Charting a Course into the Science of Information

by Luke Redington

I. A Worthwhile Destination

Spectators pressed themselves into the small room so tightly that, viewed from above, they must have looked like a tessellation. All eyes focused on one corner of the plain, undecorated room, where a man sat placidly at a desktop computer. The crowd politely crushed each other for a viewing angle of the computer's monitor, where a marvel was occurring. The seated man had seen it many times before; the crowd had never seen anything like it. On the monitor, a bright green rectangle moved across a white screen, and each motion left a narrow green line tracing the rectangle's previous position. The man had evidently been moving the rectangle around for quite some time; the screen looked like a neon spiderweb. Although the spiderweb was clearly the center of attention, people kept glancing at the man's hat. White Velcro straps criss-crossed his head, and wherever the straps overlapped, they held a rubber suction cup to his scalp. Wires sprouted from the Velcro and branched in all directions. But the truly strange aspect of this scene was the man's hands. They sat perfectly still in his lap even while the bright rectangle on the screen moved as if guided by a mouse or keyboard. The hat was reading his brain.

Specifically, electrodes in the suction cups were detecting brainwave patterns. Recently, scientists discovered a way to identify specific brainwave patterns that occur only when the brain is thinking about motion to the right or left. So, although the man watched the screen while he steered the rectangle with his brain, the hat was not tracking his eye movements nor any other muscular activity. It was just reading his brainwaves. Meanwhile, customized software translated the brainwave data into the real-time motion which the seated man thought into being and which the spectators observed on the screen.

Nothing about this scene seemed strange to people who work in the science of information, an emerging academic discipline concerned with how data is stored, transmitted, and interpreted. It is also the academic discipline that supplied the magic behind the brainwave-reading hat and its corresponding software. The brain-reading session did not take place in a laboratory dedicated to the science of information, but rather in a basement office in the bioengineering building at the University of California San Diego. This too is par for the course. The science of information has made inroads into a vast number of disciplines, but it is still too new to have the cache (and real estate) of a long-established discipline. That doesn't bother science of information researchers. They know their new field can take them anywhere they want to go.

II. You Can't Get There From Here

The road to information science winds through the STEM disciplines. For example, the man whose brain was being read is a researcher named Rui Ma. He picked up a masters degree in applied math while earning a PhD in neurophysiology.[1] In a 2013 interview, Ma explained that his mathematics background is key in helping him pursue his interest in “brain-computer interface, both invasive and noninvasive.”[2] (The brain-reading hat, which Ma helped design, is of the noninvasive type, and hence painless.) The point is that Ma would have neither designed nor worn the hat if he had taken a more conventional path to becoming a neurophysiologist, a path that does not need to include a masters degree in applied math.

1 Brent Ladd, “Postdoc Spotlight: Rui Ma,” *Center for Science of Information*, accessed April 13, 2015, https://www.soihub.org/resources.php?id=385&typeID=1.

2 Ibid.

Todd Coleman, the professor in whose laboratory the brain-reading was occurring, likewise spent a long time in one part of the STEM disciplines before his interest in information science propelled him into another. All Coleman's education is in electrical and computer engineering. But something funny happened on the way to completing his PhD. In a recent presentation at a science of information conference, Coleman recalled a conversation in which his advisor at MIT convinced him that his work in engineering had tremendous implications for research about how the brain works, and that information theory could be the bridge that gets him there.[3] Coleman describes his current research as "multi-disciplinary at its core," meaning that in retrospect, it would be impossible to separate out all the influences that have converged to make things like the brain-reading hat possible.[4]

So, it's not surprising that the science of information is rapidly growing in popularity. What young scientist doesn't want to build a brain-reading hat? For that matter, what young scientists doesn't want to build an unmanned[5] airplane you can fly with your mind? (Coleman and Ma have already done exactly that, and have the video to prove it.)[6]

Wanting to participate in the magic of the science of information and having access to it are two different things. Information science is a discipline that, for all practical purposes, a person can only specialize in during a graduate degree in a science-related field. To get into this kind of graduate program, a student needs to have had a strong if not stellar undergraduate career, usually one that includes substantial research experience. To get into that kind of undergraduate program and flourish, a student needs, well, that is the topic of this essay. For now, let's say most admissions processes are less mystical than that conducted by the Sorting Hat at Hogwarts yet less objective than granting seats to the highest test scorers.

