

Building the Innovation Economy? The Challenges of Defining, Creating and Maintaining the STEM Workforce



Understanding Change in Science & Engineering:

A Workshop

July 12 & 13, 2013

Sponsored By:



**ALFRED P. SLOAN
FOUNDATION**



With Assistance From:



For several years, policymakers in Washington, academic and other experts, and industry leaders have emphasized the importance of the so-called “STEM” fields—science, technology, engineering and math—for economic growth, national competitiveness and security, and job creation. Yet we still know little about how this crucial sector of the economy works, and in particular, why industry demands ever more foreign workers even as many US workers are leaving this vibrant sector, and how US workers keep their skill sets current in the face of continual change. Most broadly, we need to understand what STEM actually means. It is a term that is used widely, and even forms the basis of legislation, yet it resists a clear definition.

These are some major conclusions from a workshop held at the University of California-San Diego on July 12 and 13, 2013. The workshop, sponsored by the Alfred P. Sloan Foundation and the Center for Comparative Immigration Studies, brought together academic specialists from fields as diverse as economics, education, management, public policy, and sociology to meet with industry leaders representing biotech, finance, software, telecommunications, and tech journalism, for a results-oriented and wide-ranging discussion of these important issues. (A full list of participants is at the end of this report.) Several key conclusions, as well as related readings by workshop participants, are included below.





Innovation Requires More than Agglomerating Large Numbers of STEM Workers

Nearly everyone agrees that STEM workers are crucial for innovation, and innovation is crucial because it drives the economy and keeps America strong. At the same time, it is clear that simply gathering STEM workers together, even if we continue to attract the world’s best and brightest, will not produce the innovation that the economy needs to thrive. Instead, several inter-related themes came out of the discussion on how to leverage STEM skills to produce innovation.

The Importance of Innovation Clusters

While there is no recipe for success, examining past successes as well as failures indicates that networks of players working together locally, over time, can be successful in generating innovation. While a key player or “anchor tenant” can be a key factor, innovation clusters develop best when there is no dominant, “800-pound gorilla,” such as the National Institutes of Health or Big Pharma calling the shots. At the same time, the role of the government and universities in doing basic science research is crucial, and can be a foundation upon which innovative networks flourish. Some workshop participants brought up the role of an innovation “infrastructure”; this referred to both laboratories and also the social or cultural glue that helps create ideas, companies, products, jobs and wealth.

The Importance of Interdisciplinary or Broad-View Approaches

STEM skills are important, but overspecialization—which is often encouraged by the grants and lab cultures--can adversely affect innovation. Several workshop participants agreed it is valuable to have persons who can bring insights from diverse fields to new problems. An example is an aeronautical engineer who used knowledge of jet propulsion to understand fetal hearts. Outside-the-box innovative thinking can sometimes come from non-STEM workers, and some tech- or web-oriented start-ups, such as Etsy, Kickstarter, and Makerbot, were founded by persons without STEM backgrounds--but who know how to talk to engineers.

The Value of “Failure”

Many speakers emphasized the importance of failure, though this was discussed in multiple senses. On the one hand, for social scientists, it is important to study the failure of innovation along with the successful cases of innovation in order to understand what factors are related to success. Too often, we only hear of success stories of innovation clusters, such as Silicon Valley, or innovative entrepreneurs, such as Steve Jobs or Sergey Brin, but we need to balance these with the multiple cases of failure. In another sense, innovators need to have a culture of risk-taking and a tolerance for failure—with “failure” understood simply as trials, challenges and opportunities. Innovation is often an iterative process, so an ability to learn from failure is key. The larger point here is contextual: for innovation to occur with regularity, STEM workers need to be given the opportunity to take risks, to have chances to use their skills even if there is often no payoff.

STEM Skills are Not Enough

While STEM skills are essential, they are not worth much unless workers can communicate across disciplinary divides, and in an era of high immigration and globalization, communicating across cultures is also

necessary. A scientist’s ability to network is a prized asset in many cases. The term “soft skills” is often used here, but participants saw these abilities as so essential that this name is misleading, because for many, so-called soft skills are actually harder, and another name, such as “plus skills” or even “foundational skills,” would more fairly describe them. Since “innovation is not invention,” a wide variety of skills are necessary to make transformative innovations possible.





*The Workers’
Challenge:
Matching Skills to an
Ever-Changing
Context*

Though most college students know that a STEM degree is a safe bet for a job offer, this does not mean that there are STEM jobs for everyone who wants one, or that STEM jobs promise stable, lifetime employment. There are about 15 million Americans with STEM degrees, and only 5 million of them work in STEM occupations.

At the same time, tech employers complain frequently and loudly that the current workforce is not adequate for their needs. How can we understand these persistent puzzles?

