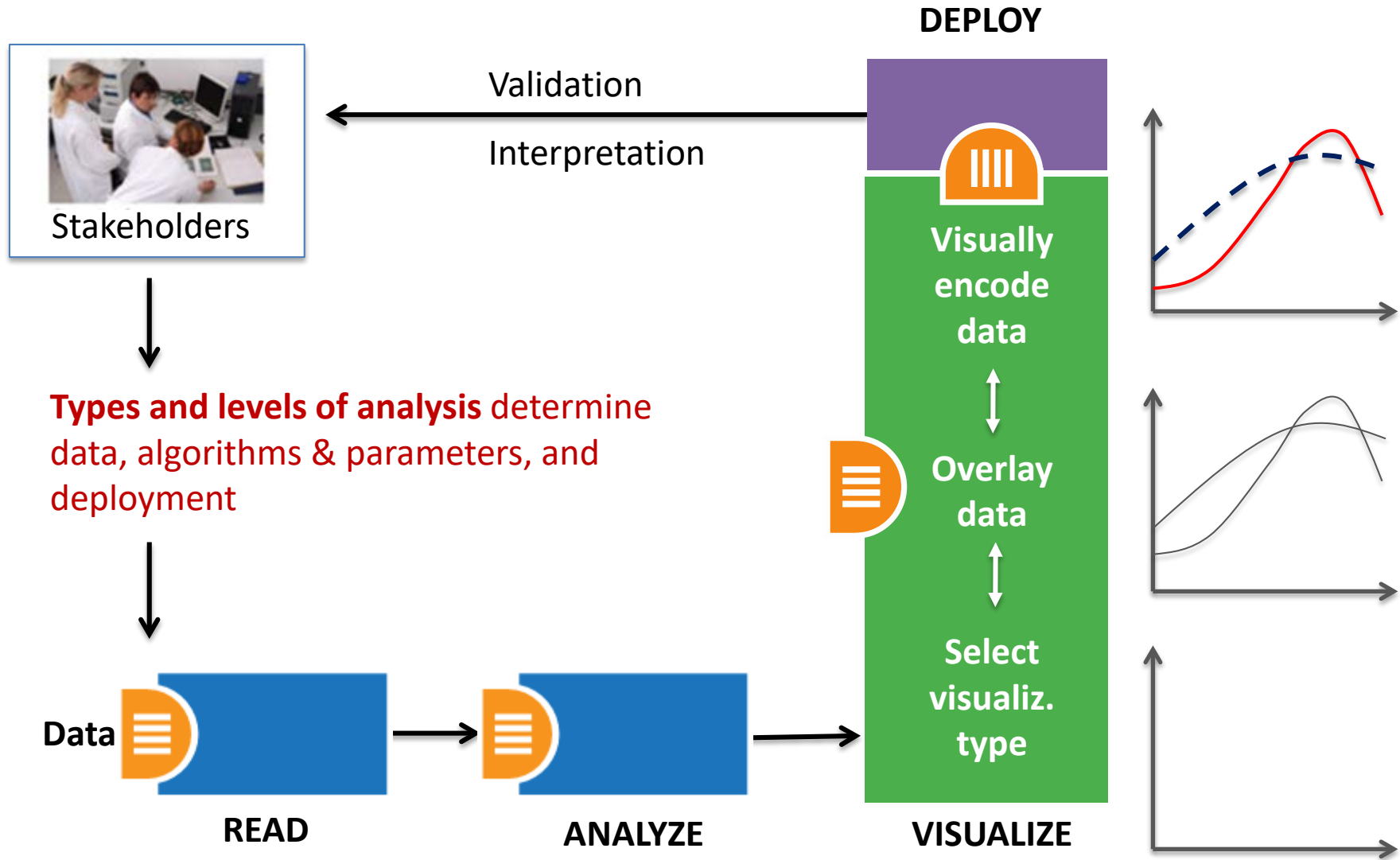
LEVELS

	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
TYPES			
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

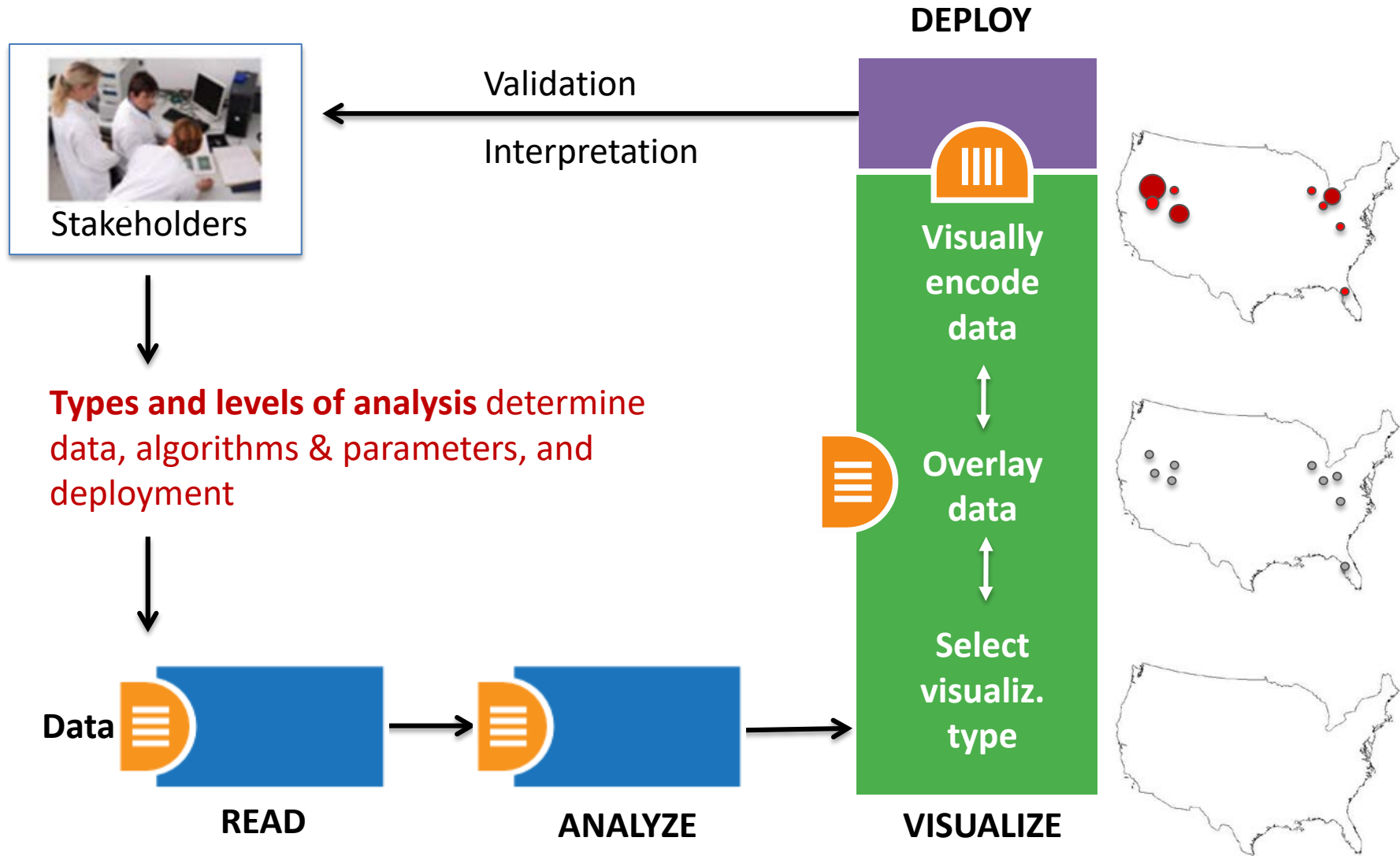


See *Atlas of Science: Anyone Can Map*, page 5

Needs-Driven Workflow Design

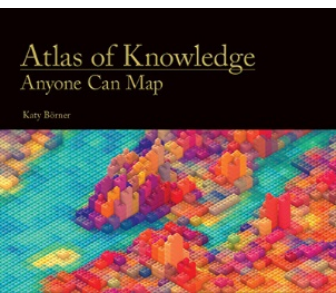


Needs-Driven Workflow Design



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
<ul style="list-style-type: none"> • categorize/cluster • order/rank/sort • distributions (also outliers, gaps) • comparisons • trends (process and time) • geospatial • compositions (also of text) • correlations/relationships 	<ul style="list-style-type: none"> • nominal • ordinal • interval • ratio 	<ul style="list-style-type: none"> • table • chart • graph • map • network layout 	<ul style="list-style-type: none"> • geometric symbols <ul style="list-style-type: none"> point line area surface volume • linguistic symbols <ul style="list-style-type: none"> text numerals punctuation marks • pictorial symbols <ul style="list-style-type: none"> images icons statistical glyphs 	<ul style="list-style-type: none"> • spatial <ul style="list-style-type: none"> position • retinal <ul style="list-style-type: none"> form color optics motion 	<ul style="list-style-type: none"> • overview • zoom • search and locate • filter • details-on-demand • history • extract • link and brush • projection • distortion



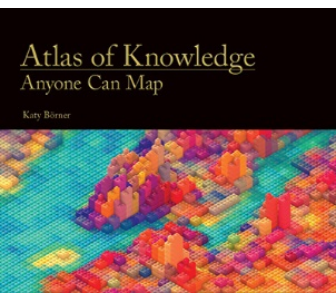
See *Atlas of Science: Anyone Can Map*, page 24

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
<ul style="list-style-type: none"> • categorize/cluster • order/rank/sort • distributions (also outliers, gaps) • comparisons • trends (process and time) • geospatial • compositions (also of text) • correlations/relationships 	<ul style="list-style-type: none"> • nominal • ordinal • interval • ratio 	<ul style="list-style-type: none"> • table • chart • graph • map • network layout 	<ul style="list-style-type: none"> • geometric symbols <ul style="list-style-type: none"> point line area surface volume • linguistic symbols <ul style="list-style-type: none"> text numerals punctuation marks • pictorial symbols <ul style="list-style-type: none"> images icons statistical glyphs 	<ul style="list-style-type: none"> • spatial <ul style="list-style-type: none"> position • retinal <ul style="list-style-type: none"> form color optics motion 	<ul style="list-style-type: none"> • overview • zoom • search and locate • filter • details-on-demand • history • extract • link and brush • projection • distortion



See *Atlas of Science: Anyone Can Map*, page 24

Graphic Variable Types Versus Graphic Symbol Types

			Geometric Symbols					
			Point		Line		Area	
Spatial	x	quantitative						
	y	quantitative						
	z	quantitative						
Retinal	Form	Size	quantitative	NA (Not Applicable)				
		Shape	qualitative	NA				
		Rotation	quantitative	NA				
		Curvature	quantitative	NA				
		Angle	quantitative	NA				
		Closure	quantitative	NA				
	Color	Value	quantitative					
Hue		qualitative						
Saturation		quantitative						

Graphic Variable Types Versus Graphic Symbol Types

			Geometric Symbols			Linguistic Symbols Text, Numerals, Punctuation Marks		Pictorial Symbols Images, Icons, Statistical Glyphs	
Spatial	x	quantitative							
	y	quantitative							
	z	quantitative							
Form	Size	quantitative	NA (Not Applicable)						
	Shape	qualitative	NA						
	Rotation	quantitative	NA						
	Curvature	quantitative	NA						
	Angle	quantitative	NA						
	Closure	quantitative	NA						
	Value	quantitative							
Color	Hue	qualitative							
	Saturation	quantitative							

			Geometric Symbols			Linguistic Symbols Text, Numerals, Punctuation Marks		Pictorial Symbols Images, Icons, Statistical Glyphs	
Texture	Spacing	quantitative							
	Granularity	quantitative							
	Pattern	qualitative							
	Orientation	quantitative	NA						
	Gradient	quantitative							
	Blur	quantitative							
	Transparency	quantitative							
Optics	Shading	quantitative							
	Stereoscopic Depth	quantitative	Point in foreground -- background	Line in foreground -- background	Area in foreground -- background	Surface in foreground -- background	Volume in foreground -- background	Text in foreground -- background	Icons in foreground -- background
	Speed	quantitative							
Motion	Velocity	quantitative							
	Rhythm	quantitative	Blinking point slow -- fast	Blinking line slow -- fast	Blinking area slow -- fast	Blinking surface slow -- fast	Blinking volume slow -- fast	Blinking text slow -- fast	Blinking icons slow -- fast

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

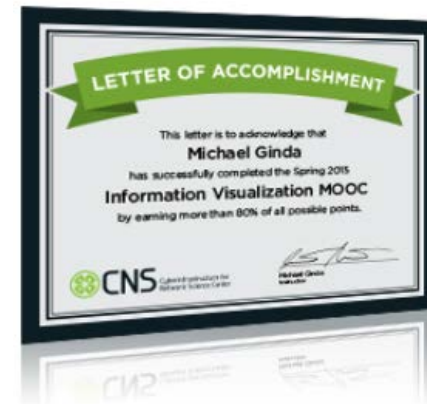
Mid-Term

- **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 Homework and Quizzes (**10%**), Midterm (**20%**), Final (**30%**), Client Project (**30%**), and Class Participation (**10%**).