A good first step in trying to figure out which students go where and why is simply to look at recent data about choices college undergraduates are making about science-related fields. That's part of the approach taken by Corey Schimpf, a PhD student in Purdue University's department of engineering education. Schimpf has drawn on some large-scale assessments by the National Science Foundation and the Computing Research Association to analyze enrollment trends. His research ultimately aims to outline measures which might broaden access to excellent STEM education and increase student success. When asked who is signing up for science classes these days, Schimpf gives the prototypical graduate student answer: "It depends."[7]

He smiles, then elaborates: "In the life sciences, you see a somewhat diverse field. It is the STEM field with the highest percentages of female students at the undergraduate level. But, there is a fractal nature to the

3 Todd Coleman, "Neuroscience and Information" (Center for Science of Information Summer School, University of California, San Diego, August 5, 2014), www.youtube.com/watch?v=d9xT6IwPIcw.

4 Todd Coleman, "UCSD Jacobs School of Engineering," *UC San Diego Jacobs School of Engineering*, accessed April 20, 2015, http://www.jacobsschool.ucsd.edu/faculty/faculty_bios/index.sfe?fmp_recid=331.

5 "Unmanned aerial vehicle" remains the official term used by the Department of Defense for such machines even though the DoD website boasts that women have been serving in the U.S. as combat pilots since World War II. See Rudi Williams, "Defense.gov News Article: Women Aviators Finally Fill Cockpits of Military Aircraft," March 19, 2003, http://www.defense.gov/news/newsarticle.aspx?id=29276.

6 The video is accessible at www.youtube.com/watch?v=bXk6F8e-2XI. In it, Ma wears a different but equally as dapper hat than that described on page one. A full description of the technology underlying the brain-reading hat can be found in *Abdullah Akce, Miles Johnson, and Timothy Bretl, "Remote Teleoperation of an Unmanned Aircraft with a Brain-Machine Interface: Theory and Preliminary Results," ed. IEEE Robotics and Automation Society (2010 IEEE International Conference on Robotics and Automation, [Piscataway, N.J.]: IEEE, 2010), 5322–27.*

7 Corey Schimpf, Personal Interview, In person, February 13, 2015.

nation-wide data about diversity among students in STEM fields. If you look at all the fields that make up STEM, you get one picture, but if you zoom in on a particular field, you get another."[8] Figure 1 shows what Schimpf got when he zoomed in on four particular STEM fields:

