Higher Education and the S&T Job Market

Katy Börner

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

NAS Sackler Colloquium on Modeling and Visualizing Science and Technology Developments
Arnold and Mabel Beckman Center, Irvine, California

December 4, 2017

Science & Technology vs. Education/Training vs. Jobs
Katy Börner, Olga B. Scrivner, Xiaozhong Liu, Indiana University

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 B. Scrivner, Xiaozhong Liu, Indiana University

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 B. Scrivner, Xiaozhong Liu, Indiana University

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 B. Scrivner, Xiaozhong Liu, Indiana University

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 B. Scrivner, Xiaozhong Liu, Indiana University

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?
Enter a Job, Get Course Recommendations

The system represents information on jobs, courses, companies, etc. via a heterogeneous knowledge graph with 395,030 nodes and 993,526 edges. Students pick a dream job; then text and graph-based algorithms recommend optimized education opportunities, i.e., courses that maximize time, money, and/or learning.

Network Graph

- Jobs: 8350
- University courses: 716
- MOOCs: 750
- Locations: 954
- Companies: 1774
- Company specialties: 6924

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).
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.
US STEM: Academic Career Pathways
Michael Ginda, Adam Maltese & Katy Börner, Indiana University

Measure and visualize how students enter, exit and persist in pathways toward STEM degrees and careers. Uses data on students and the workforce by the National Center for Education Statistics and the National Center for Science and Engineering Statistics. Funded by NSF NCSE-1538763. Interactive web site: http://demo.cns.iu.edu/webvis/stem
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 Google Course Builder (GCB)
- 674 remarks on 215 different forum threads in Drupal
- 64 students submitted projects via Drupal
IVMOOC Student Registration and Activity
Michael Ginda & Katy Börner, Indiana University

Jan. 22: Course Starts
March 11: Final Exam Deadline
IVMOOC Student Client Projects: All Interactions
Michael Ginda & Katy Börner, Indiana University
IVMOOC Student Engagement and Performance
Michael Ginda & Katy Börner, Indiana University

### Learning Analytics

#### IVMOOC 2015 Student Group Engagement and Scores

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

#### IVMOOC 2015 Student Group Engagement for Midterm

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

**Legends**

- **Engagement**
  - Inactive
  - Active
  - Very Active

- **Score**
  - F: 0% - 25%
  - D: 26% - 50%
  - C: 51% - 75%
  - B: 76% - 100%

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.

## Analysis and Visualization Types vs. User Need Types

<table>
<thead>
<tr>
<th>A</th>
<th>Student</th>
<th>B</th>
<th>Teacher</th>
<th>C</th>
<th>Researcher</th>
<th>D</th>
<th>Developer</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Statistics</strong></td>
<td><img src="#" alt="Statistics" /></td>
<td><img src="#" alt="Statistics" /></td>
<td><img src="#" alt="Statistics" /></td>
<td><img src="#" alt="Statistics" /></td>
<td><img src="#" alt="Statistics" /></td>
<td><img src="#" alt="Statistics" /></td>
<td></td>
</tr>
<tr>
<td><strong>Temporal</strong></td>
<td><img src="#" alt="Temporal" /></td>
<td><img src="#" alt="Temporal" /></td>
<td><img src="#" alt="Temporal" /></td>
<td><img src="#" alt="Temporal" /></td>
<td><img src="#" alt="Temporal" /></td>
<td><img src="#" alt="Temporal" /></td>
<td></td>
</tr>
<tr>
<td><strong>Geospatial</strong></td>
<td><img src="#" alt="Geospatial" /></td>
<td><img src="#" alt="Geospatial" /></td>
<td><img src="#" alt="Geospatial" /></td>
<td><img src="#" alt="Geospatial" /></td>
<td><img src="#" alt="Geospatial" /></td>
<td><img src="#" alt="Geospatial" /></td>
<td></td>
</tr>
<tr>
<td><strong>Topical</strong></td>
<td><img src="#" alt="Topical" /></td>
<td><img src="#" alt="Topical" /></td>
<td><img src="#" alt="Topical" /></td>
<td><img src="#" alt="Topical" /></td>
<td><img src="#" alt="Topical" /></td>
<td><img src="#" alt="Topical" /></td>
<td></td>
</tr>
<tr>
<td><strong>Network</strong></td>
<td><img src="#" alt="Network" /></td>
<td><img src="#" alt="Network" /></td>
<td><img src="#" alt="Network" /></td>
<td><img src="#" alt="Network" /></td>
<td><img src="#" alt="Network" /></td>
<td><img src="#" alt="Network" /></td>
<td></td>
</tr>
</tbody>
</table>

See Figure 1  
(Seaton, Bergner, et al., 2014)  
See Figure 3  
(Anderson et al., 2013)

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