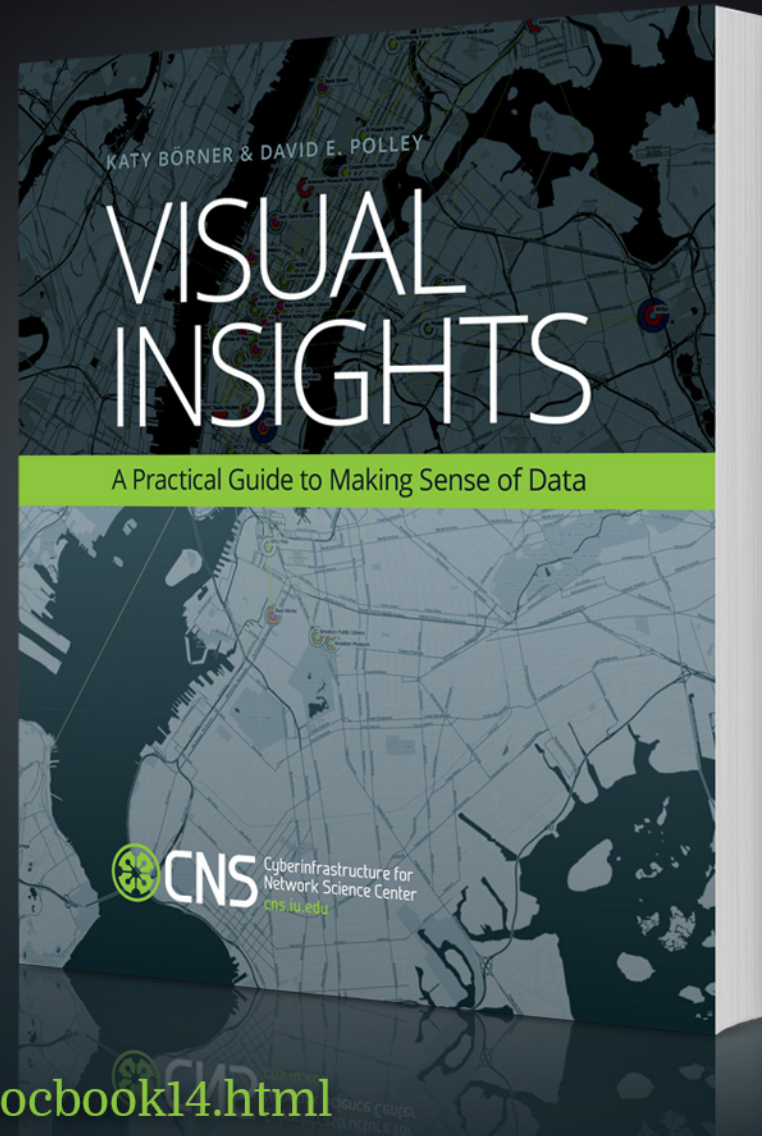
The IVMOOC Companion Textbook

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.

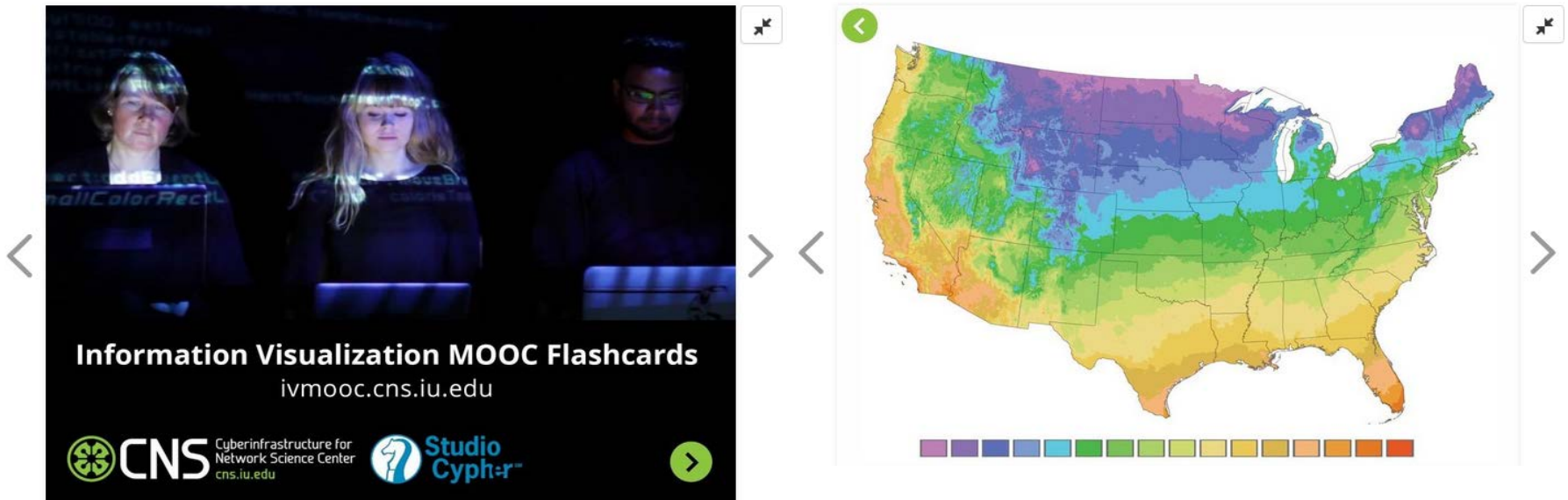
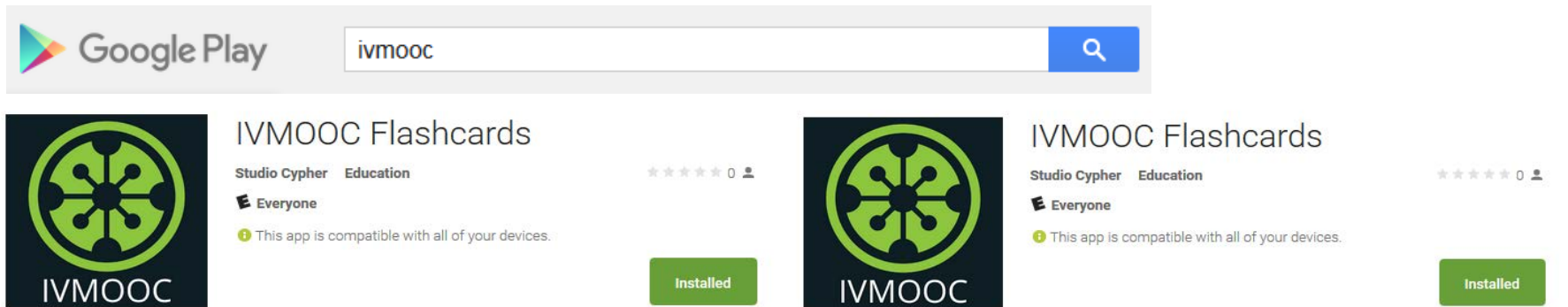
<http://ivmooc.cns.iu.edu>

cns.iu.edu/ivmoocbook14.html



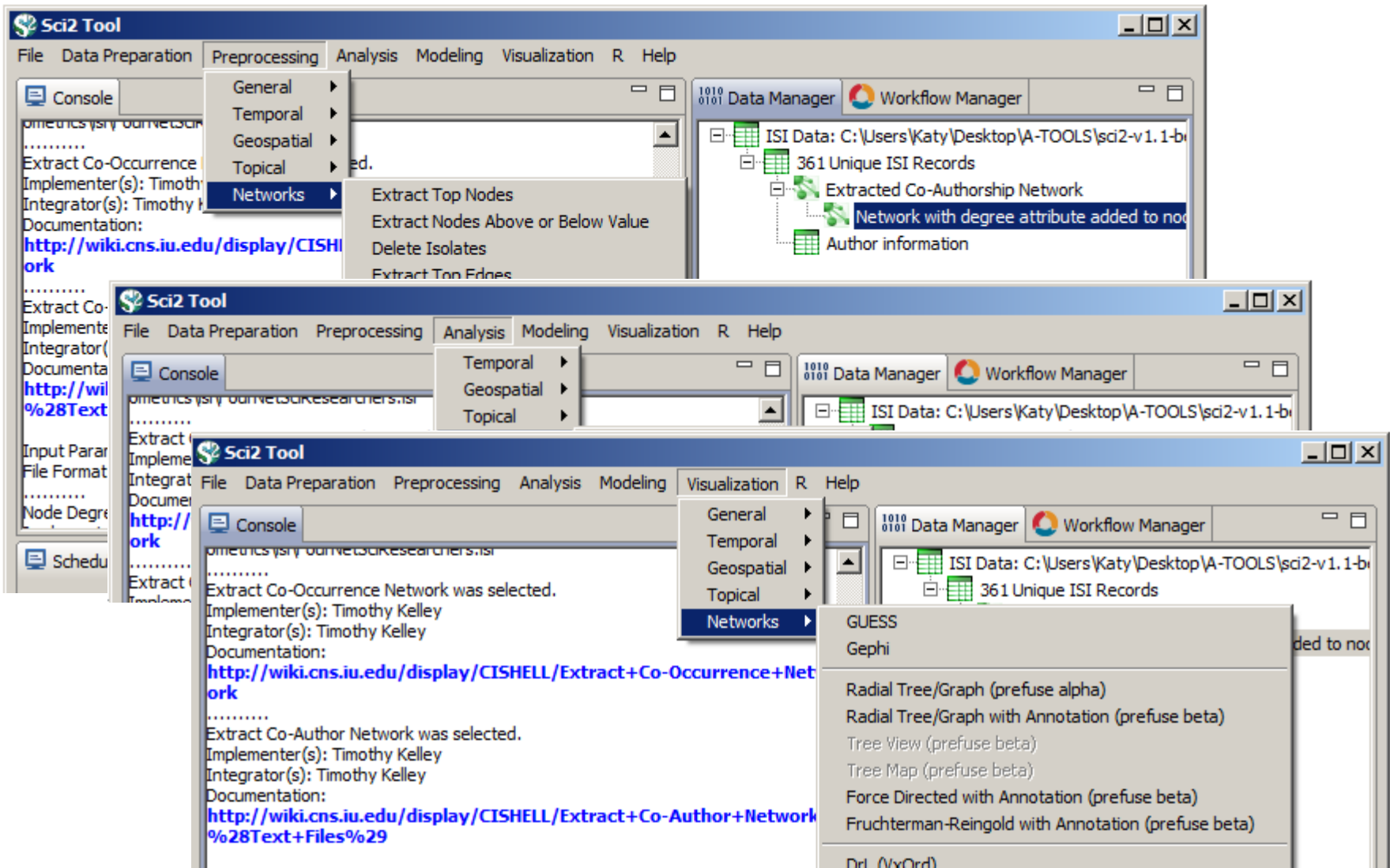
IVMOOC App

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



Sci2 Tool Interface Components Implement Vis Framework

Download tool for free at <http://sci2.cns.iu.edu>



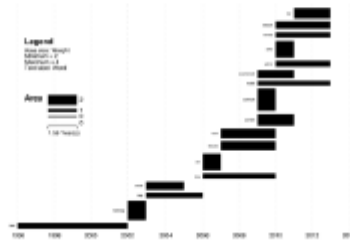
Load **One** File and Run **Many** Analyses and Visualizations

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 Microscopes	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

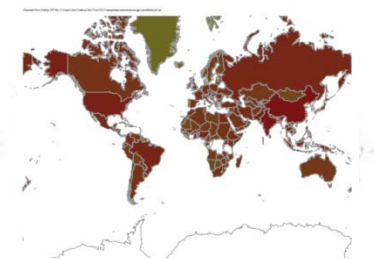
Temporal Burst Analysis—p. 48



Geospatial Analysis—p. 52



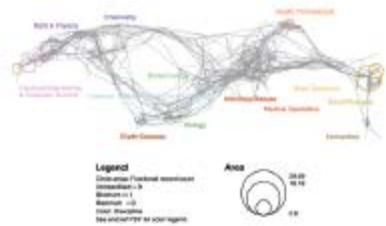
Geospatial Analysis—p. 52



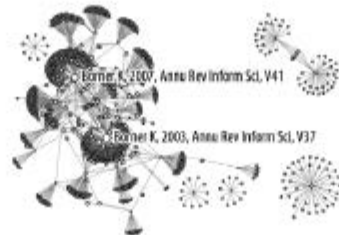
Load **One** File and Run **Many** Analyses and Visualizations

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

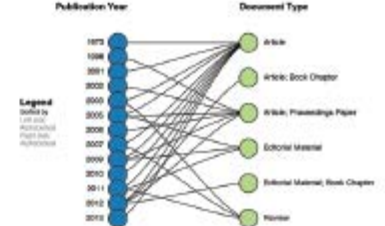
Topical Analysis—p. 56



Paper Citation Network—p. 60



Bi-Modal Network—p. 60



Co-author and many other bi-modal networks.



Learning Analytics



Learning Analytics

Empowering Teachers: How to make sense of the activities of thousands of students? How to guide them?

Empowering Students: How to navigate learning materials and develop successful learning collaborations across disciplines and time zones?

Empowering Researchers: How do people learn? What pedagogy works (in a MOOC) and when?

Empowering MOOC Platform Designers: What technology helps and what hurts?