Not All Stem Labor Markets are the Same

STEM is convenient shorthand, developed decades ago by the National Science Foundation, to highlight a variety of related but disparate fields related to national competitiveness. The problem with STEM, from a workforce perspective, is that the different STEM fields have very different employment dynamics. The “E”, for engineering, represents diverse fields of practical, applied work that have very different demand dynamics than do, for example, the “S”, for science, where basic research is often driven by government funding. In short, the STEM concept may obscure as much as it reveals (more on this below).

The Boom and Bust Pattern in Demand for STEM Workers is a Problem

While the STEM acronym obscures much field-specific diversity, some workshop participants agreed that especially engineering labor markets are plagued by boom and bust cycles that present great challenges for workers. Employers may proclaim a shortage whenever they cannot find exactly what they are looking for, and students may move to these fields while at the same time the H-1B visa program admits more foreign STEM workers to fill the immediate demands. When the inevitable bust occurs, firms shed workers, who may move out of the field or remain unemployed for long periods. A new boom, typically requiring a new skill-set, creates demand for *new* migrants and newly-graduated STEM workers, as firms do not want to take the time and expense to retrain the laid-off workers from the previous cycle.



The Doctoral Program/Job Market Mismatch

A major problem identified during discussions was that doctoral programs in many STEM fields train students for jobs that do not exist. There are simply too many PhDs being produced for the very limited number of academic jobs. The dominant career paths, then, are actually non-academic, but the incentives within the graduate programs are for faculty and students to focus on research output and grant funding, which maintains the status quo. This leaves STEM graduates often cut off from institutionalized channels to help connect them to jobs in industry, forcing them to rely on informal networks that may or may not be available. It was these networks that led many mathematical scientists to move to Wall Street when science jobs could not be found. One possible solution to the mismatch, developed by the Sloan Foundation, is the Professional Science Master's programs, which simultaneously develop advanced science training and workplace skills.

The Challenge of Upgrading Skills in Advancing Tech Careers

Many speakers described the difficulties that workers face, particularly as they get older, in keeping their skill sets current. While some found the need for continual training and retraining to be exciting or stimulating, there is no doubt that the stakes are high and the pressure great. Many workers train themselves by signing up for “stretch work,” agreeing to do jobs based partly on what they know and partly on what they do not know, and then using informal networks for help when new skills are required. Some “job hop” in order to learn new skills, and for some tech employers, repeated job changes on a resume is no longer a red flag but a selling point—and may be expected. However, some STEM workers may find it increasingly difficult to job hop or find and retain employment as they age and start families, making it hard to continually master new skill sets. Moreover, some employers, particularly in start-ups, often want workers who will work long and unpredictable hours. Those able to do so are typically workers without families—in other words, younger workers. In short, a major problem is created by the combination of the nature of many STEM sectors with the normal development of the life course: while technology changes continually, requiring frequent skill upgrades, workers who are starting families have less and less time and resources to devote to these necessary upgrades.

*How Can We Know What
is Happening Out There?
The Challenge of Data
and Measurement*



There are multiple strategies for studying the dynamics of change in the STEM workforce, ranging from survey methodologies to network analysis and ethnography. Each has advantages, but much remains unknown, partly due to difficult measurement and conceptual problems.

The Elephant in the Room: What, Exactly, is a STEM Job?

‘**Engineering**’ seems clear enough, but after that, the STEM acronym becomes quite nebulous, particularly when we consider that the “T” stands for something called “technology.” There are ambiguities relating to quantity as well. For example, what about jobs that require STEM skills only 25 percent of the time? Workshop participants noted that many jobs not normally considered STEM nevertheless require math and quantitative reasoning, including auto mechanic and some construction work, and a discussion of the growing number of microbreweries in San Diego prompted the serious question of whether brewmaster is a STEM job. The notion of a college degree as a requirement seems

arbitrary, especially because many software developers, both celebrated and little known, have no degree. The counterpoint to “how low can we go” and still be STEM is mirrored with a breadth problem at the high end: Advanced STEM skills are crucial in many jobs not normally considered STEM, including finance, marketing and the management of supply chains and distribution. In short, identifying who is in STEM and who is not will be difficult -and may not even be possible.



The Related Problem of Validity in Measurement

Assuming we can be certain that a particular job counts as a “STEM” field, other problems arise. One issue is that jobs change over time (think of how software is continually reinventing different occupations), and therefore the government must continually update and revise the occupational categories in its many and massive survey operations. Ethnographic approaches can reveal in great detail the ways that skills are used on the job, but there is reason to believe that jobs vary geographically (the term “ecosystems” came up frequently in the discussion) and between firms, and therefore many qualitative studies are needed to give a fuller picture of what is happening in STEM jobs. The Occupational Information Network (O*NET) data have made progress on this question, but a particularly promising new approach is to examine actual movement into, out of and between science and engineering firms using data from career building websites such as LinkedIn. While not all occupations are well represented, and access to the proprietary data is restricted, these kinds of data may

reveal what types of skills tend to group together, and how labor flows within and across regions, as well as the ways networks between workers facilitate movement.

