# Liberal Education as Preparation for Interdisciplinary Science

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As this talk is a witnessing for the efficacy of liberal education as preparation for interdisciplinary science, let me begin with a personal prologue to provide context. I am tenured full professor of Natural Resource Management at South Dakota State University, and Co-Director of the Geospatial Sciences Center of Excellence, an interdisciplinary research group of 45 with an annual budget of over $5 million.

I earned my B.A. from St. John’s in 1982, attending Annapolis for two years and finishing in Santa Fe. My graduate degrees (M.S. and Ph.D.) are in environmental sciences. I met my wife, Ana who is from Brazil, in graduate school in Texas. We have seven children (aged 14 to 27) whom we have homeschooled while living the peripatetic academic lifestyle: a post-doctoral position at Kansas State University, a Fulbright Research Fellowship in Brazil, and faculty positions at Rutgers-Newark, University of Nebraska-Lincoln, and South Dakota State University.

I serve on the editorial boards of three scientific journals, on the NASA Land Cover Land Use Change Science Team, and as Chair of the Advisory Committee of the USA-National Phenology Network. In short, I have been able to leverage my liberal education into a successful career as a research scientist and professor.

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We are witness to increasing globalization of technophilic cultures that value the instrumentality of science, technology, engineering, and mathematics or STEM. While the reinforcement of disciplinary boundaries within STEM remains strong, there is increasing recognition of need for interdisciplinary engagement to address myriad complex problems of health, environments, and governance that arise from our socioeconomic activities.

Major federal funding agencies, such as the National Science Foundation, the National Institutes of Health, and the National Aeronautics and Space Administration, have established in recent years programs to sponsor research that explicitly bridges across disciplinary boundaries. Such projects are considered higher risk than traditional disciplinary research due to the “boundary work” required to enable scientists and engineers from different—often contrasting—intellectual lineages to communicate their expertise in mutually intelligible ways.

I propose that liberal education can provide valuable solid preparation for "boundary workers" to craft practices of interdisciplinary science. Of the trivium grammar and logic enable the establishment of conceptual frameworks and disciplinary practice; whereas; rhetoric stands out as solvent for disciplinary borders. Rhetoric in scientific narrative is key to spanning assumptions and reconciling viewpoints.

What I offer here is not a disquisition. I am not a scholar of teaching and learning. Nor do I study the history or philosophy of science. I am just a professional scientist. So I can offer a report from the front lines about practicing interdisciplinary science, training Ph.D. students, and mentoring post-docs and young faculty to succeed as professional scientists.

My primary field is ecology, the study of how living and non-living things interact to shape the biosphere, that thin layer of habitable space mostly on the surface of this planet. Key to my investigations are datastreams from the constellation of earth-observing sensors orbiting this planet that sense the various kinds of electromagnetic radiation rising from the surface—from the visible part of the spectrum through the near, middle, and thermal infrared regions all the way into the microwaves. (Did you realize that you emit photons of microwaves?) And I do a lot of international work with past and present projects in European Russia, Central Asia, Hungary, Costa Rica, Brazil, Ethiopia, and recently at the continental scale.

Imagine more than 20,000 scientists converging on San Francisco for a week each December for the Fall Meeting of the American Geophysical Union (AGU). With attendance growing by 85% in the past decade, the AGU is a truly global meeting with participants from every continent. It is a union in the literal sense of the word: diverse disciplines banding together to achieve economies of scale and thereby enabling interactions that span across and between scientific disciplines.

We walk into Moscone Center's South exhibition hall. Across the 300,000 square feet are arranged aisle after aisle of boards displaying posters describing the latest in scientific research about the earth system, from earthquakes to electrical phenomena in the upper atmosphere, from measuring the various ways that water flows above and below the land to observing how vegetation grows and changes in and next to megacities and in the far-flung reaches of cloud-obscured tropical rainforests, among thousands of other topics.

As we walk down one of those aisles we see text and pictures on the posters and the key words being exchanged that are mostly in an alien tongue. But once we close our eyes to listen to the form and character of the interactions rather than the content—interactions between questioner and respondent, between student and mentor, between the striving post-docs and eminent graybeards—what we discover is that these, too, are from a tribe of science, just not ours.

But what are the tribes of science?

In 2012, according to a recent Census Bureau study [1], 42 million in the workforce between 25 and 64 held at least a bachelor's degree. Of these 12% were in STEM occupations and another 11% in STEM-related jobs (architecture and health care). Of those with a STEM degree, just over one-quarter are in STEM occupations and another 11% are in STEM-related occupations, leaving 63% in non-STEM jobs. Of those with a non-STEM degree, 92% are in non-STEM occupations.