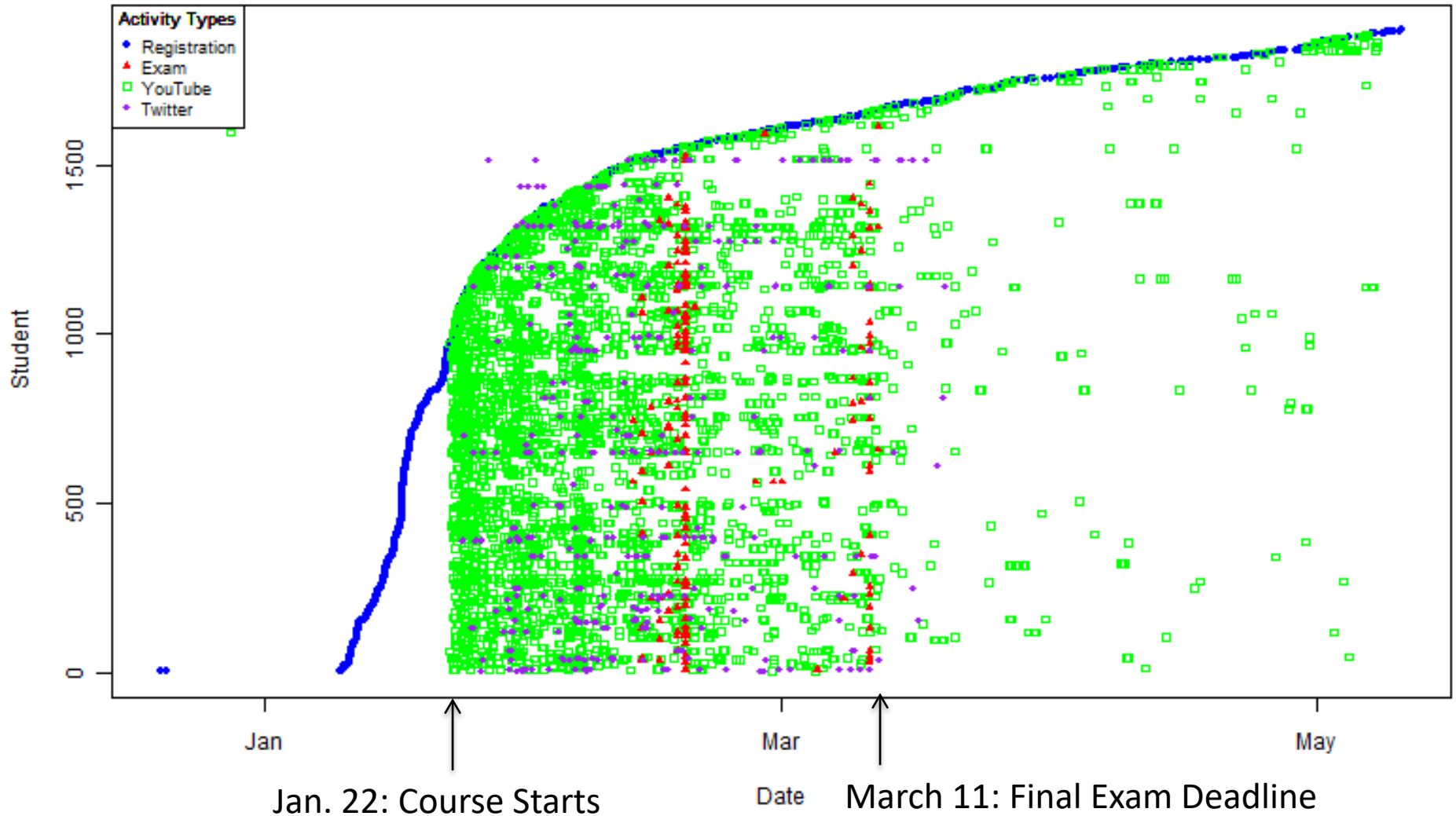
Visualizing IVMOOC Data

Data was collected from different sources:

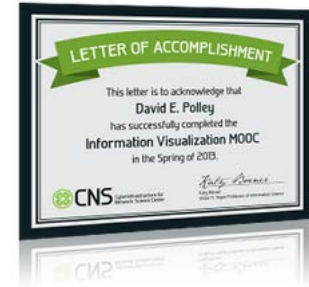
- 1,901 students registered via GCB (1215 male/557 female)
- 52,557 slide downloads from our server
- 18,893 video views via YouTube
- 193 accounts made 730 tweets
- 134 students took 183 exams in GCB
- 674 remarks on 215 different forum threads in Drupal
- 64 students submitted projects via Drupal



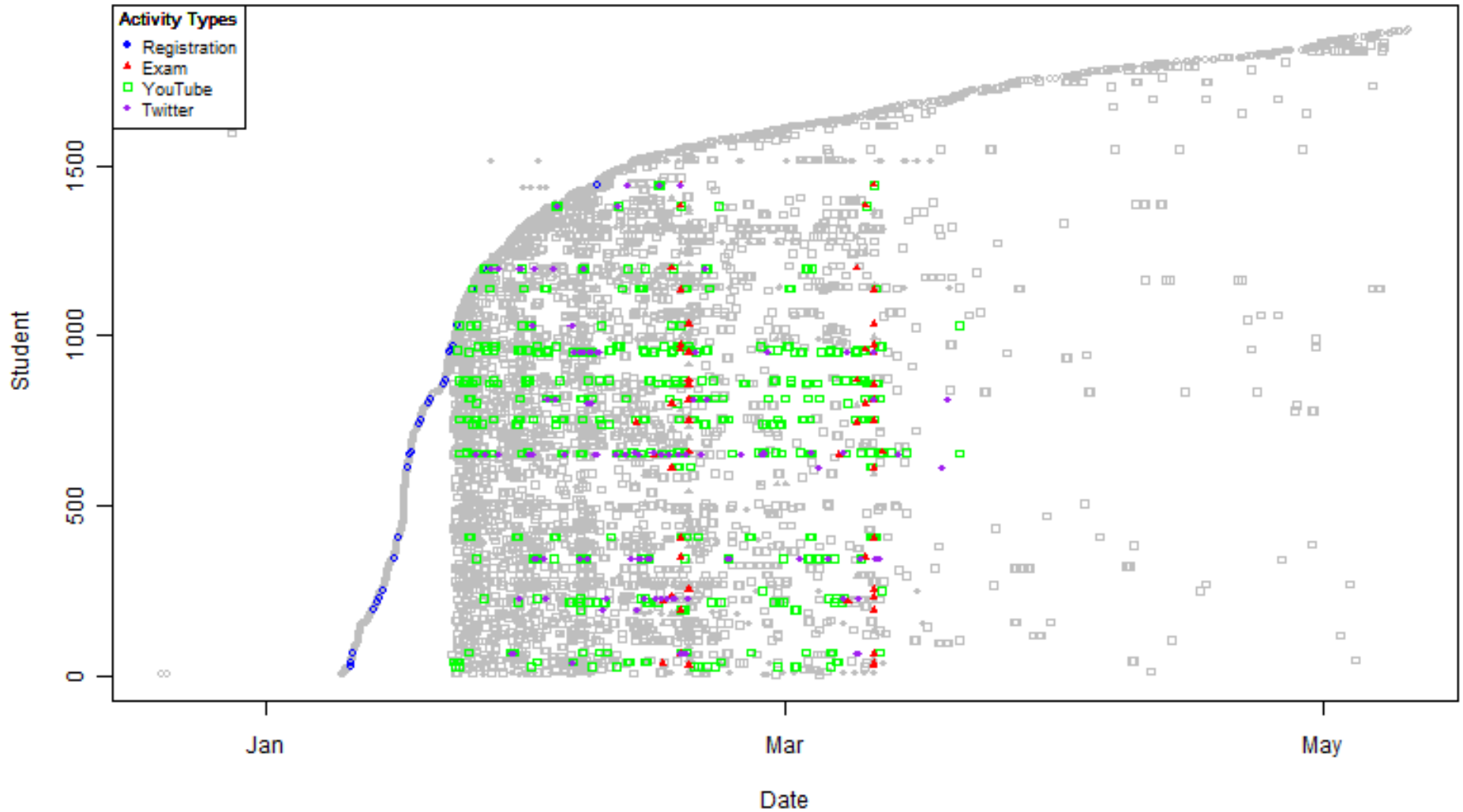
Student Registration and Activity



Student Registration and Activity



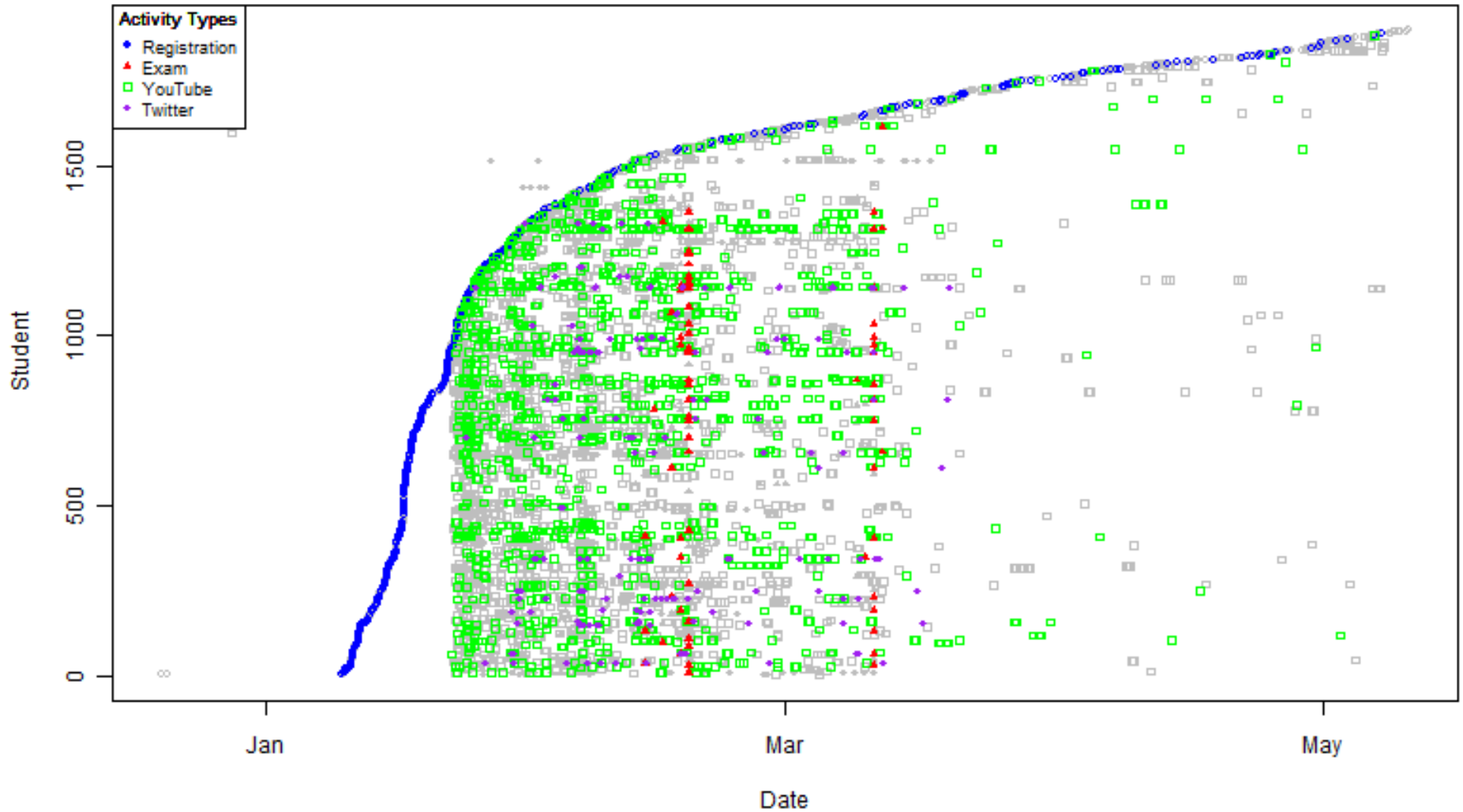
IVMOOC Student Activity (Achievement Badge)