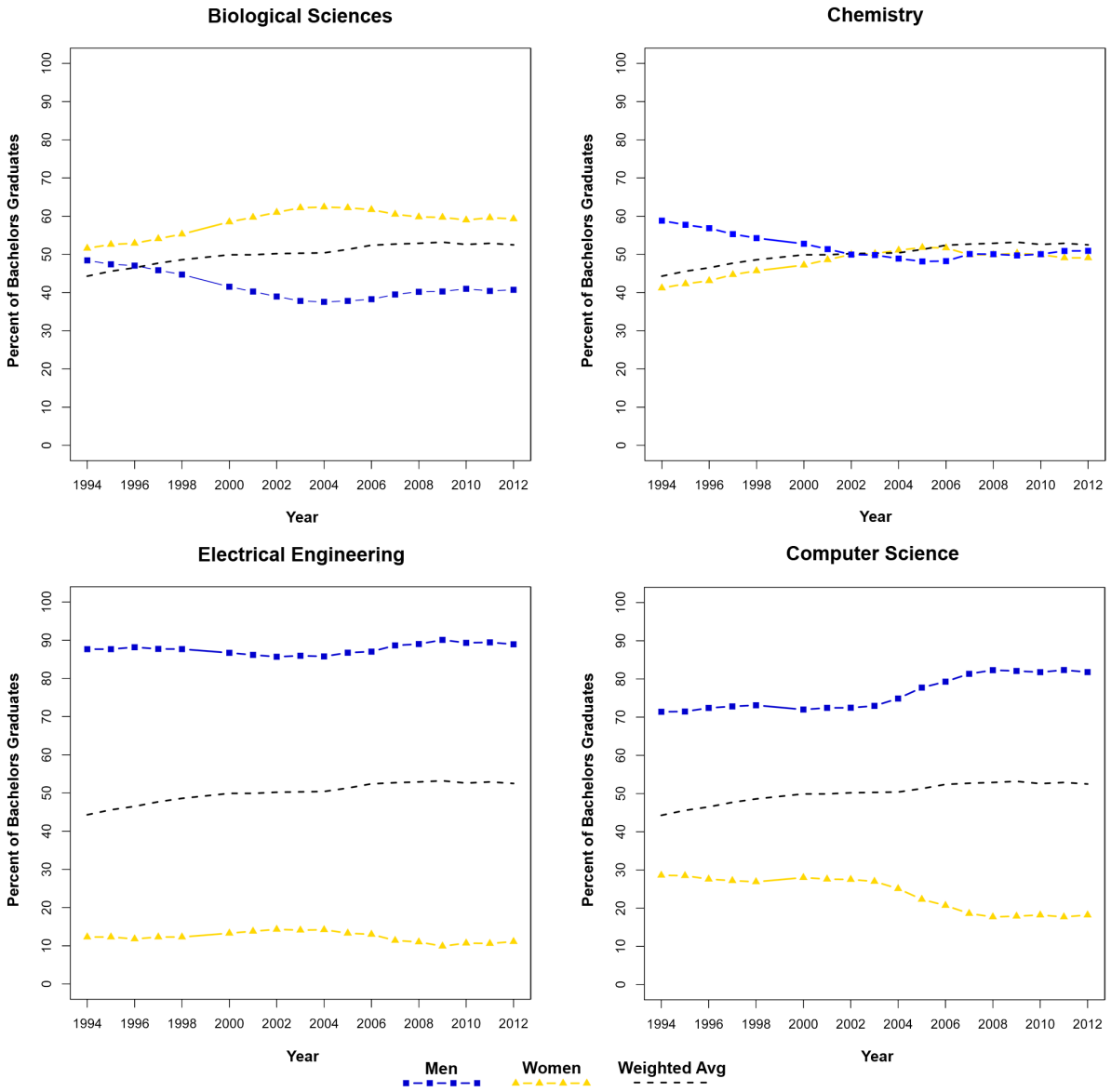

Figure 1: A comparison of the gender composition of graduates in four STEM fields. Source: National Science Foundation: Women, Minorities, and Persons with Disabilities in Science and Engineering: 2004, 2013). Graphs by Corey Schimpf.

Displayed in Figure 1 are the gender distributions of bachelor's degree earners in four different STEM fields. The black dotted line represents a weighted average of the gender differential which, as Schimpf explains, "takes into account differences in the number of women across the four fields. The weighted average reveals that despite decreases in representation in computer science and electrical engineering

8 Ibid.

women's representation in this broader collection of STEM fields primarily increased."[9] Because electrical engineering and computer science are pretty much the only paths to a career in the science of information, the gender disparity in these fields is a major roadblock.

III. Pride and Penitence

Cornfields hem the edges of Highway 231, a route running north and south across Indiana. Near the center of a small town called Greencastle, Highway 231 makes a quick lateral jog to avoid plowing through the campus of DePauw University. The campus' quaint brick buildings embody a truism of rural Indiana: Corn grows quickly, architecture changes slowly. Near the center of campus stands the Science and Mathematics Center, whose design, although dating from the 1970's,[10] harmonizes with DePauw's mid-nineteenth century feel. The Science and Mathematics Center is named after Percy L. Julian, an alumnus whose career in chemistry was characterized by tremendous scientific and commercial successes. Julian's career was also characterized by hardship. At every stage of his education and career, Julian, an African American, faced discrimination. This held true even at DePauw, a fact the university laments in a succinct, well-written biography on its website.[11] The biography notes that Julian left the discriminatory conditions of his native Alabama only to find that at DePauw, "Not everyone was welcoming." So unwelcoming, in fact, was the school's culture that no amount of meritorious accomplishments sufficed to secure Julian continuing opportunities at DePauw after graduation. The biography explains: "In 1920 Julian graduated first in his class and was elected to Phi Beta Kappa. Even with his outstanding academic record, however, Julian was denied an assistantship, fellowship or admission to graduate school." Julian would eventually need to look as far as Europe to find a doctoral program that would take him on, and when he returned to the U.S., he was repeatedly offered prestigious jobs in industry only to be rejected after employers learned he was African American. The biography touts DePauw's decision to award Julian a research position in 1933, but it quickly follows this self-congratulatory note with more penitence. The biography owns up to the fact that during this period, DePauw refused Julian any teaching positions, telling the young chemist—by then already world famous—that "the time wasn't right." The biography points to his employment at Glidden Paints as a major development. There, his research received ample funding, and Julian flourished. He would go on to make revolutionary discoveries with important commercial applications in industries ranging from pharmaceuticals to national defense.[12]