Figure 1 comes from that Census Bureau report [1] and shows where STEM majors work. I want to emphasize two things evident in this graph. First, STEM is really TESM. "T" for technology dominates – these are the "computer workers". Engineering is a strong second, and all the sciences—physical, life, and social comprise but 16% of the STEM workforce. "Math workers" account for a modest yet important 3%. The second important thing the graph shows is that many STEM majors do not end up working in STEM fields.

Figure 2 shows the meager flow of non-STEM majors into STEM occupations [1]. If we lump the literature and languages and liberal arts and history major groups, we find that just 5.4% end up in STEM occupations. If we restrict our focus to the sciences, then just 1.1% of these majors become science workers in the physical, life, and social sciences.

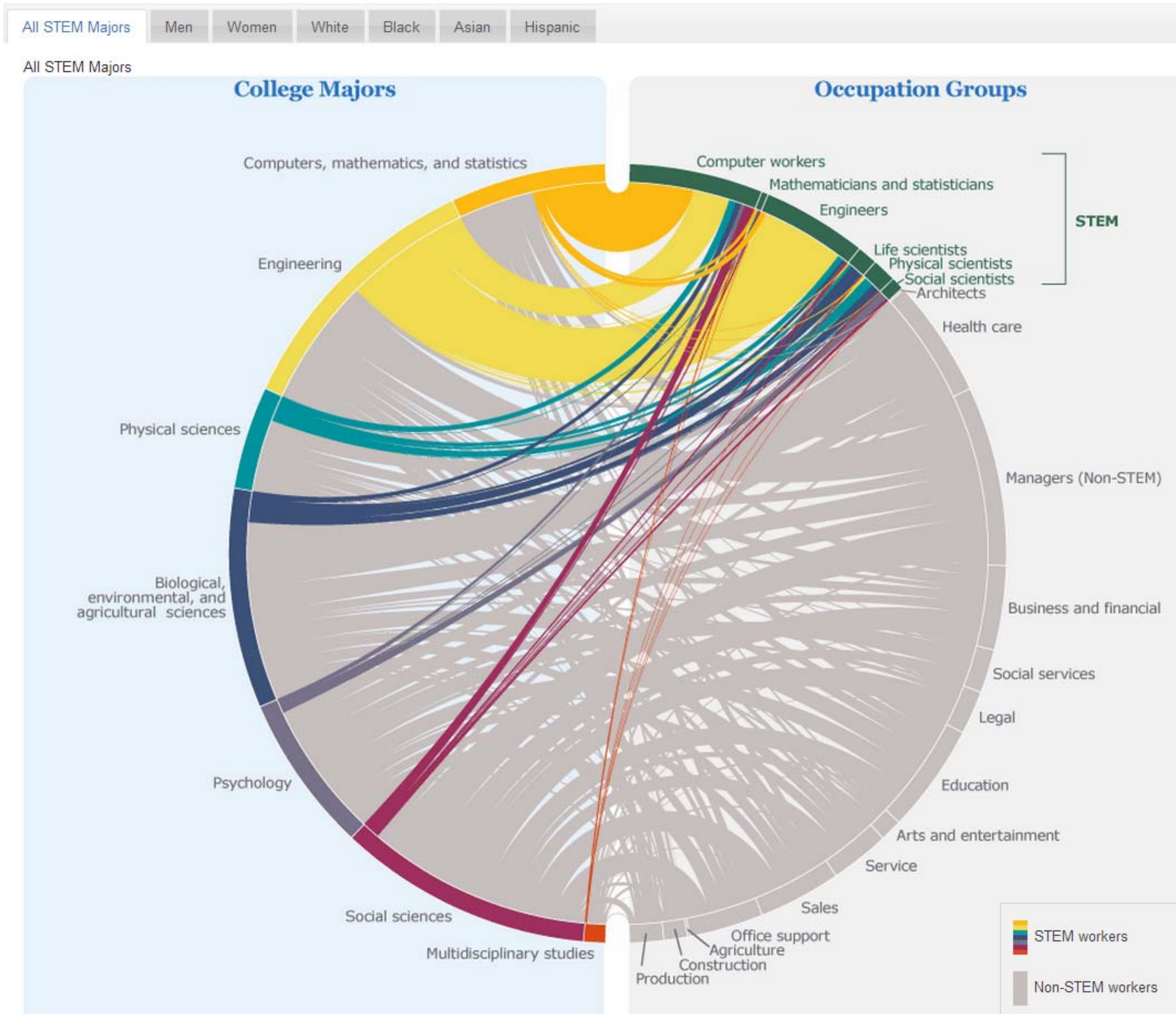


Figure 1: Where STEM majors end up in the general workforce. Graphic captured from http://www.census.gov/dataviz/visualizations/stem/stem-html/