Student Registration and Activity

1215 male students
557 female students

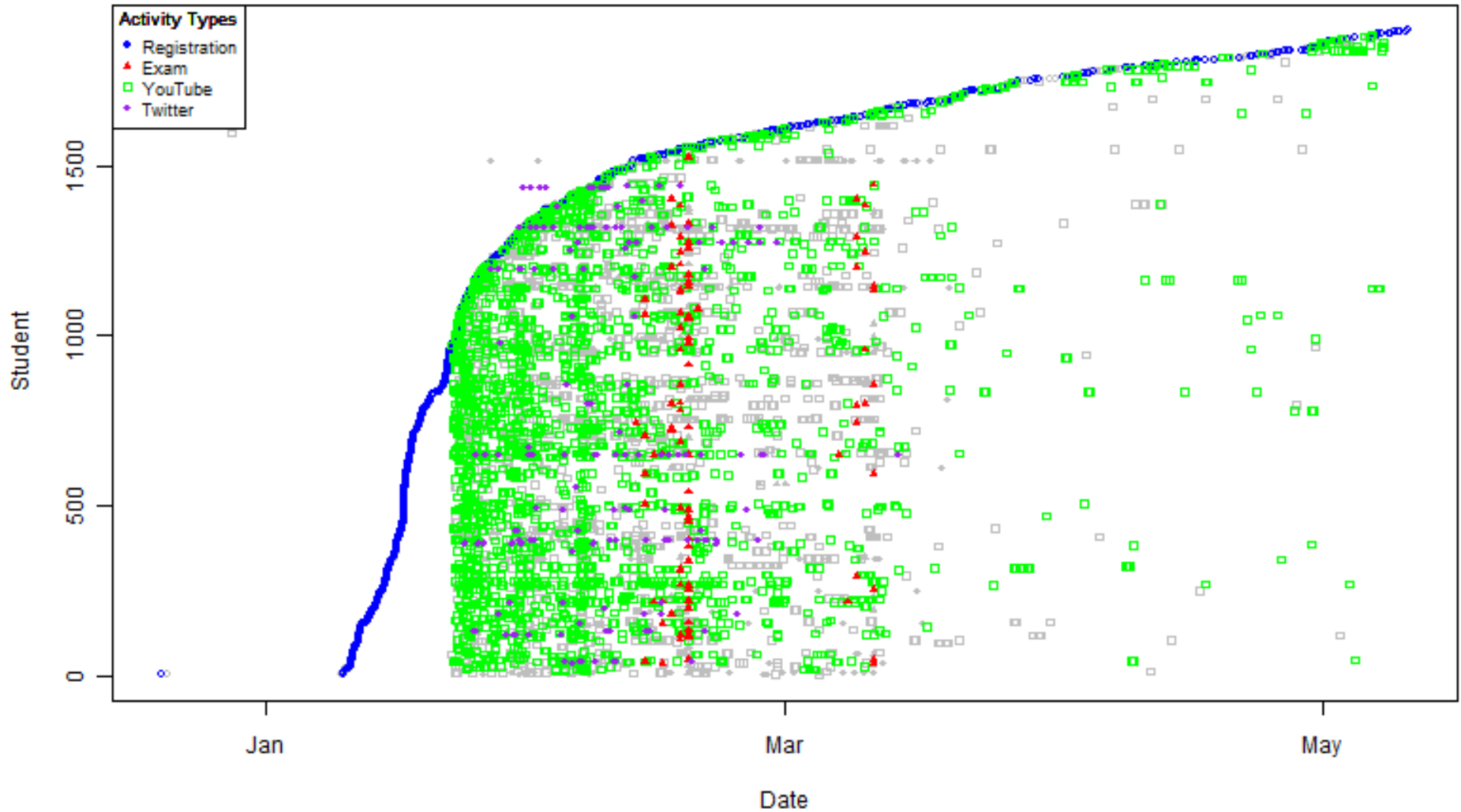
Female IVMOOC Student Activity



Student Registration and Activity

1215 male students
557 female students

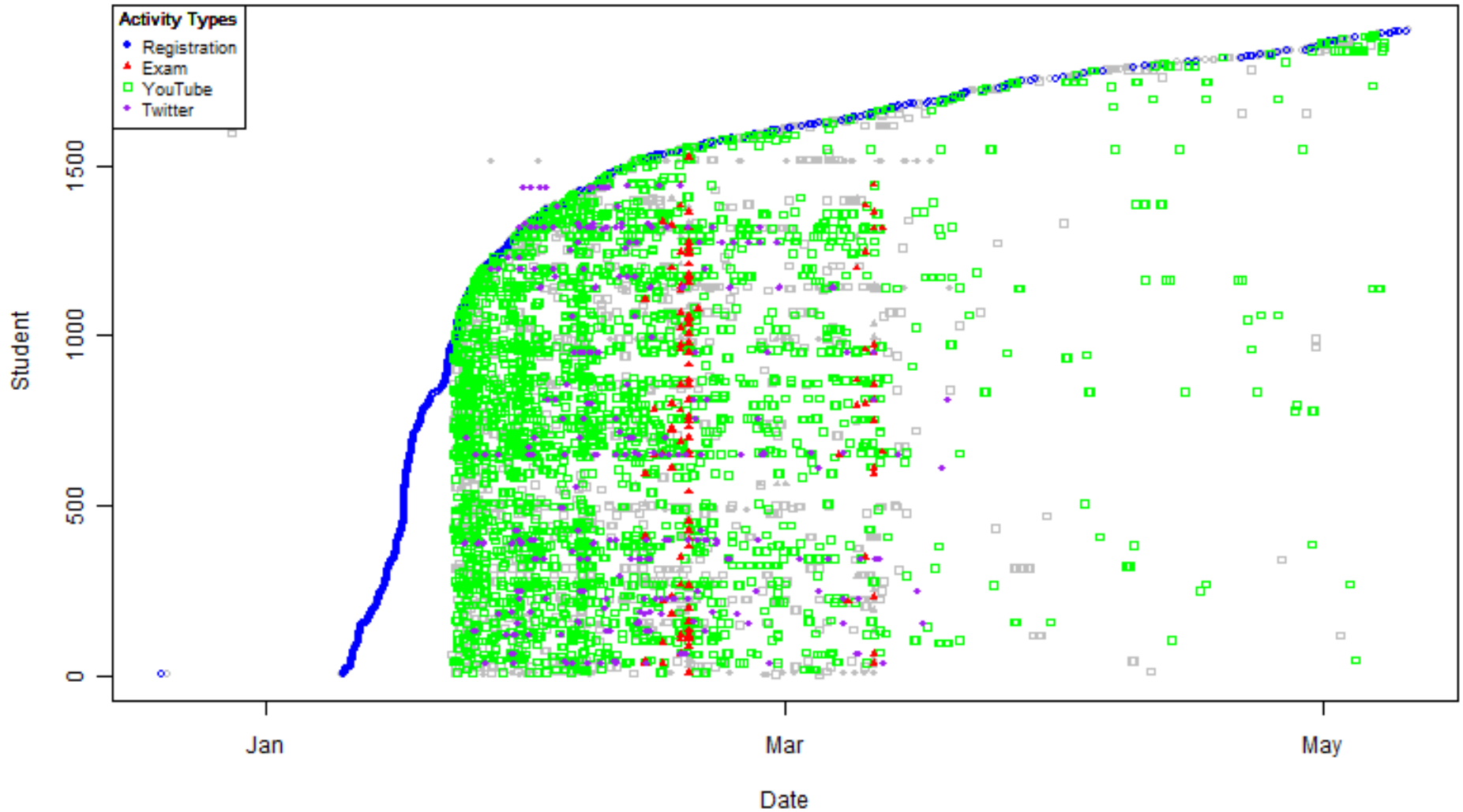
Male IVMOOC Student Activity





Student Registration and Activity

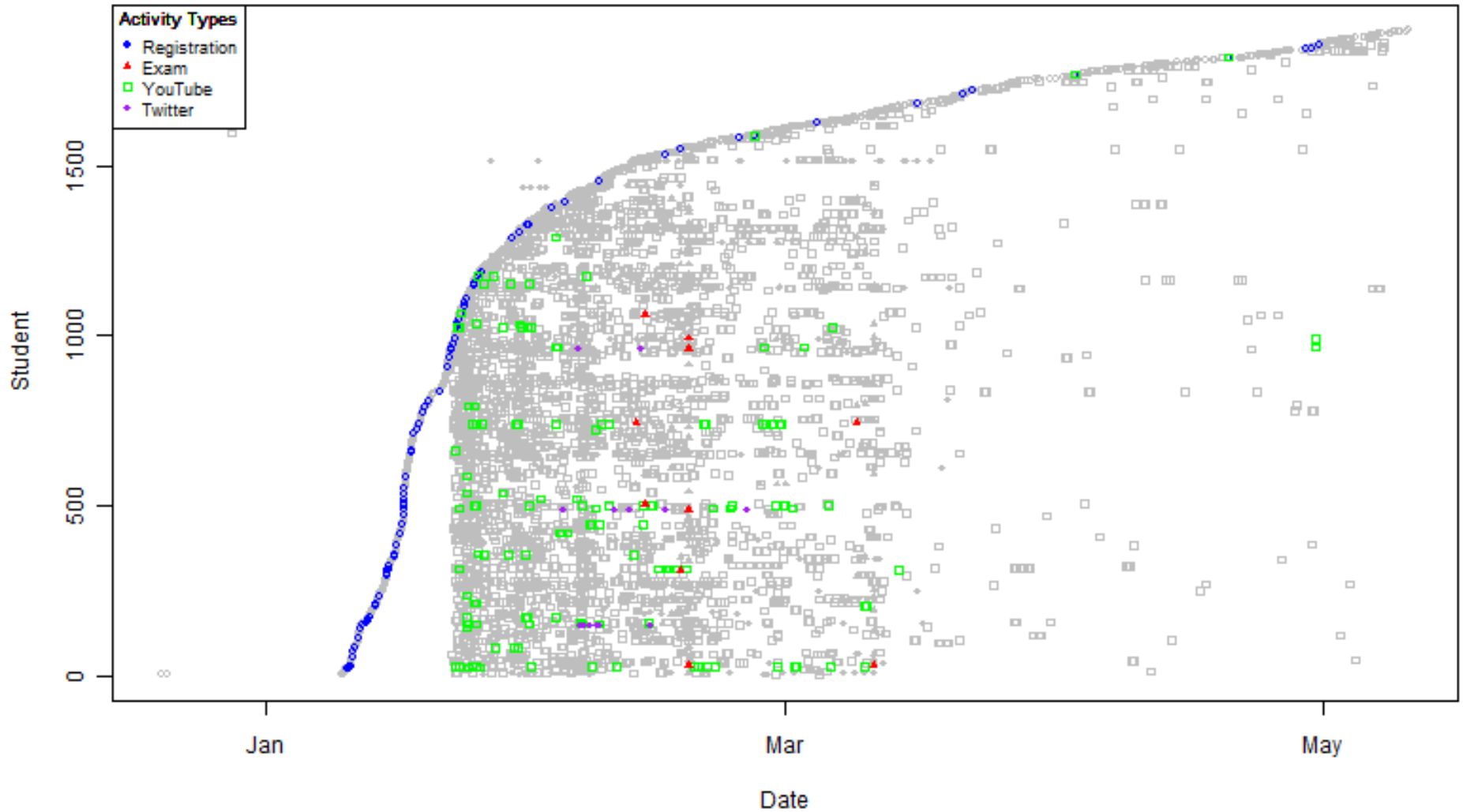
Novice IVMOOC Student Activity





Student Registration and Activity

Expert IVMOOC Student Activity



Student Client Projects: All Interactions



Student Engagement and Performance

Learning Analytics

IVMOOC 2015 Student Group Engagement and Scores

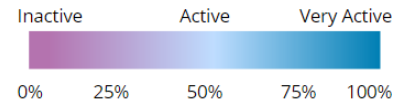
	Pre-Course	Week 1	Week 2	Week 3	Week 4	Midterm	Week 5	Week 6	Week 7	Week 8	Week 9	Final	Curr. Score
IVMOOC	26.05%	38.32%	31.32%	29.96%	27.1%	28.34%	31.07%	24.28%	16.86%	18.23%	13.08%	13.41%	20.87%
Z637-29374	33.01%	52.91%	49.89%	59.22%	50.89%	82.56%	65.04%	49.99%	39.59%	61.63%	54.91%	82.25%	82.4%
Z637-32593	25.08%	54.54%	43.58%	50.67%	53.63%	77.67%	65.7%	59.48%	52.19%	65.71%	47.27%	72.59%	75.13%
Z637-33781	29.33%	55.38%	49.26%	62.18%	77.47%	85%	87.4%	69.8%	55.56%	57.6%	45.69%	70.89%	77.94%

IVMOOC 2015 Student Group Engagement for Midterm

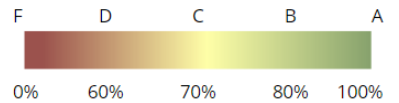
	Midterm	Final	Curr. Score	Overall Engagement
Student 198	100%	85.33%	92.67%	30.34%
Student 210	100%	84%	92%	33.91%
Student 242	97.14%	98.67%	97.9%	55.89%
Student 265	95.71%	92%	93.86%	82.64%
Student 216	95.71%	24%	59.86%	34.92%
Student 257	94.29%	98.67%	96.48%	68.25%
Student 264	94.29%	89.33%	91.81%	80.47%
Student 262	94.29%	85.33%	89.81%	79.65%

Legends

Engagement



Score



Description

The heat map visualization is a representation of student engagement (magenta to blue color scale) and performance (red to green color scale) throughout a course. The visualization has two levels. The top level provides an overview of engagement and performance for groups of students, while the bottom level provides a detailed break out of student engagement statistics for individuals with an identified group.

