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Key Issues in STEM Specific Information Education: Lessons Learned at the University of Tennessee, USA

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Abstract:

Scientific grand challenges include environmental issues such as sustainable energy and climate change (United States Global Change Research Program, 2009) that affect society in terms of citizen's health and equitable resource management. Each year, researchers produce immense quantities of data about these issues (Lynch, 2008, 2009) which is difficult for scientists, policy makers and the general public to navigate. Managing science data is a key aspect of helping society address these challenges (Hey et al., 2009) and the library and information science profession and discipline is well-positioned to fill this role. This paper focuses on the three key challenges related to providing science information and science data education programs: (1) striking the appropriate balance between multidisciplinary and subject expertise; (2) providing experiences for students that allow them to begin the "socialization process" of entering the science domains; and (3) promoting diversity of the professionals engaged in the science domains. Traditionally women and minorities are underrepresented in the science professions, and this is also a problem among science information professionals.
The paper outlines five education programs at The University of Tennessee (UT) that focus on using the interdisciplinary expertise of information science to provide a foundation for the professional and research skills that are essential to engaging the sciences, particularly the earth systems sciences, in the data-intensive world. The paper then shares how these five programs have addressed the challenges and the lessons learned from these efforts.

Science is important. It can facilitate a country's competitive edge and improve the quality of life for citizens (American Competitiveness Initiative, 2006).

Science is complex. It has revealed the world to be a complicated place (Friedman, 2008; Nicolescu, 2002) with fundamental problems to tackle. These scientific grand challenges include environmental issues such as sustainable energy and climate change (United States Global Change Research Program, 2009) that affect society in terms of citizens' health and equitable resource management. Science, technology, engineering, and medicine[1] (STEM) are all founded on the scientific process.

The scientific process relies on well-documented, well-described, well-stored information. Each year, researchers produce immense quantities of data, and this data-intensive world (Lynch, 2008, 2009) is difficult for scientists, policy makers, and the general public to navigate. Managing science data is a key aspect of helping society to address these challenges (Hey et al., 2009), and the library and information science profession and discipline are well-positioned to fill this role. For example, in 2007 the National Science Foundation (Cyberinfrastructure, 2007) noted the importance of state-of-the-art data management and distribution systems to future scientific breakthroughs, and the goals to improve these services include digital libraries and education environments. Two recent actions by the Obama administration demonstrate the focused attention on data, particularly science data. In March 2012, the "Big Data Research and Development Initiative" committed $200 million to "improve the tools and techniques needed to access, organize, and glean discoveries from huge volumes of data" (Office of Science and Technology Policy, 2012). Most recently, the February 2013 memorandum from the Office of the President's Office of Science and Technology Policy directs federal agencies to create a place where the results of federally funded research would be made freely available within a year of publication (Office of Science and Technology Policy, 2013). Countries around the world are considering how to address the need for managing science data, and international projects are emerging, based either on domain (e.g. DataONE.org for environmental sciences or EarthCube.ning.com for geosciences) or on the act of data sharing (e.g. Zenodo.org or the Research Data Alliance at rd-alliance.org).

Some schools are tackling the Big Data problem with programs focused on data science: North Carolina State University, Stanford University, Northwestern University, and University of California, San Diego, for example. However the interdisciplinary expertise of information science provides a unique foundation for the professional and research skills that are essential to engaging the sciences in the data-intensive world. At the Research Data Workforce Summit (Varvel et. al., 2010) three important themes were identified: the need for advancing professional education, the need for coordination across disciplines and sectors, and the identification of key educational challenges. In the United States, information science (LIS) education is exploring how to increase the workforce that can fill this role, and major efforts are underway at several LIS schools including those at The University of Tennessee (UT), the University of Illinois, Urbana Champaign (UIUC), Syracuse University, the University of North Carolina, Chapel Hill, the University of Michigan, and the University of California, Berkeley. Many of these schools, including UT, are part of the iSchool organization, and in the first issue of the *Journal of Big Data,* the iSchool Roundtable noted that the iSchools are taking a leadership role in Big Data problems and solutions. The University of Tennessee School of Information Sciences (SIS) is

[1] In many cases the "M" in STEM refers to mathematics, however we focus on medicine and use this version of the acronym.

uniquely positioned to address this challenge because of a close working relationship with the Oak Ridge National Laboratory, which provides intellectual input from working scientists, as well as access to cutting edge research teams.