Moving Forward



The challenges of understanding change in science and engineering, how workers can adapt to that change, and leveraging the innovation potential of STEM workers are indeed very great. Several ideas emerged during the workshop discussions that are fruitful areas for further research. Many of those are described above, and a few more are elaborated below.

Make STEM Career Paths More Transparent

While there are many unconventional career paths to and from STEM jobs, there are ways to make probable pathways more visible. For example, some professional schools in law and business track the career trajectories of their graduates. Though only a fraction of STEM PhDs end up with permanent jobs in academia, the pathways of the majority are rarely made available to prospective or current students. While workshop participants noted that it may not be in the interests of degree-granting programs to make these data available, such transparency would be very helpful to prospective students at all levels as they make their plans.

Encourage Employers to Train Workers

Though the press is filled with stories of tech companies warning that they cannot find the workers with the necessary skills--and therefore lobbying for increased immigration to fill the gap--workshop

participants reported on significant efforts by firms to train current and new employees. Qualcomm, for example, invests in both the technical and business skills of its engineers and other technical workers, and the UC-San Diego extension school has about a third of its tuition invoices paid by local firms. While employers, especially start-ups, often choose not to invest in worker training (in part because of cost, in part because of fear of workers leaving after receiving the training), employers who drive the training process are more likely to get the skills that they need. In addition, research indicates that employer-led training is the most successful at instilling the desired skills.

Improve the Ability of Educational Institutions

to Train Workers at All Levels

While there are many broad purposes and values at the basis of America’s higher education system, many workshop participants noted that more can be done by colleges and universities to produce the workers that employers need. A college degree in a STEM field is often not enough to prepare an employee to start working. More specific certifications often help students become workers, and industry linkages to university engineering programs, such as that at UCSD’s Jacobs School, set students in those fields on a course to employment. But this is not just about research universities. Focusing on



the lower end of the STEM workforce is also crucial. While workers with advanced skills in tech corridors like Silicon Valley attract the most attention, workshop participants noted that innovative STEM work is happening all over the country, and often with the crucial support of STEM workers without college degrees. Many firms would benefit from high schools reinvigorating their shop classes which have

become increasingly rare in the last few decades as the testing culture has taken over secondary schooling. Community colleges can work with employers to produce the skills needed in local STEM job markets. At the high end, more programs like the Professional Science Master’s will go far toward maximizing the innovative potential of America’s existing STEM talent.

Workshop write-up by John D. Skrentny, with assistance from Kevin Lewis, Natalie Novick and workshop participants.

FOR FURTHER READING

Barley, S. R. and Kunda, G. (2004) *Gurus, Hired Guns and Warm Bodies: Itinerant Experts in a Knowledge Economy*. Princeton, NJ: Princeton University Press.

Barnow, Burt S. and Christopher T. King, eds. 2000. *Improving the Odds: Increasing the Effectiveness of Publicly Funded Training*. Washington, D.C.: Urban Institute Press.

Brown, Clair. "Crisis 6: Finding talent", *Chips and Change: How crisis reshapes the semiconductor industry* (with Greg Linden). MIT Press, 2009 (Paperback edition with updated Preface, 2011)

Cech, Erin and Mary Blair-Loy. 2010. "Perceiving Glass Ceilings? Meritocratic vs. Structural Explanations among Women in Science and Technology." *Social Problems* 57: 371-397.

Kannankutty, Nirmala. 2007. "Multiple Pathways to Science and Engineering Employment: Characteristics of the U.S. S&E Workforce." 2007 Atlanta Conference on Science, Technology and Innovation Policy. IEEE Catalog Number: CFP07ACS-RPT.

<http://ieeexplore.ieee.org/xpl/articleDetails.jsp?tp=&arnumber=4472909&queryText%3Dkannankutty>.

Karr, Rick. 2011. "The Smartest Place on Earth." Episode 103 (featuring Kickstarter). *NYC 2.0* (television show). available at <http://a002-vod.nyc.gov/html/nyc20.php?id=1227&pn=1>.

Lee, Carolyn W. B. and Mary L. Walshok. 2002. *Alternative Paths to Competency Through Continuing Education and Lifelong Learning*. Sacramento: California Council on Science and Technology.

Martin, Philip. 2012. "High-Skilled Migrants: S&E Workers in the United States." *American Behavioral Scientist* 56: 1058-1079.

Powell, Walter and Eric Giannella. 2010. "Collective Invention and Inventor Networks," in B. Hall and N. Rosenberg, editors, *Handbook of the Economics of Innovation*. Amsterdam: Elsevier. Pp. 575-605.