Custom interactive visualizations of IVMOOC student engagement and performance data, explore functionality online at <http://goo.gl/TYixCn>

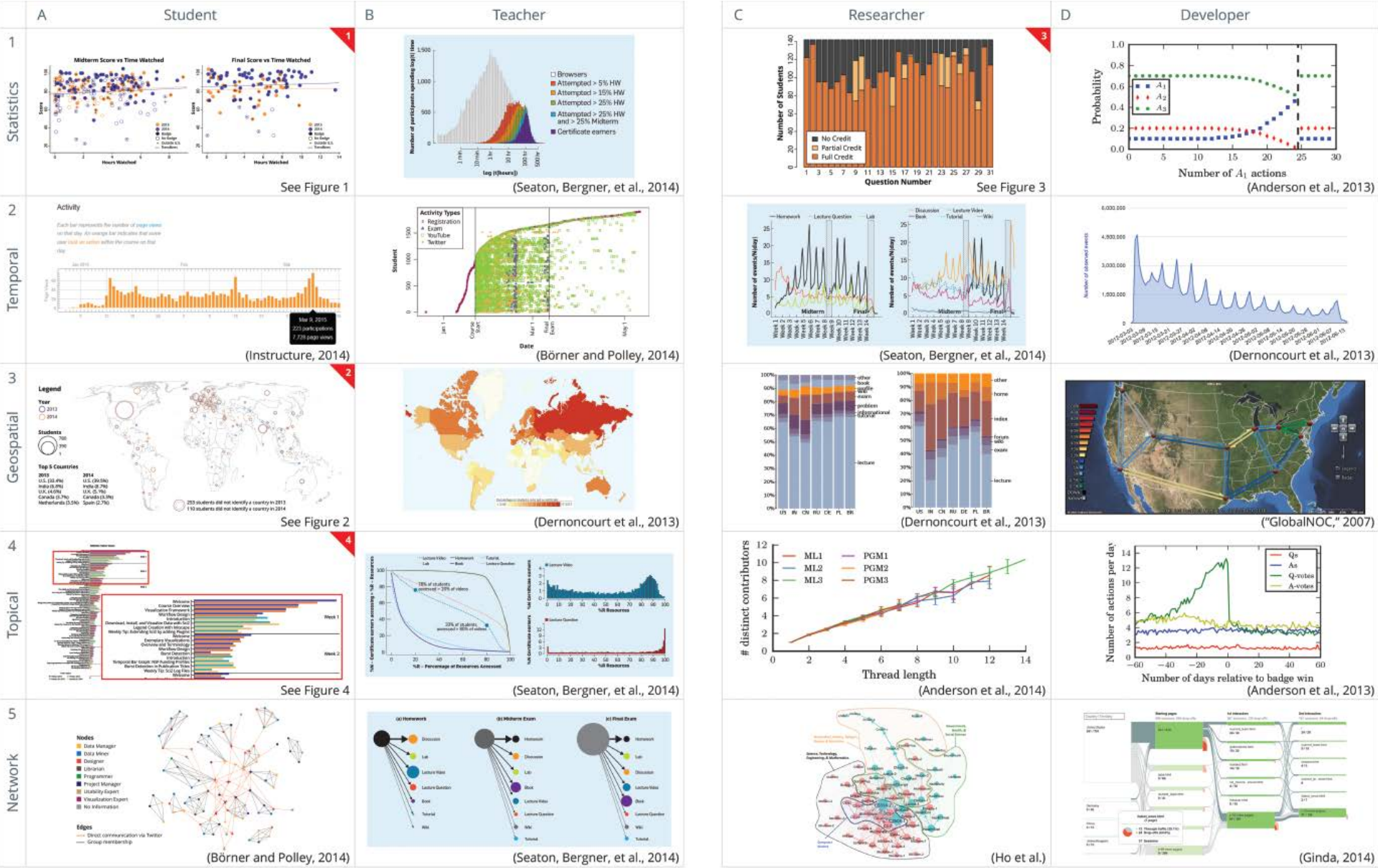


Figure 1: Analysis types vs. user needs.

Emmons, Light, and Börner. "[MOOC Visual Analytics: Empowering Teachers, Students, Researchers, and Developers of Massively Open Online Courses](#)". *Journal of the Association for Information Science and Technology* (in press).

Next Generation IVMOOC

Instructor: Victor H. Yngve Distinguished Professor Katy Börner & CNS Team, ISE, SICE, IUB

Duration: 6 weeks x 5 hours = 30 hours (3 CEUs)

Format: Online | Theory and Hands-on Instruction, Concept Questions, Graded Assignments, Case Studies, Discussions

Start: Sept 15, 2018

Covers:

Temporal, geospatial, topical (linguistic), network analyses and 60+ visualization types

Tools: Tableau, Gephi, BI,

Industry case studies such as

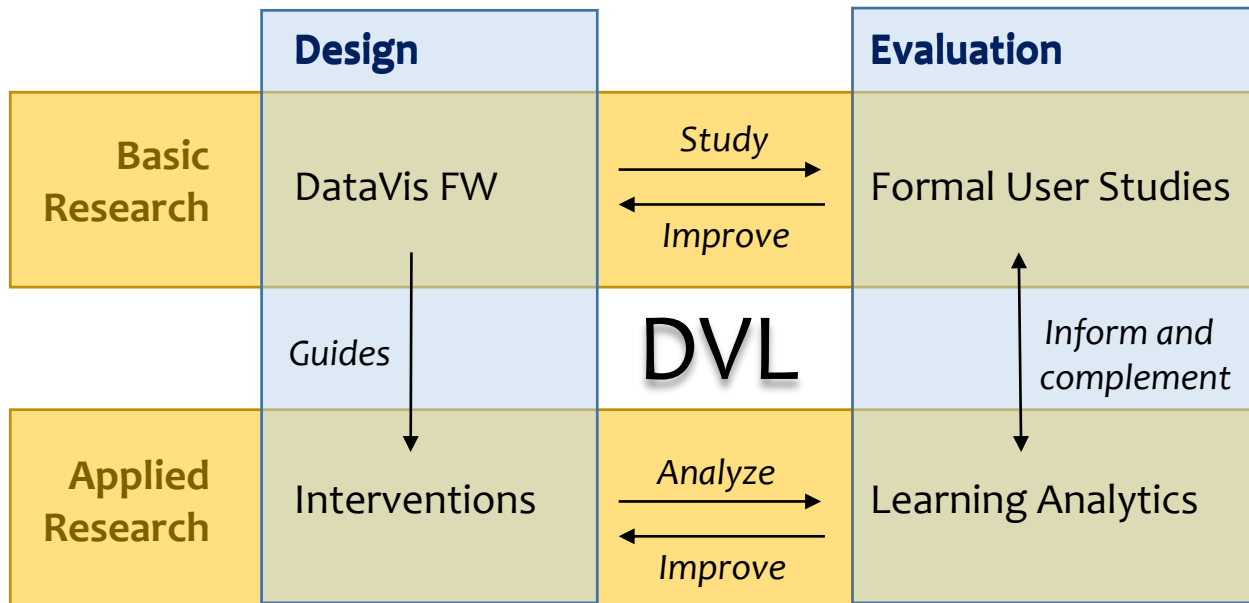
- Acting on customer complaints data.
- Improving communication/traffic flows.
- Understanding web page usage.
- Visualizing online shopping behavior.
- Optimizing supply chains.
- Reducing customer/supplier churn.
- Monitoring emerging R&D areas.
- Workforce development planning.

The screenshot displays the IVC MOOC website. At the top, the CNS logo is visible. The main heading is "IVC MOOC Data Visualization Essentials". Below this, there are two short stories: "Here's the story of a lovely lady. Who was bringing up three very lovely girls. All of them had hair of gold. Like their mother. The youngest one in suits." and "Here's the story of a man named Brady. Who was busy as three boys of his own. They were four men, living all together, yet they were all alone." A "Register" button is present. The main content area features a grid of six thumbnails, each titled "Visualizing Framework & Workflow Design" and labeled "Week 1" through "Week 6". These thumbnails show various data visualizations: a circular sunburst chart, a network graph, a map with red circles, a world map with black dots, a network graph with a legend, and a complex network graph. Below the grid is a "Course Books" section with four book covers: "Visual Insights", "Atlas of Knowledge", "Atlas of Knowledge", and "Atlas of Science". Each book has an "Order" button. The footer contains the text "© 2018 CNS Center of Informatics Systems" and "Privacy | Terms of Service".

Next Generation IVMOOC

Systematic study of how different student cohorts learn best—using Mechanical Turk formal user studies and extensive learning analytics.

Optimization of **Data Visualization Framework** and **Learning Modules**.



Next Generation IVMOOC

Systematic study of how different student cohorts learn best—using **Mechanical Turk formal user studies**, e.g., to optimize horizontal transfer:

Table

Columns by rows

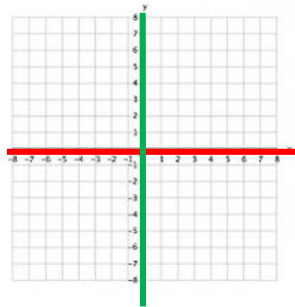
column row

<i>x</i>	<i>y</i>
0	3
2	11
4	19
6	27
8	35

cell

Graph

x-y coordinates
linear/log scale



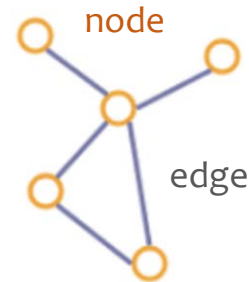
Map

Latitude/
longitude



Network

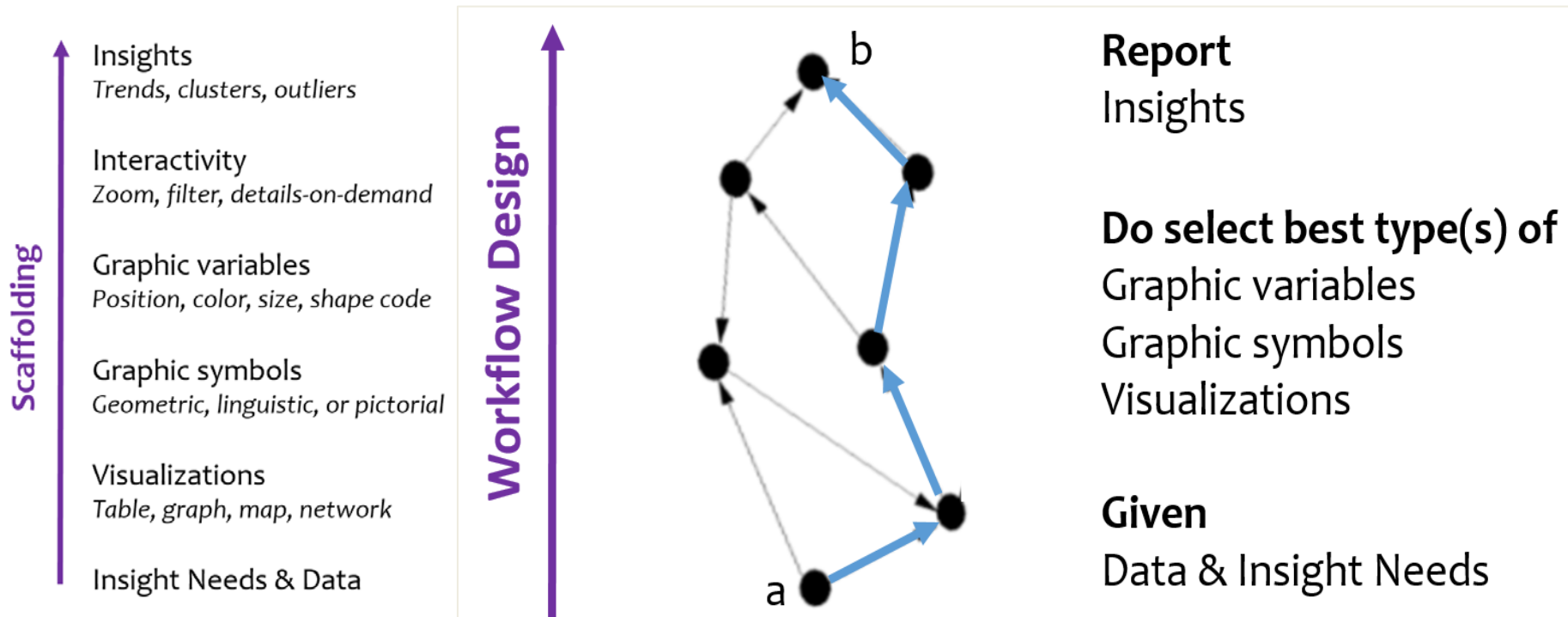
Local
similarity



Horizontal Transfer

Next Generation IVMOOC

Systematic study of how different student cohorts learn best—using **Learning Analytics** to optimize scaffolding and learning trajectories:



MIT xPRO: Systems Engineering



FULL SCREEN

Four new courses, which will be delivered by MIT Professional Education via the edX platform, will marry the research and knowledge of MIT's world-renowned faculty with lessons and case studies in industry and government from Boeing and NASA professionals.



MIT, Boeing, NASA, and edX to launch online architecture and systems engineering program

Four-course program will train professionals in latest practices on models and methods to manage complex systems

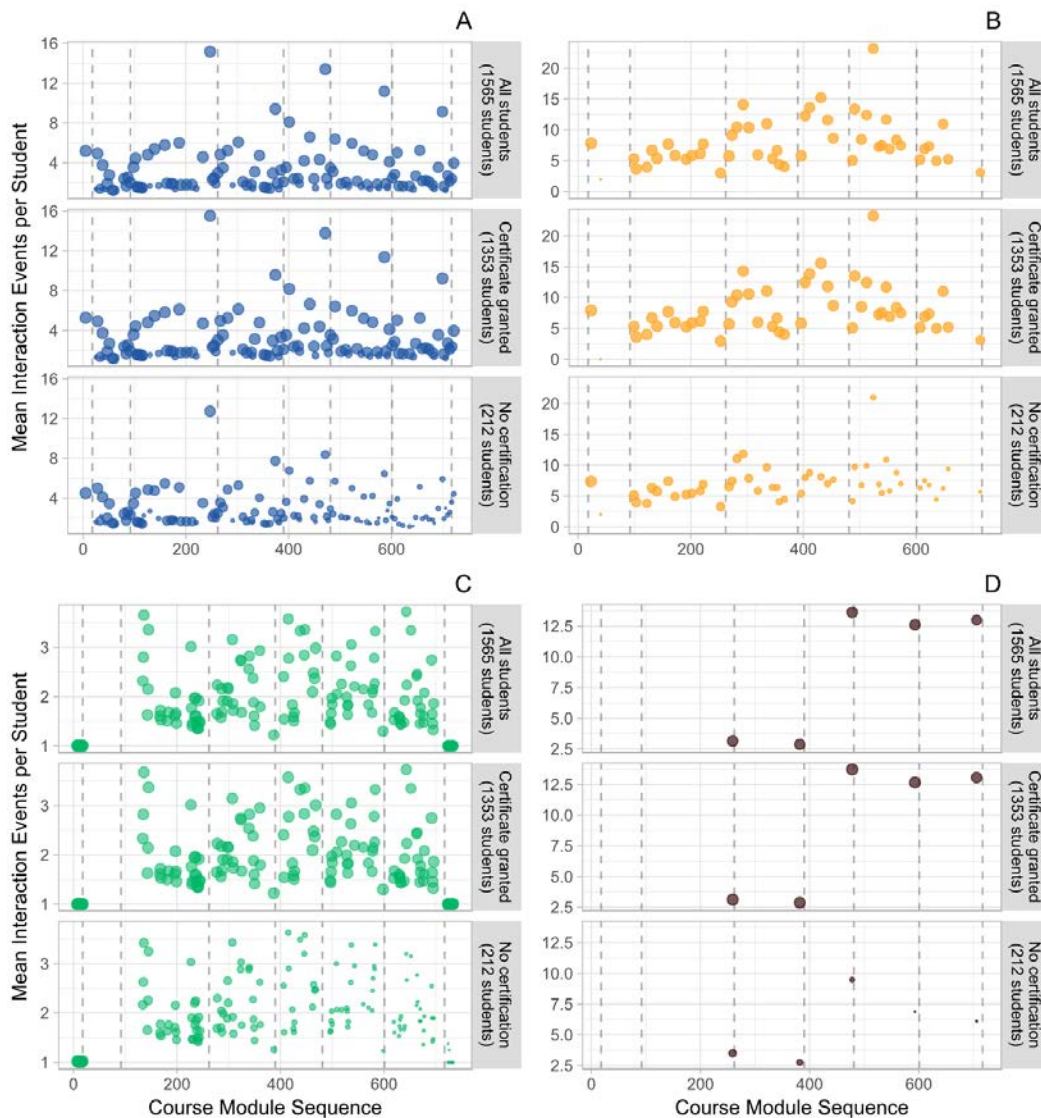
<https://sysengonline.mit.edu>

Improving Return on Investment in Education: Measuring, Visualizing, and Optimizing Learner Trajectories

Michael C. Richey, Michael Ginda, Mark Cousino, Katy Börner

MIT xPRO Course
“Architecture of Complex Systems” delivered via the edX platform in Fall 2016.
1,611 Boeing engineers registered; 1,565 were active and generated nearly **31 million click event records** while accessing videos, projects, and assessments. Some students generated over 100,000 separate events.