SIS has been engaged in STEM information for many years in terms of research (e.g. Tenopir et.al., 2011; Allard, 2012; Wang, 2006) and education. Based on a review of the scientific literature, our experiences with STEM education, and our faculty's deep engagement with a major science data project, DataONE, we identified three key challenges related to developing and maintaining STEM information and science data education programs.

THREE CHALLENGES FOR STEM INFORMATION EDUCATION

The first challenge is striking the appropriate balance between having multidisciplinary understanding and thorough subject expertise. Environmental issues have a high level of cognitive complexity since they incorporate social, economic, and scientific dimensions (Coppola, 1999) and their resolution requires interdisciplinary interaction. However, scientific inquiry also requires a high level of subject expertise, which raises a tension between being a "science domain agnostic" and a "science domain specialist."

The second challenge is providing experiences for students that allow them to begin the "socialization process" of entering the science domains as information professionals. While classroom learning is essential, working directly with scientists during the education process provides a level of understanding that enhances success in the profession after graduation. As professionals they will often be working in a situation that has few if any other information professionals on their immediate team. We know that our students need to create a social identity that allows them to enter the scientific world comfortably. The process known as anticipatory socialization suggests that individuals will choose to join organizations with which they can identify (Kramer, 2010), and individuals play a significant role in their own career development. Additionally students benefit from having multiple mentoring relationships, which introduces them to a range of perspectives and research frameworks (de Janasz & Sullivan, 2004; Tenenbaum, Crosby, & Gliner, 2001). Therefore, it is essential that students have an opportunity to interact with scientists and begin building the ability to identify with the domain. Mentoring relationships involve opportunities for students to observe their mentors in a professional context, to have discussions about professional issues, and to receive feedback (de Janasz, Ensher, & Heun, 2008). Providing the opportunity to "try out" being a professional in the science domain allows the student to envision his or her own career future.

While it may seem simple to "put" students in a scientific setting, it is difficult for two reasons. First, while there are information professionals working in science, they are often concentrated in an organization's library (which is contrary to the sought-after immersive experience with the scientists), or they work in isolated pockets among scientists. Additionally, some team members who focus on the information issues have no formal training in information science beyond what they have learned on the job, which can make it difficult for the student to understand how the foundations of information apply. Finding and successfully engaging "scientist mentors" also entails some obstacles, including identifying willing mentors, matching students and mentors, and negotiating an environment in which both the student and the scientist mentor benefits.

The third challenge is promoting diversity of the information professionals engaged in the STEM domains. Traditionally, women and minorities are underrepresented in the science professions, and this is also a problem among science information professionals. The National Science Foundation specifically describes underrepresented minorities as all groups other than white[2]. The benefits of support, guidance, and observation that accompany a mentoring relationship are essential for the successful professionalization of graduate students, but for minority students, this kind of mentoring relationship is especially important (Hernandez, 1994).

THE SIS STEM EDUCATION INITIATIVES

SIS has engaged in five major initiatives to build STEM specific information education. STEM information needs are dynamic, and each of these five initiatives addresses very different issues associated with STEM related information professions. This section briefly describes the five initiatives, and then we discuss the lessons we learned about each of the three challenges.

1. ***Science Links.*** This masters level program, begun in 2005, is designed to increase the science librarian workforce. It focused on recruiting students from underrepresented populations for professional positions in science libraries and government/industry organizations. The first eight students successfully completed the by summer 2008. This program was initially funded by the Institute of Museum and Library Services (IMLS). Major outcomes of Science Links include: (1) heightening the focus on science information education at SIS; (2) creating a model for integrating internships at science-related organizations into the education program; and (3) successfully being a first effort at recruiting for diversity in science information.

2. ***Science Links^2.*** This doctoral level program, begun in fall 2009, is designed to educate the next generation of science information educators and STEM information research scholars. This program was initially funded by the IMLS. Major outcomes of Science Links^2 include: (1) enhancing interest in STEM information in the UT College of Communication and Information's interdisciplinary doctoral program; (2) creating a focus that led to curriculum change, including adding a doctoral level STEM information and communication course; (3) extending the recruiting mechanism established with Science Links to the doctoral level; (4) including a plan for mentoring using academic and science mentors; (5) demonstrating sustainability, as new students have joined this pathway even though the initial grant funding was exhausted; and (6) resulting in a model for full-time Oak Ridge National Laboratory employees to participate in doctoral education.