Salzman, Hal. 2013. "What Shortages? The Real Evidence about the STEM Workforce." *Issues in Science and Technology* Summer. Available at <http://www.issues.org/29.4/hal.html>

Hall, Matthew, Audrey Singer, Gordon F. De Jong, Deborah Roempke Graefe. 2011. "The Geography of Immigrant Skills: Educational Profiles of Metropolitan Areas." *Metropolitan Policy Program at Brookings*. Available at http://www.brookings.edu/~media/research/files/papers/2011/6/immigrants%20singer/06_immigrants_singer.pdf.

Stephan, Paula. 2012. *How Economics Shapes Science*. Cambridge, MA: Harvard University Press.

Tambe, P. Big Data Investment, Skills, and Firm Value. Forthcoming in *Management Science*. Available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2294077.

Teitelbaum, Michael S. and Virginia T. Cox. 2007. "A Degree of Professionalism." *Nature* 445: 458. Available at http://www.sloan.org/fileadmin/media/files/teitelbaum/psmnaturejobs1_25_07.pdf.

WORKSHOP PARTICIPANTS

Session Speakers

Jared Aaker currently serves as Director of Business Development for San Diego Regional Economic Development Corporation (EDC).

Stephen Barley is the Richard W. Weiland Professor of Management, Science and Engineering, the Associate Chair of the Department of Management, Science and Engineering, and the Co-Director of the Center for Work, Technology and Organization at Stanford's School of Engineering.

Burt S. Barnow is the Amsterdam Professor of Public Service at the Trachtenberg School of Public Policy and Public Administration at George Washington University.

Claude D. Benchimol, Ph.D. is the recently retired Senior Vice President, Biological Information Systems at Life Technologies, a \$3.6 billion life sciences company headquartered in Carlsbad, California.

Thomas Bliss runs the partnering activities for Kyocera International, the group holding company of the Americas for most of Kyocera Corporation's business lines.

Clair Brown is Professor of Economics and Director of the Center for Work, Technology and Society at the University of California, Berkeley.

Tamar Elkeles is the Chief Learning Officer of Qualcomm and is responsible for defining the strategic direction for the company's overall training and development.

Tsvi Goldenberg, Ph.D., is CEO and Co- Founder of eemRa, co-founded Itherx (formerly known as Immusol, Inc.) and served as its Chairman since 1994 and Chief Executive Officer from 1994 to January 1, 2008.

Ronita Griffin is the Leader of Talent Acquisition and Diversity & Inclusion for Life Technologies.

Nirmala Kannankutty is Senior Advisor in the Division of Science Resources Statistics at the National Science Foundation.

Michael Kamal, Ph.D., is Director at Wells Fargo Bank.

Rick Karr is a public broadcast journalist who reports for the PBS Newshour.

Kevin Lewis is Assistant Professor in the Department of Sociology at UCSD and a Faculty Associate at the Berkman Center for Internet & Society at Harvard University.

Philip Martin is Professor of Agricultural and Resource Economics at the University of California-Davis.

Walter W. Powell is Professor of Education (and) Sociology, Business Engineering, Public Policy, and Communication at Stanford University, and faculty co-director of the Center on Philanthropy and Civil Society.

Hal Salzman is Professor of Public Policy at the Edward J. Blaustein School and Senior Faculty Fellow at the John J. Heidrich Center for Workforce Development.

John D. Skrentny is Co-Director of the Center for Comparative Immigration Studies and Professor of Sociology at the University of California, San Diego.

Audrey Singer is Senior Fellow at the Brookings Metropolitan Policy Program.

Paula Stephan is Professor of Economics, Georgia State University and a Research Associate of the National Bureau of Economic Research.

Prasanna Tambe is Assistant Professor at the New York University Stern School of Business.

Michael S. Teitelbaum is Wertheim Fellow at Harvard Law School and Senior Advisor to the Alfred P. Sloan Foundation in New York

Invited Guests

Mary Blair-Loy is Professor of Sociology and directs the Center for Research on Gender in the Professions at UCSD.

Melanie B. Cruz is Senior Director for the UC San Diego Division of Physical Sciences and a member of the senior management team for the Dean of the Division of Physical Sciences.

Edward Hunter is currently a lead computer scientist with the Oceans Observatories Initiative (001) Cyberinfrastructure Project at Scripps Institution of Oceanography.

Natalie Novick is currently pursuing a Ph.D. in Sociology at the University of California, San Diego.

Mary Walshok received her B.A. from Pomona College and her M.A. and Ph.D. in sociology from Indiana University. Currently, she is Associate Vice Chancellor for Public Programs and Dean of Extension at the University of California, San Diego.

Charles Tu is Distinguished Professor of Electrical and Computer Engineering (ECE) at the UCSD Jacobs School of Engineering.