To anyone who has faced discrimination, Julian's story offers an encouraging lesson about the benefits of enduring despite hardship. But to college administrators everywhere, Julian's story presents a lesson about the burden of a tainted legacy. DePauw will long be remembered as the school that admitted Julian to its undergraduate program and as the school that slammed many other doors in his face. The building bearing Julian's name commemorates his achievements, certainly, but it also apologizes for all those slammed doors. Like most such apologies, it arrived long overdue; the building was dedicated just three years before Julian's death, a fact the biography omits.[13] Julian's story should prompt people who shape the

9 Corey Schimpf, "Graph and Text for STEM Grads by Gender," April 13, 2015.

10 "DePauw Celebrates Science Traditions as Julian Science and Math Center Is Rededicated," *DePauw University*, accessed April 10, 2015, http://www.depauw.edu/news-media/latest-news/details/13031/.

11 "The Life of Percy Lavon Julian '20," *DePauw University*, accessed April 10, 2015, http://www.depauw.edu/news-media/latest-news/details/22969/.

12 Ibid.

13 "DePauw Celebrates Science Traditions as Julian Science and Math Center Is Rededicated." In this news article about renovations to the Julian Center, the date of the building's original dedication is mentioned in passing. It is the website's only mention of the building's original dedication date.

demographics and culture of STEM education to ask themselves this question: What aspects of STEM education seem normal now but will become regrettable in the future?

This very question motivated an extensive study of the cultural climate of one the country's leading computer science programs. In 2002, Jane Margolis and Allan Fisher published *Unlocking the Clubhouse: Women in Computing,* a book that reports the results of "more than 230 interviews conducted with over 100 male and female computer science students over four years (from 1995 to 1999) at Carnegie Mellon University".[14] Although the study covered a significant time span, Margolis and Fisher quickly identified recurrent themes in the interview responses. Prominent among them was that female students reported being overtly discriminated against by their male peers: "A quarter of the women we interviewed reported hearing comments implying that the only reason they were admitted was because of their gender."[15]

When one of these female students goes on to have a world-class career , Carnegie Mellon might find itself in a similar situation as DePauw, needing to ask itself: Now that this alumna is too famous for us not to honor, do we have to eat crow while we sing her praises?

IV. "Obsession is a Young Man's Game."

Christopher Nolan's movie *The Prestige* is decidedly complex. Set in a realistically rendered late Victorian London, the movie uses a series of intertwining flashbacks to tell a story that is part magic show, part science fiction thriller, and part murder mystery. But for all these complexities, the movie is fundamentally simple; it tells the story of a competition between two men. Each wants to be the most famous magician in London, and each is convinced the other man stands in his way. One of the magicians seeks help from a former businesses associate, an engineer with decades of experience designing equipment for magic shows. Discerning the depth of the magician's competitive drive, the engineer refuses and explains, "Obsession is a young man's game."[16]

Margolis and Fisher's study suggests that this character's proverb applies directly to the climate permeating the countries leading computer science programs, the programs most likely to be gatekeepers to a future in the science of information. Margolis and Fisher found that among the students they interviewed, "An exceptionally high level of obsession and expertise has become the expected norm."[17] They also found that many of their male interviewees had been obsessed with computers from such a young age they could not remember a distinct point in time when they chose to major in computer science; it had always been a foregone conclusion.[18]

But most importantly, Margolis and Fisher found that many male computer science students view their studies not so much as an education but as a game, a perpetual competition among peers. The researchers found that female students were far less likely to view their computer science education this way, but they were fairly eager to describe the drawbacks of such a competitive climate. They specifically cited being mocked for asking questions during class and ridiculed for seeking legitimate forms of help from peers.[19]

---

14 Jane Margolis and Allan Fisher, *Unlocking the Clubhouse: Women in Computing* (Cambridge, Mass.: The MIT Press, 2003), 4.
15 Ibid., 54.
16 Christopher Nolan, *The Prestige* (Buena Vista Home Entertainment / Touchstone, 2007).
17 Margolis and Fisher, *Unlocking the Clubhouse*. 70.
18 Ibid., 50.
19 Ibid., 88-9.

