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Communications in INFORMATION LITERACY

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REFLECTING ON THE STANDARDS [ARTICLE]

TRANSFORMING INFORMATION LITERACY IN THE SCIENCES THROUGH THE LENS OF E-SCIENCE

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ABSTRACT

In 2011, the ACRL Science & Technology Section (STS) completed its five-year review of the *Information Literacy Standards for Science and Engineering/Technology*. Predicated by the evolving nature of scholarship and research in the sciences, the reviewing task force strongly recommended that the standards be revised. This paper considers the broad recommendations of the task force, using the framework of e-Science – team-based, data-driven science – to address areas of necessary transformation in information literacy: an advanced team-based model that crosses disciplinary boundaries; a recognition that individuals and groups not only consume information, but also produce it; and stronger interplay between information literacy and complementary literacies. This paper also extrapolates beyond the sciences, referencing broader trends within higher education.

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INTRODUCTION

In 2006, the ACRL Science and Technology Section (STS) published the *Information Literacy Standards for Science and Engineering/Technology* (ALA/ACRL/STS Task Force on Information Literacy for Science and Technology, n.d.), a document based on the ACRL *Information Literacy Competency Standards for Higher Education.* This subject-specific set of standards defined information literacy in the science, engineering and technology disciplines as, "a set of abilities to identify the need for information, procure the information, evaluate the information and subsequently revise the search strategy for obtaining the information, to use the information and to use it in an ethical and legal manner, and to engage in lifelong learning" (para. 1).

In 2010, STS charged the Information Literacy Standards Review Task Force with the five-year review of the *Information Literacy Standards for Science and Engineering/Technology*, to determine the document's currency and relevancy. The task force was comprised of five ACRL/ STS librarians, with different subject backgrounds, and a liaison from the American Society for Engineering Education, Engineering Libraries Division (ASEE-ELD). Task force members reviewed current (2006-2011) literature related to information literacy practices in the science disciplines. Additionally, disciplinary faculty and accreditation standards were consulted, along with pedagogical journals in the sciences, to assess broader instructional strategies. Task force members also looked more generally at trends and critiques of information literacy, both in the sciences and in higher education.

The task force reviewed the information using the following questions as guidelines:

- What are the curricular trends in this discipline? What are the research trends in this discipline?
- What are the information needs of the students in this discipline? What types of resources are needed? What methods are used for acquiring information?
- What accreditation or professional standards exist for this discipline?
- What skills or competencies are students in this discipline expected to have mastered for graduation?
- What complementary literacies impact or intersect information literacy in this discipline?

Based on discussions about the changing nature of instruction and research in the sciences, the task force recommended that the *Information Literacy Standards for Science and Engineering/Technology* be revised (ACRL/STS Information Literacy Standards Review Task Force, 2011). This paper will address the recommendations of the task force, using the lens of e-Science to explore the transformation of information literacy in the sciences.

THE WHAT AND WHY OF E-SCIENCE

e-Science is still a relatively new concept in academia, and is a compelling case study to use when considering the changing information literacy ecosystem. The rapid advancement of technology has ushered in an era of information overload, and we now live in a world increasingly dominated by Big Data – data so large, it's difficult to process without using advanced technology.

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The term e-Science was first coined in 1999 by John Taylor, then Director General of the Office of Science and Technology in the UK, and describes the new methodology as a set of tools and technologies required to support Big Data-driven science. The National e-Science Centre (n.d.) defines e-Science as, "the large scale science that will increasingly be carried out through distributed global collaborations enabled by the Internet. Typically, a feature of such collaborative scientific enterprises is that they will require access to very large data collections, very large scale computing resources and high performance visualization back to the individual user scientists" (para. 1) (For more background on e-Science, read: Szigeti & Wheeler, 2011).

In 2007, the Association of Research Libraries' (ARL) Joint Task Force on Library Support for E-Science published the *Agenda for Developing E-Science in Research Libraries*. In this document, ARL notes that e-Science embraces interdisciplinary approaches; is data intensive; and "is frequently conducted in a team context, with members of the team distributed across multiple institutions and often on a global scale" (p. 6). The organization takes a broader consideration of e-Science as a subset of e-Research, which "encompass[es] computationally intensive, large-scale, networked and collaborative forms of research and scholarship across all disciplines, including all of the natural and physical sciences, related applied and technological disciplines, biomedicine, social science and the digital humanities" (ARL, n.d., para. 1).

Thus, using the framework of e-Science allows us to more generally view transformations in information literacy in the sciences: it seeks new partnerships, or collaborations, to solve complex problems; it embodies a new model of information consumption and production; and it requires a diverse set of professional skills and literacies that intersect with information literacy. What is happening on the e-Science frontier – and how it impacts and interacts with information literacy – has implications across the sciences, and beyond.