All but 255 engineers passed the course, resulting in a completion rate of 84.1%.



Improving Return on Investment in Education: Measuring, Visualizing, and Optimizing Learner Trajectories

Michael C. Richey, Michael Ginda, Mark Cousino, Katy Börner

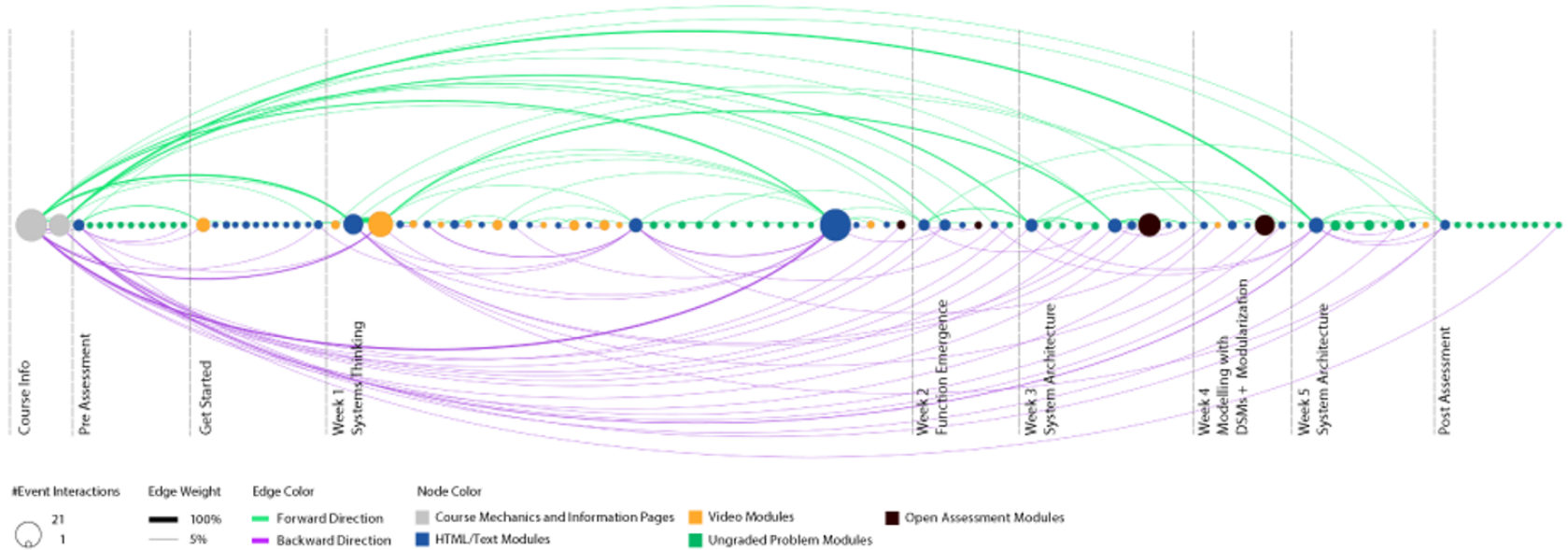


Figure 1: Learner path overlaid on linear sequence of course modules. Linear, temporal sequence of learning modules accessed by a high performing student plotted from left (first) to right (last) with dividing lines for pre and post but also week 1-5 modules.

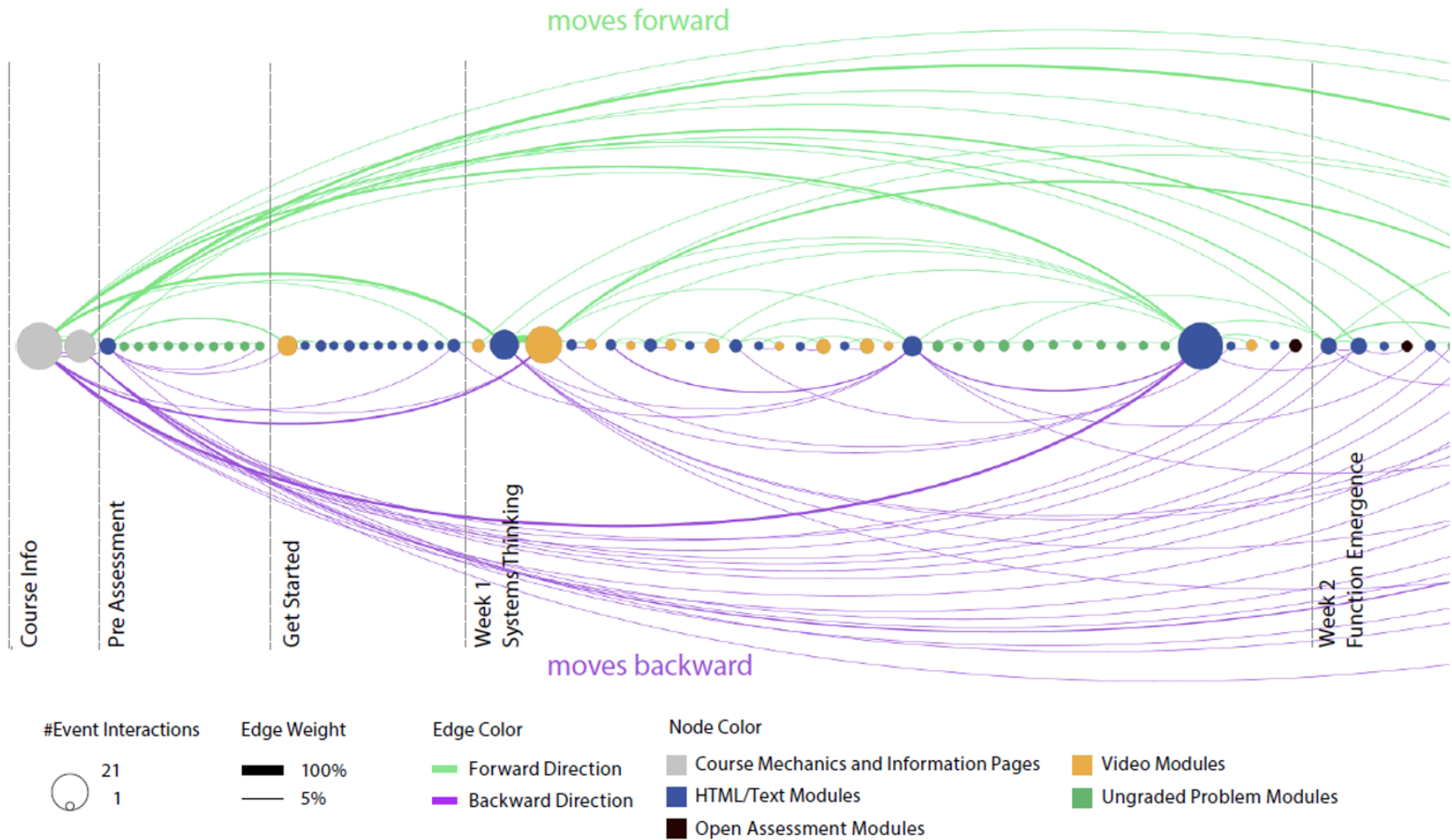
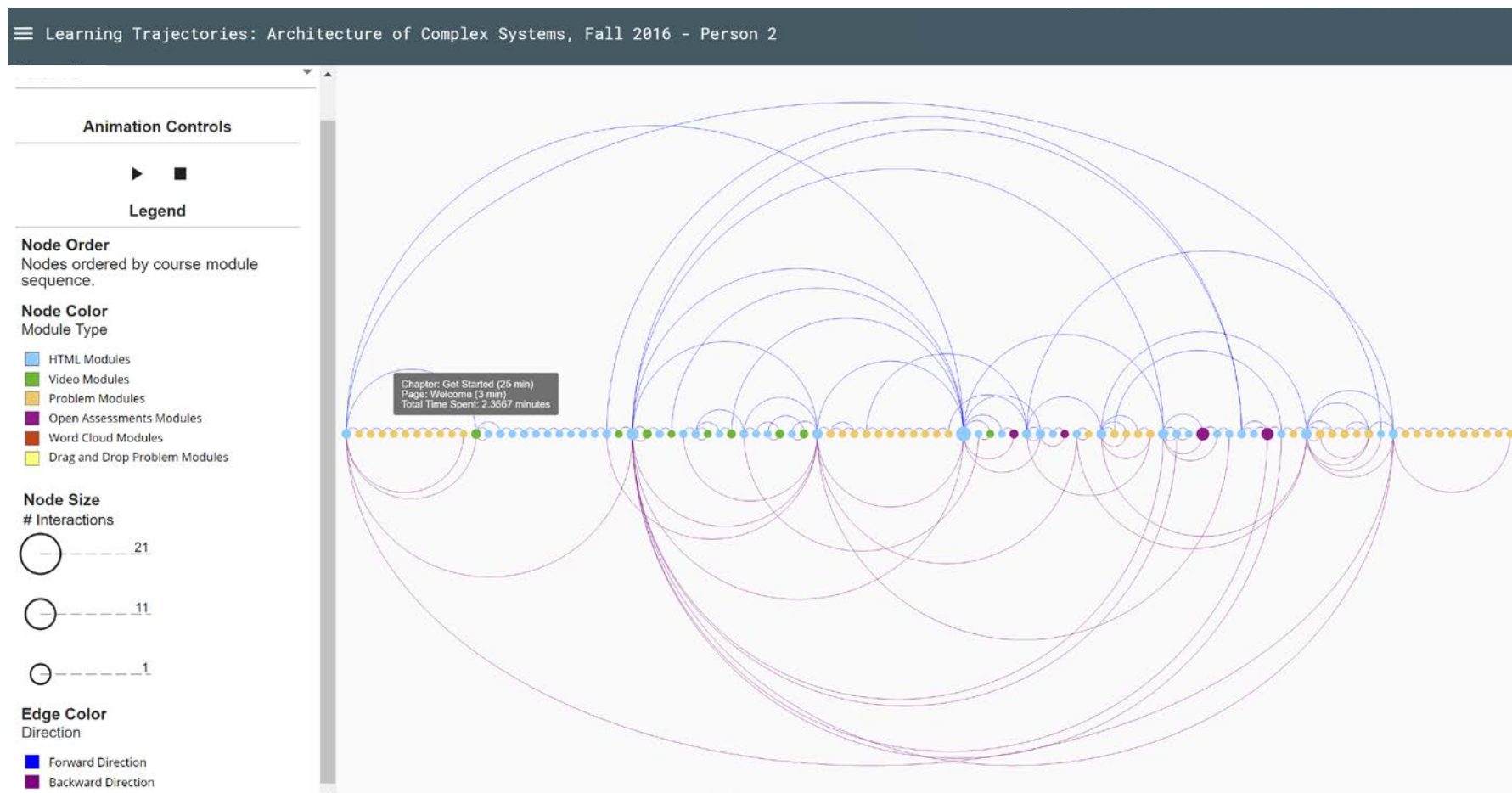


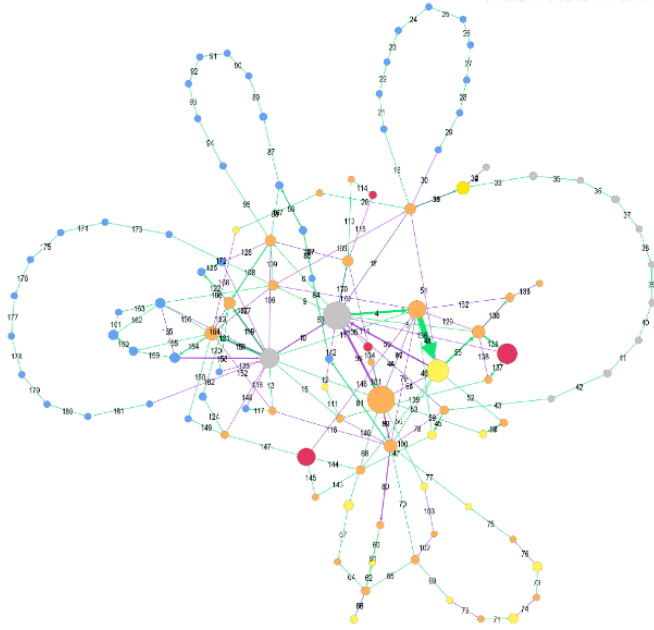
Figure 2. Zoom into learner path overlaid on linear sequence of course modules. Linear, temporal sequence of course modules used by a high performing student; plotted from left (first) to right (last) with dividing lines for different module sections.