3. ***Digital Curation in Environmental Research Centers (DCERC).*** This program, begun in fall 2010, is a joint project led by UIUC. The program addresses both masters and doctoral level studies, with the SIS portion focused on masters

[2] See report at <http://www.nsf.gov/statistics/databrf/sdb96331.htm#note1> (see Footnote 1 in report).

education. This initiative aims to increase the science information workforce functioning as "embedded" information professionals with teams of scientists. The program is funded by the IMLS. Major outcomes of DCERC include: (1) demonstrating the power of collaboration between two iSchools; (2) developing residential practica at the National Center for Atmospheric Research; (3) demonstrating that two LIS programs could share one course successfully; (4) creating a unique mentorship program for matching students with both a science mentor and an information mentor during the residential internship; and (5) graduating the first three masters students.

4. ***SciData.*** This masters initiative focuses on training students for the data intensive world by featuring data science related coursework and experiences, and focusing on skill sets that will address all aspects of the data lifecycle. The program's initiation was funded by IMLS in fall 2011. Students began in fall 2012. SciData is still young but major outcomes include: (1) developing a new recruiting strategy to find students with strong science backgrounds; (2) fully integrating the ePortfolio into the STEM educational experience; (3) helping facilitate the addition of a Big Data analytics course; and (4) introducing cohort level mentoring to encourage students to integrate into the SIS student body, and to help them build a professional identify that includes networking skills.

5. ***La SCALA***. This doctoral level initiative focuses on increasing the presence of Latinos in science information research conducted in the LIS educational community. The program is funded by IMLS. This initiative is finishing its first year so to date, we have been engaged primarily in recruiting students, and now we are heavily involved in developing the formal mentoring plans.

ANSWERING THE CHALLENGES

This section discusses the lessons we have learned in relation to each of the challenges. This discussion references what we have learned in aggregate, rather than focusing on each initiative individually.

Challenge 1: The tension between multidisciplinary and subject expertise

We found that the best way to address this challenge was to employ two strategies: (1) domain sensitive agnosticism, and (2) recruiting.

Domain sensitive agnosticism is the term we use to describe an approach which provides students with a broad view of science and how the different disciplines and domains may interact. By definition, it means that STEM information expertise is not only about subject knowledge, but also heavily features building an understanding of the "science culture" embedded in the domain. We regard "science culture" as the way a domain's scientists "do" science, including their workflow, the granularity of their observations, and their propensity toward interdisciplinary collaboration.

Recruiting was a key to helping promote domain sensitive agnosticism, although discovering this was somewhat serendipitous. While recruiting for each initiative, we encountered a similar issue -- finding prospective students to engage in science domain specialties is difficult. An information degree is often not on the radar of those with STEM bachelor degrees, so finding potential students can be a challenge. After getting the attention of science-oriented people, it is often difficult to explain what information professionals do. Finally, most prospective masters students want to know about their professional prospects, and it is difficult to point prospective students towards employment resources, since there is substantial variation in the names for STEM information-related jobs. However, this situation proved to be a solution to this challenge because it created cohorts that mixed together students with backgrounds from different scientific domains and those with information rich backgrounds which had two advantages. First, it allowed us to avoid the pitfall of specialized approaches, such as educating within specific domains, which ultimately leads to isolated learning (Orr, 1992). Second, it allowed us to build on the success of blending disciplines, (e.g. computational sciences and health informatics) which has successfully been used to address multi-faceted problems and topics (Fischer & Glenn, 2009).

Challenge 2: Socializing students to be information professionals in the science domains

We embraced the importance of practicums that was reinforced by the concept of anticipatory socialization, and also by the findings of the Summit on Research Data Workforce Development (Varvel et. al., 2010). We learned that providing students with an opportunity to complete a practicum is essential, in order to help students learn how to apply their professional toolkit and develop the interpersonal skills necessary to operate successfully in the STEM intensive environment. Practicums help students develop an affinity for working in a science organization, which allows them to envision this as their future career. We learned it was especially important since there is not yet a consistent, preferred job title for STEM information professionals, so students cannot simply use a single job title as a means of identification.