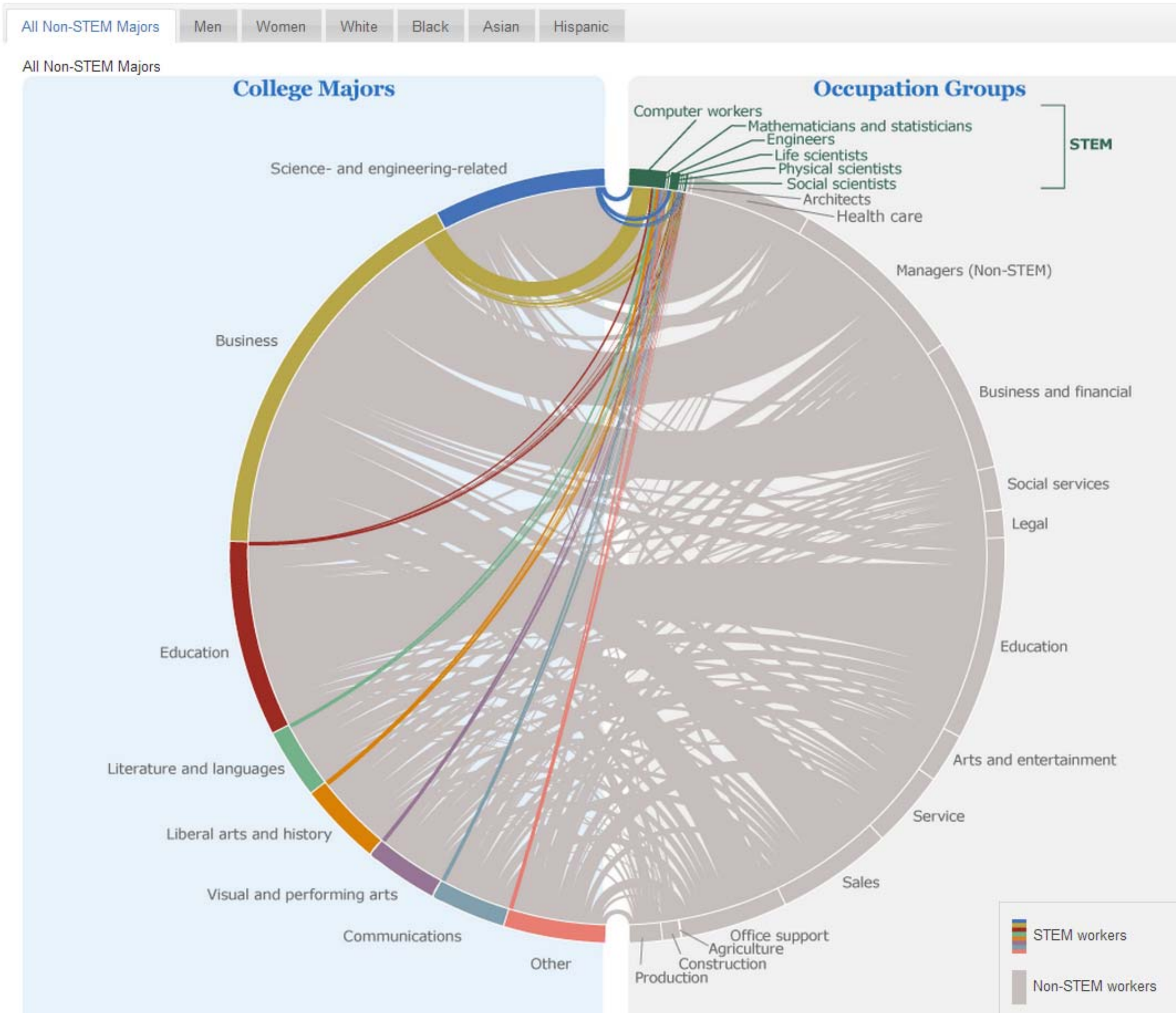


Figure 2: Where non-STEM majors end up in the general workforce. Graphic captured from http://www.census.gov/dataviz/visualizations/stem/stem-html/

Let's ask again: what are the tribes of science? One answer is that there are as many tribes of science as there as recognizable disciplines. Within a tribe members share conceptual schemata full of technical terms that refer precisely to things of interest, but which sound like jargon to the uninitiated. Yet disciplinary specialization proliferates as the bodies of knowledge grow. Sometimes disciplines converge and fuse, but far more often they subdivide messily. So can scientists from different tribes collaborate? And if so, then how do they work together? Over the past two decades or so there has been a re-orientation of science and, importantly, science funding agencies toward seeking understanding about complex problems that involve interactions between human settlements and their supporting ecosystems.