Improving Return on Investment in Education: Measuring, Visualizing, and Optimizing Learner Trajectories

Michael C. Richey, Michael Ginda, Mark Cousino, Katy Börner



A



#Event Interactions

Student A Student B

21 77

1 1

Edge Weight

100%

5%

Edge Color

Forward Direction

Backward Direction

Node Color

Course Mechanics and Information Pages

HTML/Text Modules

Video Modules

Ungraded Problem Modules

Open Assessment Modules

B

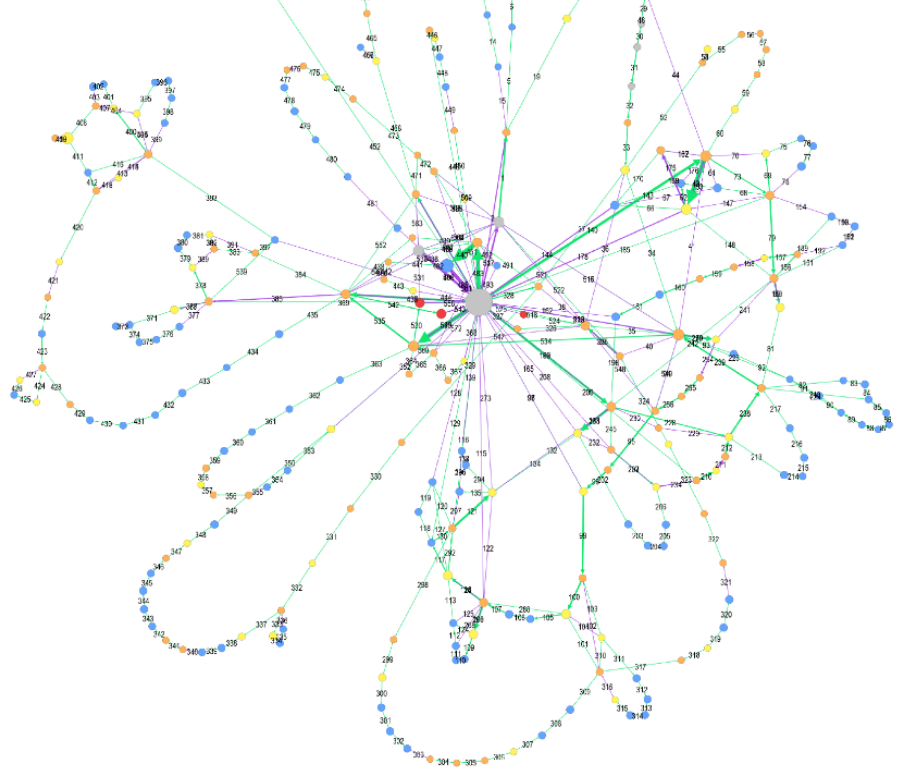


Figure 3: Learner path overlaid on force-directed layout of used course modules. Learner path of a students with high (left) and low (right) performance scores overlaid on force-directed layout of course modules.

MIT xPRO: Additive Manufacturing



HOME

ENTERPRISE



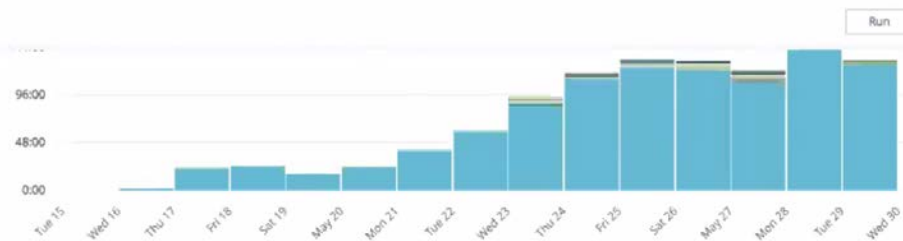
Additive Manufacturing for Innovative Design and Production

*A 9-week online course on creating new products,
processes, and business models using 3D printing.*

<https://additivemanufacturing.mit.edu>

Students use Onshape to practice what they learned

The screenshot shows the Onshape web interface. At the top, there are navigation tabs for 'Activity', 'Documents', and 'Analytics'. A search bar labeled 'Search in My Onshape' is present. On the right, there are buttons for 'App Store', 'Learning Center', and a user profile for 'Katy Borner'. Below the navigation, there is a 'Create' button and a 'My Onshape' section. The main area displays a list of documents under the heading 'Last opened by me'. Two documents are visible: 'Optimized B-0128-g' and 'Bracket Optimization', each with a 3D model thumbnail. Below this is a table with columns for 'Name', 'Workspace', and 'Modified ...'. The table lists three folders: '[SUBMISSION] Graded Assignme...', '[SUBMISSION] Design Track I: To...', and 'Week 7-8 - Strategy Track'. On the left sidebar, there are options for 'Recently opened', 'Created by me', 'Shared with me', 'Teams', and 'Trash'. On the right, there is a 'Share' button and a 'My Onshape' panel with a close button and the text 'Select a document, folder or project to view its details'.



Students use Onshape to practice what they learned

The image displays two overlapping screenshots of the Onshape web interface. The top screenshot shows the 'Documents' view for a user named 'Katy Borner'. It features a navigation bar with 'Onshape', 'Activity', 'Documents', and 'Analytics'. A search bar is present with the text 'Search in My Onshape'. Below the navigation, there is a 'Create' button and a 'My Onshape' section showing a list of documents, including 'Optimized B-0128-g' and 'Bracket Optimization'. A sidebar on the left lists navigation options: 'My Onshape', 'Recently opened', 'Created by me', 'Shared with me', 'Teams', and 'Trash'. A floating window on the right prompts the user to 'Select a document, folder or project to view its details'.

The bottom screenshot shows the 'Analytics' view, specifically the 'Document Access' section. The breadcrumb trail is 'Analytics > Documents > Document Access'. The page title is 'Document Access' with a 'just now' timestamp and a settings icon. Below the title, there are filters: 'FILTERS Usage count is any value Permission source is not "Company"', and a 'Run' button. The main content area is titled 'Document network with modeling time' and contains a complex network graph. The graph consists of numerous nodes and connecting lines. A legend on the right side of the graph identifies the nodes: blue circles for 'Document', green circles for 'User', red circles for 'Project', red dashed circles for 'Collapsed Project', blue lines for 'Document-User', and grey dashed lines for 'Not accessed'. The graph shows a dense network of connections between users and documents, with some nodes highlighted in red, indicating collapsed projects.

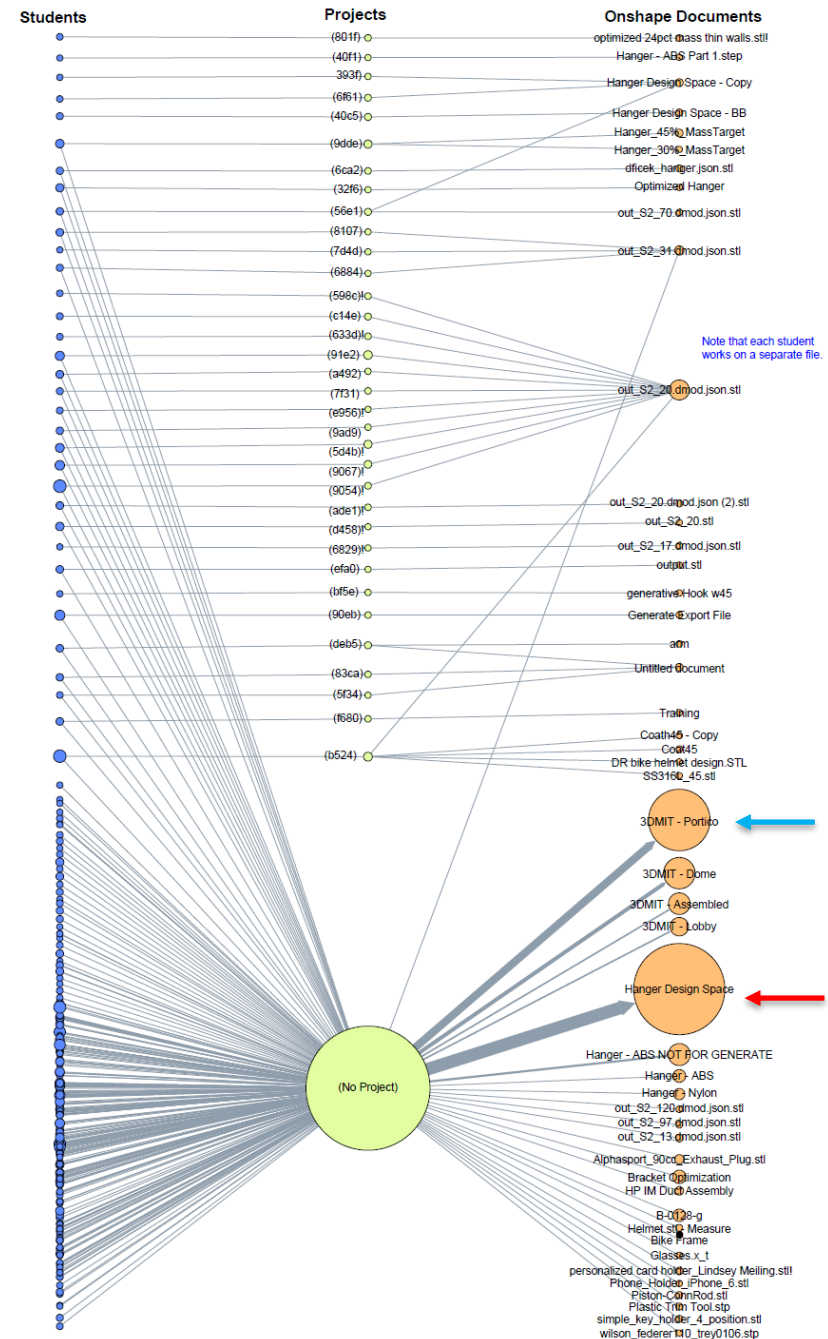
Additive Manufacturing

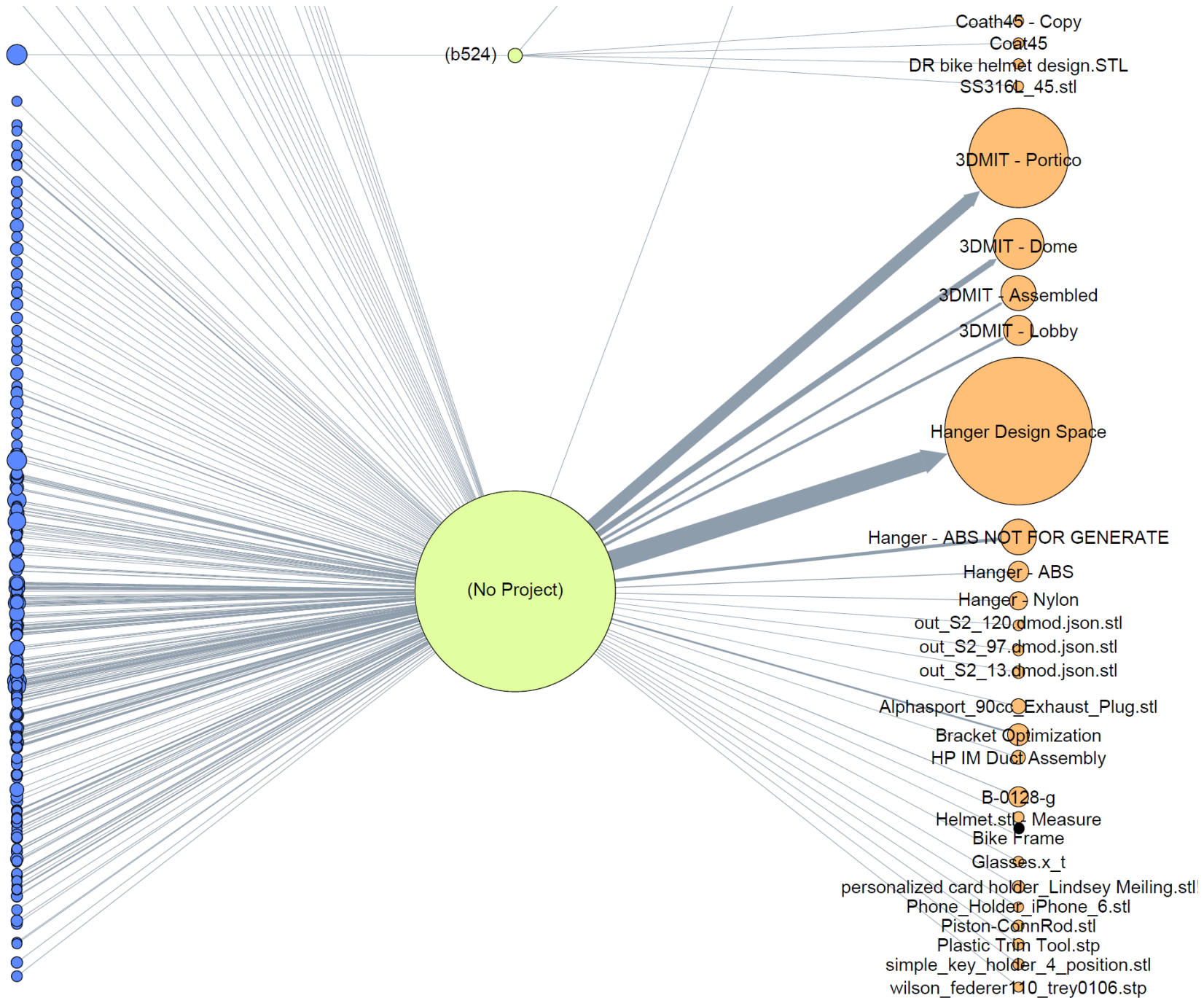
3-modal network of all Students (blue), Teams (green), Documents (orange) used in course by May 31, 2018.