BEYOND SILOS

Through the networked, team-based approach of e-Science, researchers are working together to solve complex problems, across – or without – geographical or disciplinary boundaries. In the medical profession examples date back to the 1970s, where scientists and researchers acknowledged that human health was dependent on a combination of medical, social, cultural and economic factors; Rosenfield (1992) argued that, "to achieve the level of conceptual and practical progress needed to improve human health, collaborative research must transcend individual disciplinary perspectives and develop a new process of collaboration" (p. 1344). In fact, these transdisciplinary collaborations have permeated the sciences and engineering, from human health to agriculture to complex systems, where a conceptual framework allows multiple facets of an issue to be considered in order to actively seek solutions to complex problems.

These changes in the science fields have trickled down to changes in classroom pedagogy. Active learning and problem-based learning pedagogies become imperative in the exploration of new organizational models for team science. Beyond e-Science, science curricula more generally is moving away from traditional lecture-based instruction towards problem-

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based or active learning, with students being tasked to address "real world" issues through experiential learning, service learning, place-based learning, cooperative learning, inquiry-based learning, and community engagement. These methods teach scientific content through activities which are designed to improve students' critical thinking skills, and which allow students to take the information that have learned and apply it to real-world situations.

Integrative and critical thinking – benchmarks of information literacy – are highly valued in the science professions. Critical thinking involves a number of skills that prepare students to understand and evaluate arguments about complex problems and current issues. The interdisciplinary framework also requires students to be able to think critically across the subjects they study in order to present different viewpoints, analyze bias, and present a balanced conclusion or recommendation; students need to develop an understanding of the social, cultural, ethical, aesthetic, and political aspects of the scientific issues they are investigating. Barnett and Miller (2009) write: "progressive learning experiences that privilege experience over rote learning, interaction over silence, applied learning over isolated experimentation and lecture… make learning more meaningful" (p. 1). This shift, crossing boundaries to address complex issues, creates a more realistic approach to today's scientific research environment and affects all facets of information literacy.

The success of this problem-based instruction embedded into the curriculum is that it is built on a progressive, scaffolded approach, while at the same time it is strategic and systematic. Irregular, one-shot library instruction sessions are insufficient to tackle the needs of these students. Even curricular mapping of information literacy competencies through a student's academic career may be unsatisfactory if the process doesn't acknowledge the complexity of the skills and knowledge the students require. Upon graduation, students will be faced with complex – and often ambiguous – issues and problems, and our collective approach needs to be more organically integrated into the curriculum to better prepare students. Our approach to information literacy should not be rote mechanics, but transformative to how students think and behave.

Just as disciplinary silos are dissolving in order to move science forward, so too must the long critiqued, but still popularly internalized, belief that librarians remain gatekeepers, or even watchmen, of the information ecosystem. It is even more imperative now to work within and across teams to implement information literacy in meaningful ways; what this means is a more comprehensive collaboration with disciplinary faculty members and curriculum committees. While faculty have come to understand information literacy in its broadest strokes, librarians have often lacked the means to communicate information literacy competency goals and methods clearly to faculty and administrators, entrapped by the language specific to the field of information science. Moving forward, a more sustained effort needs to be made to translate the concepts of information literacy for stakeholders, and to employ the team-based model of e-Science to implement its principles in meaningful ways for students.

Beyond consumption

Scientists are learning and applying new data science research techniques in order to analyze, visualize, and organize data to

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solve scientific problems, and e-Science represents a major structural and cultural redesign of how knowledge is produced. It's not just about accessing data, but also about manipulating data, often from several disparate sources, in order to create new knowledge. This moves scientists beyond simply consuming – accessing – information, into the realm of producing new information.

Hey & Hey (2006) acknowledge this shift, stating, "the nature of scholarly publishing is changing. Not only is publication on the web, in one form or other, enabling access to a much wider range of research literature but also we are seeing the emergence of data archives as a complementary form of scholarly communication" (p. 522). In fact, starting in 2011, all proposals submitted to the National Science Foundation (NSF) require a supplementary document that outlines the researchers' data management plan for dissemination and sharing of research results. In 2013, the Office of Science and Technology Policy (OSTP) released a mandate, "…the direct results [of] federally funded scientific research are made available to and useful for the public, industry, and the scientific community. Such results include peer-reviewed publications and digital data" (para. 1). As a result of directives such as these, much of the focus in the libraries, therefore, has revolved around the development of data management planning, the process of preserving and curating the information generated during a research project. Tools, such as Data Curation Profiles (http://datacurationprofiles.org/) and DMPTool (https://dmp.cdlib.org/), have been created to help meet the needs of researchers.

