How can System Dynamics Guide Our Thinking About Education

Ralph Brauer
John Heinbokel
Jeffrey Potash
Larry Weathers

Systems Thinking and Dynamic Modeling Conference
Wellesley MA, June 2010
The Problem: US STEM labor force is falling behind in producing a highly skilled workforce for adequately addressing global problems

A look at 2 of 5 models which attempt to explore and give insights into relevant factors

Raytheon
Boeing
### Five Models on STEM and US policy

Table by Paul Newton et al, *STEM Pressures from Birth to Globalization: Five Related Models*

<table>
<thead>
<tr>
<th>Model</th>
<th>Model Focus</th>
<th>Sectors Included (or Feedback Loops if so noted)</th>
<th>Policies Tested</th>
<th>Time Frame; INITIAL to FINAL time</th>
<th>Calibrated to Historical Time Series Data?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boeing</td>
<td>Represent the dynamic relationship between scientific/engineering enterprise and prosperity from the NAS report, &quot;Raising Above the Gathering Storm.&quot;</td>
<td>US Prosperity &amp; Science-Engineering Enterprise Reinforcing Feedback Loop</td>
<td>Increase fraction of national prosperity invested in STEM education</td>
<td>1850-2000</td>
<td>To anecdotal historical tendencies</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US Overseas Investment</td>
<td>Increase fraction of national prosperity invested in R&amp;D</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Overseas Prosperity &amp; Science-Engineering Enterprise Reinforcing Feedback Loop</td>
<td>Encourage STEM immigration</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Relative Attractiveness of US to foreign-born scientists, engineers &amp; students</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MIT</td>
<td>Cause of the nearly twenty-five year decline in the percentage of U.S. born undergraduates earning degrees in engineering.</td>
<td>STEM Labor Supply/Demand Feedback Loop</td>
<td>Various teacher wage increases to increase teacher quality</td>
<td>1940-2040</td>
<td>To historical tendencies</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Availability of Jobs Feedback Loop</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Teaching Quality Feedback Loop</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raytheon</td>
<td>Can STEM college graduates be doubled by 2015?</td>
<td>K-12 STEM Interest &amp; Not</td>
<td>Training, mentoring, layoff or denying tenure to the local eligible teachers after 3 years</td>
<td>2003-2025</td>
<td>Not yet, but planned (Wells et al., 2008b, p14.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Teacher College STEM</td>
<td>Changing STEM Teacher Salary and Compensation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Industry College STEM</td>
<td>Changing the class size</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Teacher Workforce STEM &amp; Not</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Industry STEM Workforce</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>STEM Labor Supply/Demand Feedback Loop</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>U.S. Reputation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sandia</td>
<td>Attractiveness of STEM Centers</td>
<td>K-12 with degree of STEM literacy</td>
<td>Lift H-1B Visa Cap</td>
<td>1993-2003</td>
<td>To historical tendencies</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Undergraduate &amp; Grad School</td>
<td>Boost K-12 STEM literacy</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Workers Entry Level (EL)</td>
<td>Curtail firing of jobs</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Workers Higher Level (HL)</td>
<td>Maintain STEM worker training</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Exported Workers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jobs EL Domestic &amp; Offshored</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jobs HL Domestic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Continuing Education, EL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Labor Adequacy EL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Labor Adequacy HL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>STEM Attractiveness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SimBios NIH</td>
<td>Concern about aging demographics of Principal Investigator (PI) Pool</td>
<td>An aging chain of Principal Investigators</td>
<td>Adding various numbers of new young PIs to the PI Pool</td>
<td>1980-2020</td>
<td>To historical demographic age distributions</td>
</tr>
</tbody>
</table>
Table by Paul Newton et al, STEM Pressures from Birth to Globalization: Five Related Models

Figure 4: Sectors and model areas of focus
Launching a New Policy Tool in STEM Education

July 8, 2009
The Newseum
Washington, D.C.
View/Download/Use the Raytheon Model

- [www.STEMnetwork.org](http://www.STEMnetwork.org)
- [www.forio.com/simulate](http://www.forio.com/simulate)

  keyword: education

  scroll to U.S. Education Model
Business-Higher Education Forum

- **Mission**
  - Enhance U.S. competitiveness by advancing innovative solutions to our nation’s education challenges