Because Margolis and Fisher conducted their study over fifteen years ago, it is fair to ask whether the education-as-game culture still prevails in the fields most closely related to the science of information. A more recent study suggests it does. Paul M. Leonardi and his associates interviewed over 100 students in a large electrical and computer engineering program about their habits and attitudes regarding school work.[20] Leonardi, et al. discovered eight recurrent themes with one common denominator: machismo. The researchers of course use a more erudite description, surmising that students frequently engage in these practices "to rationalize their ongoing actions as members of a student engineering culture and to justify their emerging identities as engineers".[21] They observed the following eight habitual actions:

- Delaying the start of assigned tasks
- Ignoring instructions
- Working without a plan (especially when instructed to start by making a plan)
- Monitoring the difficulty of a task (i.e., watching to see if classmates struggle)
- Completing work alone (especially when instructed to collaborate)
- Ensuring one's contribution
- Ranking self against others
- Excluding inferiority (i.e. shunning group members who appear to lag behind)[22]

Leonardi et al. point out the irony that the habits described above differ drastically from habits valued—indeed required—by workplaces which rely heavily on input from electrical and computer engineers. In those workplaces, collaboration, timeliness, and good communication are all built into the culture .[23] For the emerging field of the science of information, where projects almost always require collaboration across disciplines, these healthy workplace traits are indispensable. The presence (or relative absence) of these traits also affects who decides to major in the fields that open doors to a career in the science of information. Margolis and Fisher found that due solely to the perception that they don't belong in computer science—not because of grades—many women drop out.[24] Many others never join. In a 2012 study by psychologists at the University of Washington, women considering a major in computer science were significantly deterred from pursuing it by even brief contact with men who fit the work-obsessed stereotype.[25]

20 Paul M. Leonardi, Michelle H. Jackson, and Diwan Amer, "The Enactment-Externalization Dialectic: Rationalization and Persistence of Counterproductive Technology Design Practices in Student Engineering," *Academy of Management Journal* 52, no. 2 (2009), 402.

21 Ibid., 410.

22 Ibid., 404-8.

23 Ibid., 415.

24 Margolis and Fisher, *Unlocking the Clubhouse*, 90-1.

25 S. Cheryan, B. J. Drury, and M. Vichayapai, "Enduring Influence of Stereotypical Computer Science Role Models on Women's Academic Aspirations," *Psychology of Women Quarterly* 37, no. 1 (March 1, 2013), 76-7.

V. Rerouting

Kelly Andronicos, CSoI Diversity Director. Photo by Mike Atwell.

Kelly Andronicos took a circuitous route to where she is today. She majored in theater as an undergraduate, but her first job in academia was as the Program Coordinator for a faculty development center at the University of Texas at El Paso. There, Andronicos oversaw a faculty mentoring program for women. This program eventually got upgraded by a grant from NSF into a larger scale effort to recruit, retain, and promote women in science and engineering. Andronicos explains that for her, the setting itself was as important as the nature of the work: "Entering the field of diversity through the unique portal that is UTEP—located on the US/Mexico border and known for being the number one producer of female doctoral students in engineering[26]—provided me with not only important insight into the challenges women face in the field but also a valuable bi-cultural perspective."[27] An award-winning playwright, Andronicos combines her theater background with her efforts to diversify STEM education. The combination is actually exceedingly practical. Hiring and admissions processes are where the rubber hits the road on most diversity-related issues in academic contexts, and Andronicos works with a theater troop specializing in role-playing sessions which help hiring authorities gain new perspectives on how they perceive job applicants.[28]

Andronicos is currently the director of diversity at the Center for Science of Information (CSoI), an NSF Science and Technology center which seeks to coordinate the research efforts of this emerging discipline. At CSoI, Andronicos fuels a variety of efforts designed to get students and researchers where they want to go. One such effort is the Channels Program, which seeks to foster success for women and underrepresented minorities in their roles as undergraduates, graduate students, or faculty. One of the Channels Program's defining features is the pairing of each student with a faculty mentor. Why? Andronicos explains: "At the end of the day, relationships have the biggest impact on students' career choices. It's important to have someone the student respects and admires prodding them along and setting expectations, especially when there are few or no role models. Role models signal what's possible. In their absence, this notion has to be conveyed more explicitly, which is part of a mentor's job."[29]