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Scientists tell stories—highly structured, tightly condensed—but stories nonetheless. Liberal education, too, revels in stories and in the great conversation. It is the great conversation, the connecting of ideas spanning space and time, which teaches and hones rhetoric. Listening is a critical aspect of rhetoric because persuasive speech requires engagement with others.  Seminar simulates sitting around a table with scientists from diverse disciplines. I propose that the liberal art of rhetoric enables the bridging across disciplines: the liberally educated boundary worker can identify the key elements of the story above the particularities of the jargon that enforces disciplinary borders.

I would like to share briefly three of the several interdisciplinary projects in which I have played a key role.

The first project, sponsored by the National Science Foundation, was about sand, water, and grass. It asked a simple question: why does the largest dune field in the western hemisphere, the Sandhills of Nebraska, tend to stay vegetated in the face of environmental stresses like drought and grazing? After all, the grass cover is mostly sparse and can be grazed down to nothing within several days. Why are they not bare moving dunes like we see at White Sands in New Mexico or the Sahara desert in North Africa?

To address this question we assembled a team of ecologists, hydrologists, climatologists, and geologists, mostly from the same university. Now this sounds like a rather harmless bunch of "ologists" but how these four disciplines conduct their science is radically different because of the kinds of evidence or data they collect to construct their stories. It took a full year of frequent meetings before we were able to bridge the differences in narrative structure and quality of evidence to develop a successful proposal for a four-year study that included a large landscape manipulative experiment to test our hypotheses. We were able to answer the question and learn to pose many other interesting questions besides! And this is the hallmark of science – to ask questions, albeit in a particular manner.

The second project, sponsored by NASA, is still underway. It asks how urban areas influence the behavior of severe storms. In particular it seeks to understand how the size and shape of the city and the pollution state of the urban air affects the interaction of storm and city. The project involves satellite imagery and derived products, weather radar data, and computer models of weather. So the team includes mesoscale meteorologists to run the models that simulate the storms, radar meteorologists to analyze the weather radar time series, atmospheric chemists to make sense of the interactions between the differently polluted rural and urban air, landscape ecologists to track how cities affect the growing season of vegetation, remote sensing scientists specializing in cities to character size and shape, and a professor of landscape and urban planning to help formulate findings from the science community into the language of the design community.  The project involves scientists at six universities and the National Severe Storms Laboratory, a government agency located in Norman, Oklahoma. In addition to the logistical challenges of having project meetings, there is again the challenge of learning the differences in scientific narrative across fields.

The last project I will highlight is the most ambitious and potentially the most far-reaching. It involves epidemiologists, ecologists, software engineers, and public health officials. The National Institutes of Health, specifically the National Institute of Allergy and Infectious Disease, has been funding us since 2009 to develop a forecasting system to warn public health officials and early responders, such as non-governmental organizations (NGOs), about when environmental conditions are ripe for the outbreak of epidemic malaria in the Amhara highlands of Ethiopia.

Malaria is one of the great scourges of humanity. Millions in the tropics live in areas where malaria is endemic, it is always around and so its threat is well known. In highland areas malaria is not endemic, its transmission is unstable, and mortality is rare. But sometimes conditions are favorable for a generalized outbreak, an epidemic. The public and private health systems are then rapidly overwhelmed and mortality rates are very high.  What are those environmental conditions that set the stage for an epidemic? Can they be monitored and then predicted? How to communicate useful information to the public health officials?

Ethiopia is the second most populous country in Africa at about 95 million. It is a mountainous country, with more than three-quarters of peaks on African continent. The population is overwhelming rural—more than 80% live outside of cities—and it is poor.

The literacy rate is among the lowest in the world. It is estimated that fewer than half the males and fewer than 30% of the females aged 15 and older can read. Thus, once we can forecast increased risk of an epidemic communicating it is a challenge, both technological and cultural.

Let me mention just one example. To write the code to build a computer system that interacts both with scientists and public health officials requires eliciting from each group their requirements for the system. Discerning what is important from what is desirable and reconciling different requirements is surprisingly difficult task! However, rhetorical skills are once again crucial to the process: listening, synthesizing, and repeating in different words to build consensus. And coffee helps, too.

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To conclude, I want to speak to the question of "What is liberal education for?" There is an answer in the motto of St. John's College: *Facio liberos ex liberis libris libraque.* Google Translate renders it as "I do have children with free books debtor appealed", which points to the need for Latinists to improve the Technologists' grasp of grammar! A proper translation of the motto reads "I make free men out of children by means of books and a balance." This process of making free men and women is a preparing for the rest of life – a transforming of children into adults. Liberal education provides the foundation for choosing, intelligently, *what is next* and provides the awareness and skills to excel at that next stage. Liberal education is, indeed, preparation for interdisciplinary science, and countless other paths as well.

**Reference**

[1] Liana Christin Landivar, 2013, "The Relationship between Science and Engineering Education and Employment in STEM Occupations," *American Community Survey Reports*, ACS-23, U.S. Census Bureau, Washington, DC.

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