However, the process of finding and matching students to immersive STEM environments raised four issues. First, and most important, is the need to identify locations for practicums. As noted earlier, SIS has a relationship with the Oak Ridge National Laboratory, but it also has strong ties to other science intensive organizations such as Information International Associates, the Office of Science and Technical Information, and UT's medical library that is based in the teaching hospital. These partners are essential in creating opportunities for students to work alongside scientists and practicing STEM information professionals. Some of the STEM environments were established from other research collaborations. For example, SIS' engagement with DataONE provided a bridge to opportunities in the U.S. Geological Survey and in NASA's ORNL Distributed Active Archive Center. Another example is the LIS schools' collaboration in the DCERC program. The investigators at UIUC had strong ties to the National Center for Atmospheric Research, which resulted in our masters students' having the opportunity to participate in residential practicum, with possibilities for the future as well.

While faculty established the relationships, at SIS we have a practicum coordinator who helps maintain contact with these essential partners, since it requires time to discuss potential opportunities and to match the student with those openings.

Second, the practicum needs to be beneficial to both parties. The benefits for students are clear, but a practicum can be a time-consuming situation for the host that may result in too much work without enough benefit to motivate the host to participate in the future. Our practicum hosts shared that it is important for students to spend at least two semesters in the organization. This allows the host to have time to enrich the student's skill set and then to benefit from the results of the training. We found this also increases the student's affinity for working in a science intensive environment, allowing them to become more comfortable in the culture and more confident in their skills. This did not limit students to looking for jobs only in that particular disciplinary area, but it meant that the students knew they could adjust to a science intensive environment and therefore they were more confident during their job search.

The extended practicum solution led to the third issue, which is the need for a mechanism that allows open and positive feedback from the practicum host. We began with informal discussions with the practicum host on an as-needed basis. This method tended to feature discussions that occurred when a student was having a problem. Therefore, we began a more regular check-in process between the faculty advisor and the practicum host. However, this is not a scalable option, so we are moving towards using the system the practicum coordinator routinely uses for all kinds of practical settings. This method consists of a couple of contacts throughout a semester that provides the practicum host with a convenient online form as a conduit for feedback.

The final issue relates to the timing of the practicum during the student's course of study. The student has to have an adequate foundation of knowledge to function in the science intensive information environment in order to be confident enough to learn and to provide a good experience for the host. This creates an interesting tension. Our program is two years long for full-time students, and waiting to begin the practicum until after the student was well versed in STEM information (requiring at least two semesters of classes) was a not a good option, since it limited the student's ability to build an affinity for the field during a crucial time in their development. Our successful strategy is to place the student in a practicum in the second semester of study, and to provide short workshops during weekly meetings in the first semester, that begin to address key issues in STEM information. This solution means the student was better prepared to enter the STEM environment, and the practicum was less taxing for the practicum host.

Challenge 3: Promoting diversity of the professionals engaged in the science domains

While finding students from underrepresented groups can be challenging at the masters level, it is intensified at the doctoral level. Over the course of the five initiatives, we have developed several recruiting strategies.

It takes a focused effort to recruit for diversity. Posting a few announcements to selected venues is insufficient; recruiting requires personal contact and intensive commitment from the program. In our case, because of strong administrative support (we are the director and associate director of SIS) we could recruit with a very aggressive strategy. This included contacting directors and other key personnel at universities with traditionally high levels of minority enrollments. For the masters programs, we focused on institutions with strong undergraduate science programs. The doctoral initiatives were more difficult since we had to identify masters programs that would align with doctoral studies. Our recruiting campaign included personalized outreach by email, campus visits to meet with faculty and students, and a presence at several compatible conferences. We also worked closely with the UT library, which has an exemplary diversity program.

We learned that diversity recruiting is a years-long activity that requires on-going commitment. We found that several of the students who responded to our recruiting efforts had heard about us through friends or faculty a year or more before they made contact with SIS, and ultimately decided that STEM intensive information was part of their future.

The most important strategy is the personal touch. It is essential that students know they will be supported throughout the admissions and education process. They are entering a world where they are even more underrepresented than in the general population, and there are few role models. Therefore it is essential that we help them see how they can succeed personally, and become leaders for others who may enter the field in the future. Sharing this message early in the recruiting process is important, so the student is prepared for this unfamiliar world, but has expectations of success.

THE WAY FORWARD

Information professionals and information educators can make an important contribution to the well being of the nation through engagement with science information and science data. As our five STEM information education initiatives mature, we continue to learn how to create curriculum and extra-curricular activities to develop a workforce of professionals and researchers who can address the science information needs of the future. We also acknowledge that this is a particularly dynamic area and we already see new issues on the horizon that STEM information education will need to address. These include understanding the cyber security issues related to science data and science information, and the emergence of team science. The information community has a lot to offer for the future by providing leadership in both STEM education and research.

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