Andronicos is driven by a sense that she is working in the science of information during what she describes as "an auspicious moment." Like Schimpf, she is dismayed by the prevalence of the forces that discourage diversity in the fields that function as gateways into the science of information, but she is also encouraged by successes CSoI has had with its diversity-related endeavors. "The Center has populated its undergraduate program with an impressive amount of diversity – 58% women, and 39% African American

26 "UTEP Is Top Producer of Women Earning Ph.D.s in Engineering," July 11, 2014, http://news.utep.edu/?p=25469.
27 Kelly Andronicos, Personal Interview, Email, February 23, 2015.
28 Ibid.
29 Ibid.

or Hispanic."[30] She attributes this success to a combination of strategic funding and plain old footwork on the part of faculty who went out of their way during recruitment processes. Looking ahead, Andronicos foresees that "the Center will successfully engage a large percentage of diverse undergraduate students in science of information, who – with continued Center support in the form of professional development – will go on to populate the workforce in academia and industry. It is our hope that they then will continue to attract diverse students themselves, and continue to define and strengthen the demographics of this discipline."[31] Andronicos adamantly believes the time is right to actively shape the young field of the science of information because, in her words, "A chance like this only comes around once."[32]

Luke Redington is a staff writer for CSoI.

For more information about diversity efforts at CSoI, visit www.soihub.org/diversity.php.

30 Ibid.
31 Ibid.
32 Ibid.

Bibliography

Abdullah Akce, Miles Johnson, and Timothy Bretl. "Remote Teleoperation of an Unmanned Aircraft with a Brain-Machine Interface: Theory and Preliminary Results." edited by IEEE Robotics and Automation Society, 5322–27. [Piscataway, N.J.]: IEEE, 2010.

Andronicos, Kelly. Personal Interview. Email, February 23, 2015.

Cheryan, S., B. J. Drury, and M. Vichayapai. "Enduring Influence of Stereotypical Computer Science Role Models on Women's Academic Aspirations." *Psychology of Women Quarterly* 37, no. 1 (March 1, 2013): 72–79. doi:10.1177/0361684312459328.

Coleman, Todd. "Neuroscience and Information." presented at the Center for Science of Information Summer School, University of California, San Diego, August 5, 2014. www.youtube.com/watch?v=d9xT6IwPIcw.

———. "UCSD Jacobs School of Engineering." *UC San Diego Jacobs School of Engineering*. Accessed April 20, 2015. http://www.jacobsschool.ucsd.edu/faculty/faculty_bios/index.sfe?fmp_recid=331.

"DePauw Celebrates Science Traditions as Julian Science and Math Center Is Rededicated." *DePauw University*. Accessed April 10, 2015. http://www.depauw.edu/news-media/latest-news/details/13031/.

Ladd, Brent. "Postdoc Spotlight: Rui Ma." *Center for Science of Information*. Accessed April 13, 2015. https://www.soihub.org/resources.php?id=385&typeID=1.

Leonardi, Paul M., Michelle H. Jackson, and Diwan Amer. "The Enactment-Externalization Dialectic: Rationalization and Persistence of Counterproductive Technology Design Practices in Student Engineering." *Academy of Management Journal* 52, no. 2 (2009): 400–420.

Margolis, Jane, and Allan Fisher. *Unlocking the Clubhouse: Women in Computing*. Cambridge, Mass.: The MIT Press, 2003.

National Science Foundation, Division of Science Resources Statistics. *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2004.*, 2004.

———. *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2013.*, 2013.

Nolan, Christopher. *The Prestige*. Buena Vista Home Entertainment / Touchstone, 2007.

Schimpf, Corey. "Graph and Text for STEM Grads by Gender," April 13, 2015.

———. Personal Interview. In person, February 13, 2015.

"The Life of Percy Lavon Julian '20." *DePauw University*. Accessed April 10, 2015. http://www.depauw.edu/news-media/latest-news/details/22969/.

"UTEP Is Top Producer of Women Earning Ph.D.s in Engineering," July 11, 2014. http://news.utep.edu/?p=25469.

Williams, Rudi. "Defense.gov News Article: Women Aviators Finally Fill Cockpits of Military Aircraft," March 19, 2003. http://www.defense.gov/news/newsarticle.aspx?id=29276.