- **STEM Initiative**
  - Goal: Double the number of U.S. STEM grads by 2015
  - Approach: STEM Education & Modeling Project
  - Strategy: Develop more powerful and innovative tools
The STEM Challenge

- Twenty-three percent of high school seniors are proficient in math; 18 percent in science
- Less than 6 percent of high school graduates will earn a STEM degree

Source: NCES Digest of Education Statistics; Science & Engineering Indicators 2008

Courtesy of the Bill & Melinda Gates Foundation
Simplified Representation of the Student Flow Model

Many factors affect the flow

Model Helps us Think About What Happens When Factors Change
Overview of the Initial Model

Not STEM Interested

STEM Interested

College

STEM Teachers

Born

Retire

Time

STEM Industry
Results of Raytheon Model Runs

Teacher capabilities and student achievement
  – Keeping the best teachers and increasing attrition of the less capable can have a dramatic effect

Changes in class size – its impact on teachers and students

Gender differences in STEM interest
  – Women are more proficient than interested, men are more interested than proficient
    • Each must be considered using different methods

Retention of STEM students in college
  College provides the highest leverage point
Applying the Tool to Current Policy Priorities

- President Obama’s STEM education priorities
- Race to the Top
- Innovation Fund
- Teacher Incentive Fund
- College Access and Completion Fund
Analyzing Current Policy Issues

- Teacher Recruitment
  - How many STEM undergraduates do we need to recruit into teaching in order to raise student achievement?

- Teacher Pay
  - What impact would increasing teacher pay have?

- Student Enrollment Incentives
  - What incentives will encourage STEM-capable high school graduates to enroll in college?

- STEM Undergraduate Persistence
  - How can the STEM undergraduate experience be changed to improve persistence?
Boeing/Sandia Model

SANDIA REPORT

Science, Technology, Engineering, and Mathematics (STEM) Career Attractiveness System Dynamics Modeling
Andjelka Kelic and Aldo Zagonel

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy’s National Nuclear Security Administration under Contract DE-AC04-94AL85000. Approved for public release; further dissemination unlimited.
Figure 16: Offshoring causal diagram
K-12 Education

K12: Desired aggregate literacy
K12: Targeted STEM literacy
K12: STEM resource adequacy
K12: Entering 1st grade
K12: Graduating from HS
K12: Initial number of students
K12: Length of program
K12: STEM budget scenario
K12: STEM $$ per student per year
K12: STEM $$ per student per year
K12: Number of graduates considering STEM degrees
K12: Fraction of graduates interested in STEM degrees
K12: Effect of literacy on interest in STEM careers
K12: Effect of literacy on interest in STEM careers
K12: Normal fraction of graduates interested in STEM degrees
K12: Effect of resource adequacy on targeted STEM literacy
K12: Avg STEM literacy at entry
K12: Avg STEM literacy at exit
K12: STEM literacy entering
K12: STEM literacy exiting
K12: STEM literacy at exit
K12: Smooth time
K12: Literacy change due to resource adequacy
K12: Avg STEM literacy at entry

STEM literacy

- 2,000 $/person
- 1,000 $/person/year
- 500 $/person/year
- 0 $/person
- 0 $/person/year

Time (Year)


K12: This
Quasi – meta analysis of 2 models

- Importation/off-shoring of skilled labor = symptom of inadequate labor force
- Boosting STEM literacy in K-12 boosts college STEM choice (STEM literate teachers)
- Improving the quality as opposed to the quantity of K-12 STEM teachers increases numbers of students choosing STEM majors in college
- Enhancing continual professional development of domestic skilled labor boosts attractiveness
- Improving job security and promotion opportunities affects recruitment of graduates into STEM careers
- Attractiveness of STEM careers is equally as important as having high numbers of student graduates in STEM fields in order to maintain a highly skilled STEM workforce
Resources

- http://stemnetwork.org/
- http://grants1.nih.gov/grants/new_investigators/NIH_Aging_Model_Valdiation_4_June_08.ppt
- STEM Pressures from Birth to Globalization: Five Related Models (Google)