Area size represents the total time associated with a given node in the modeling software.

- Top Student - 16.91 hours
- (b524) Project - 7.74 hours
- *Hanger Design Space* Document - 367.28 hours

Edge thickness denotes number of times an relationship occurred in the data.







Embracing Human and Machine Intelligence Symbiosis

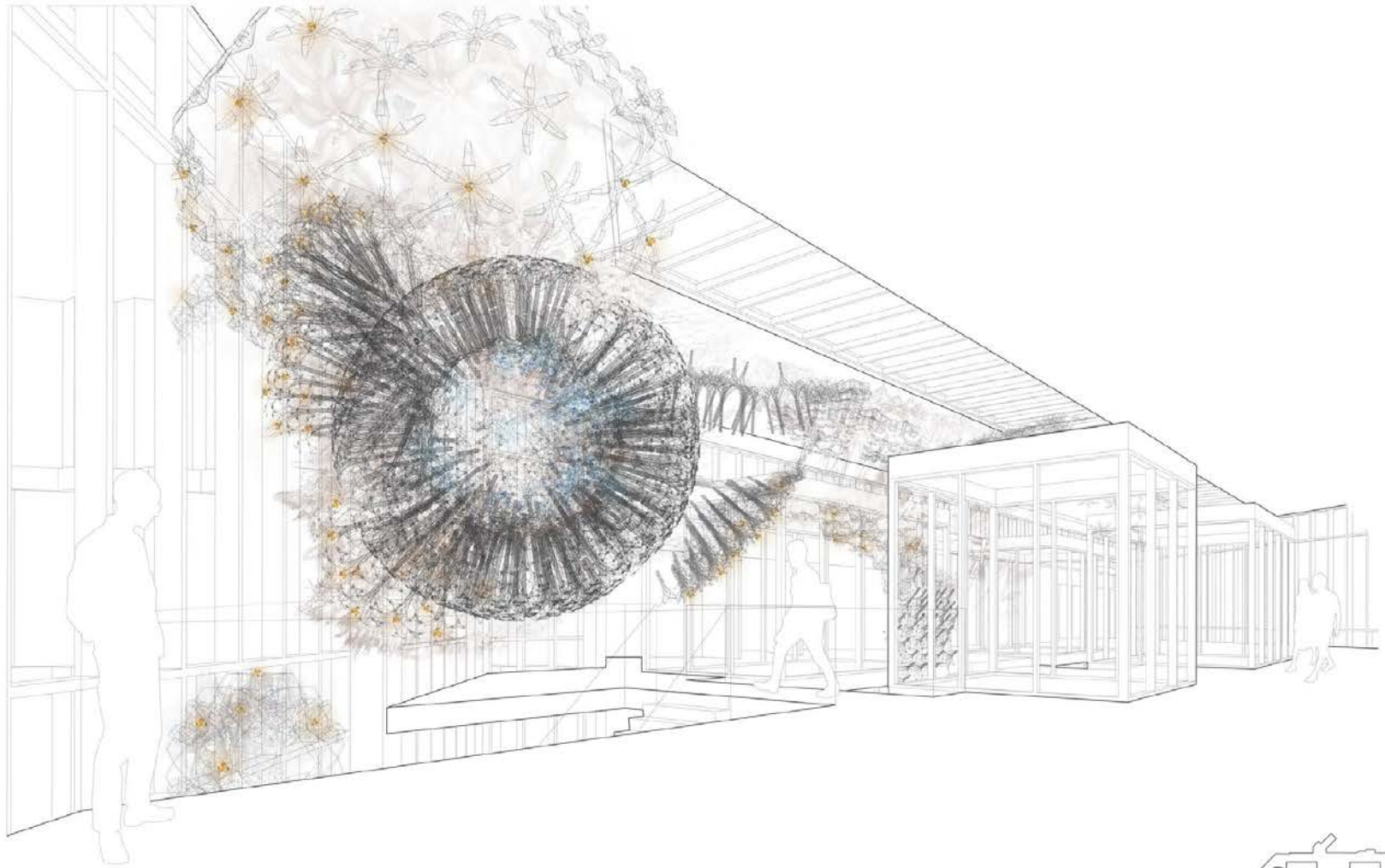
Visualizing the Internet of Things (IoT)

Using large scale datasets, advanced data mining and visualization techniques, and substantial computing resources.



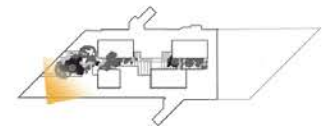
Work by Philip Beesley | www.philipbeesley.ca | www.lasg.ca



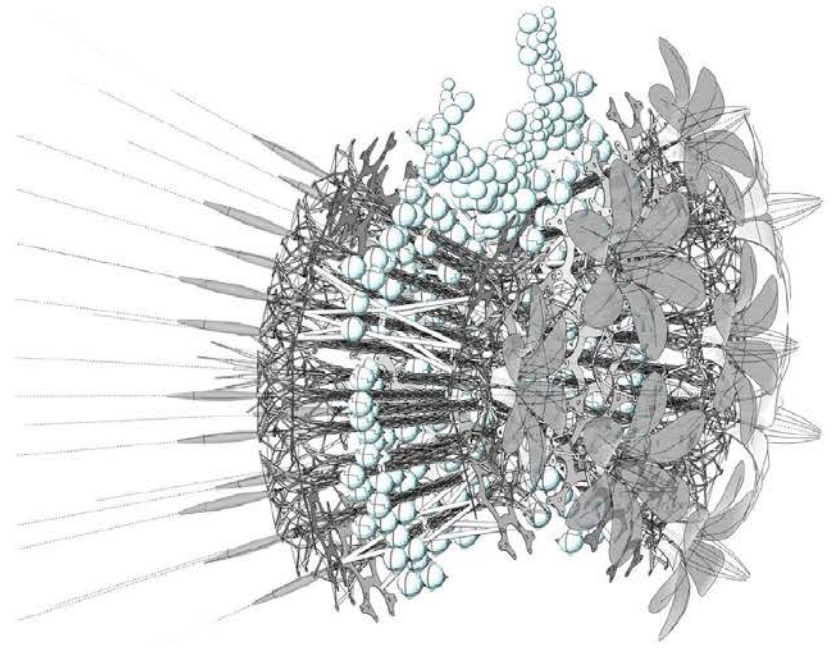
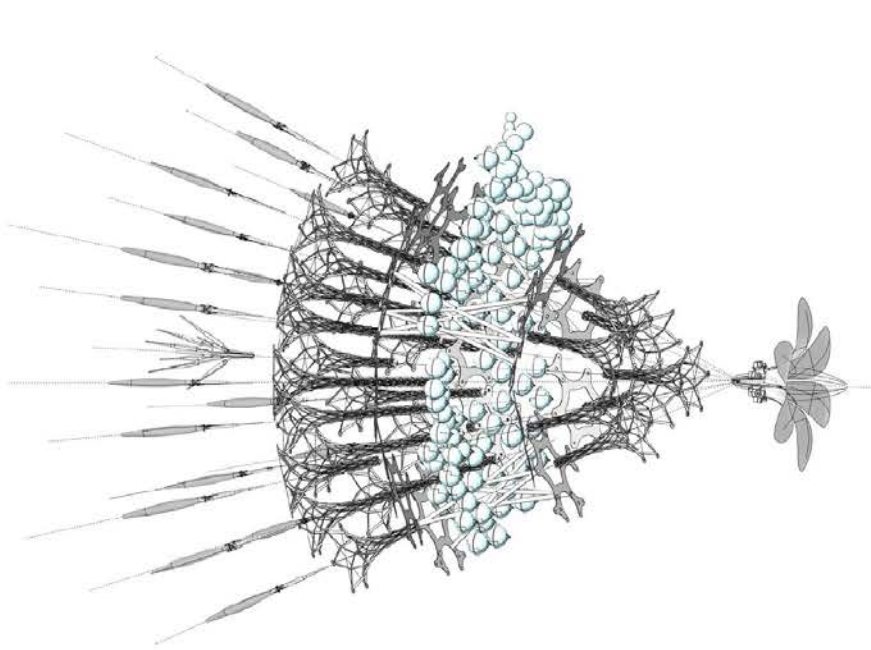


Luddy Hall Installation
Indiana University Bloomington
April 29 2017

UPPER ATRIUM



Philip Beesley • Living Architecture Systems



Luddy Hall Installation
Indiana University Bloomington
April 29 2017

ASSEMBLY SAMPLE

Philip Beesley • Living Architecture Systems





Amatria Unveiled by Andreas Bueckle et al. Data visualizations of sensor/actuator positions and types, energy and communication flows, and emergent behavior of smart environments.

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

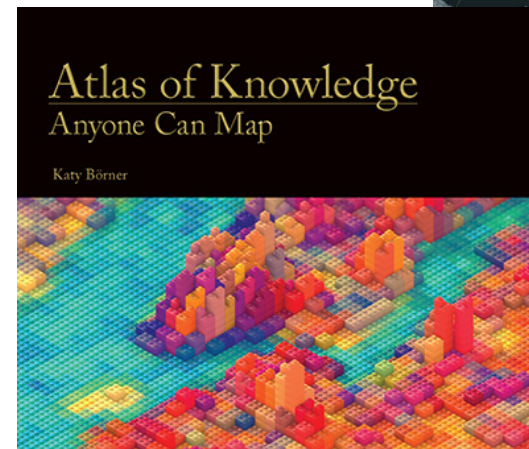
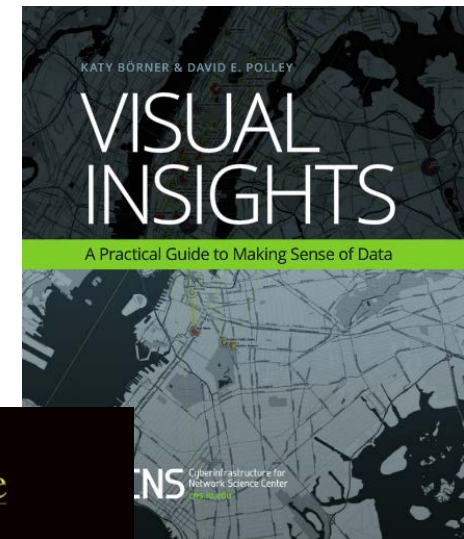
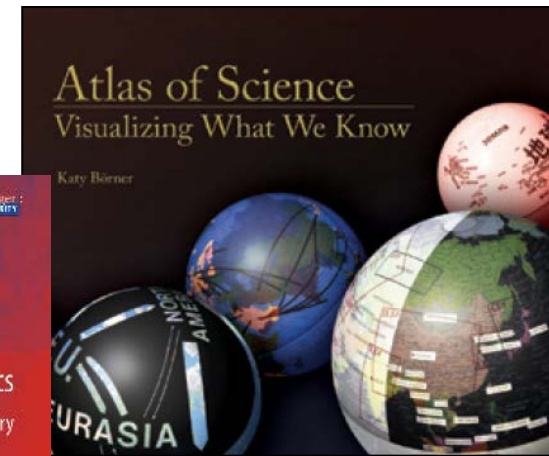
Börner, Katy (2010) **Atlas of Science: Visualizing What We Know**. The MIT Press.

<http://scimaps.org/atlas>

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

Katy Börner 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>






We work closely with clients to provide custom-made data, visualization, and software solutions

▶ Research

 Open Data and Open Code for Big Science of Science Studies


▶ Latest News

 Put your money where your citations are: a proposal for a new funding system (website accessed 9/05/13)

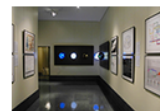
▶ Upcoming Events

- OCT 1** Katy Börner attends PIUG 2013 Northeast Conference
- 10.13** Katy Börner presents Mapping Science Exhibit at WSSF
- 10.15** Ted Polley & Google Team present IVMOOC at EDUCAUSE
- 10.22** Katy Börner presents at the SciELO 15 Years Conference


▶ Development

 Behind the scenes of the design and development of *AcademyScope*


▶ Outreach

 See some of the most fascinating data visualizations in the world.


▶ Videos

 Watch Katy Börner's full presentation from TEDxBloomington

▶ Teaching

 Successful IVMOOC will be offered again in January of 2014

▶ Our Products

 We work closely with clients to provide custom-made data, visualization, and software solutions

All papers, maps, tools, talks, press are linked from <http://cns.iu.edu>

These slides are at <http://cns.iu.edu/presentations.html>

CNS Facebook: <http://www.facebook.com/cnscenter>

Mapping Science Exhibit Facebook: <http://www.facebook.com/mappingscience>