The ability to discover, search, access, as well as mine and manipulate data, has become a central requirement not just for scientists, but also students engaged in data-centric methodologies. "To prepare the next generation of scholars, the knowledge and skills for managing data should become part of an education process that includes opportunities for students to contribute to the creation and the preservation of research in their fields" (Ogburn, 2010, p. 244).

Curriculum, with an emphasis on content creation and management in the digital environment, is being adapted to meet these needs. Carlson et al. (2011) emphasize that, "it is not simply enough to teach students about handling incoming data, they must also know, and practice, how to develop and manage their own data with an eye toward the next scientist down the line" (p. 632). This idea, termed data information literacy by the authors, teaches students about managing their own data with an understanding that it may need to be accessed in the future to validate, explain or augment subsequent research, which reinforces the real world needs of research groups. "E-Research is, by definition, a social process, and contributing to – not just extracting from – the community's knowledge base is crucial. Data information literacy, then, merges the concepts of researcher-as-producer and researcher-as-consumer of data products" (p. 634).

Purdue University Libraries has developed the Data Information Literacy Project (http://wiki.lib.purdue.edu/display/ste/Home), an IMLS-funded project to investigate the information needs of researchers in the e-Sciences, and to develop a data information literacy curriculum. Other efforts include the NSF-funded Science Data Literacy Project at Syracuse University (http://sdl.syr.edu/), which focused mainly on data management, and an IMLS grant used to develop e-Science learning outcomes for integration

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into science curriculum that include: an overview of research data management; types, formats and stages of data; contextual details needed to make data meaningful to others; data storage, backup and security; legal and ethical considerations for research data; data sharing and re-using policies; and planning for archiving and preservation of data (Piorun et al., 2012).

"The capture, dissemination, stewardship, and preservation of digital data have therefore been identified as critical issues in the development and sustainability of e-research" (Carlson et al., 2011, p. 630). Curation and preservation of data can be seen as a subset of personal records management, which transcends the sciences. While above curricula is being developed specifically related to managing and preserving data, there are broader considerations that can be extrapolated; students and researchers produce a variety of digital objects – from documents, to multimedia, to games and simulations – whose preservation needs to be understood and addressed long-term if the knowledge is to remain a part of the future information ecosystem.

BEYOND INFORMATION LITERACY

Students graduating with degrees in the sciences and engineering are expected to graduate with scientific and technical expertise in their fields by demonstrating competency in areas such as experimentation, laboratory research, fieldwork, and mechanical drawing, and producing technical reports, scientific papers and presentations, lab reports, datasets, and prototypes. e-Science goes beyond interdisciplinary collaboration and data management planning, requiring student proficiency in navigating numerous complementary and intersecting literacies, including information literacy, technology literacy, digital literacy, visual literacy, and data literacy.

Data literacy – which differs from the more nuanced data information literacy concept outlined above – focuses on the functional ability of collecting, using and evaluating data, and involves, "understanding what data means, including how to read graphs and charts appropriately, draw correct conclusions from data, and recognize when data are being used in misleading or inappropriate ways" (Carlson et al., 2011, p. 633). Likewise, in order to handle vast amounts of Big Data, fluency in technological or computer literacy is requisite.

e-Science concerns itself not just with creating and manipulating data, but also creating visual representations of data (data visualization). According to Friedman (2008), "…the main goal of data visualization is its ability to *visualize* data, communicating information clearly and effectively… *Infographics* – visual representations of information, data or knowledge – are often used to support information, strengthen it and present it within a provoking and sensitive context" (para. 1). Data visualization – both its creation and interpretation – falls under ACRL's definition of visual literacy: "Visual literacy skills equip a learner to understand and analyze the contextual, cultural, ethical, aesthetic, intellectual, and technical components involved in the production and use of visual materials. A visually literate individual is both a critical consumer of visual media and a competent contributor to a body of shared knowledge and culture" (ACRL Visual Literacy Standards Task Force, 2011, para. 2).

Beyond these specific literacies, science and

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engineering students are expected to graduate with a set of professional, or "soft," skills in order to be successful in their fields. Employers recruit graduates who have experience with professional skills that include: written and oral communication; problem solving, investigative, analytic, critical and creative-thinking; teamwork, leadership and conflict management; project management; and ethical behavior (ABET, 2011; ACS Committee on Professional Training , 2013; Institute of Physics, 2010). These types of professional skills have been broadly defined in the literature as "21st century literacies." One of the main precepts of this framework is the recognition that some of these competencies are external to an individual, and are predicated on social skills, including the ability to listen to and actively engage with others. Recent discussions of digital literacy skills acknowledge the necessity of participatory learning and collaboration, especially as social media becomes more predominant and content creation proliferates (ALA OITP Digital Literacy Task Force, 2013); this view recognizes the symbiotic relationship between information literacy and digital literacy.

Likewise, the concept of transliteracy is, "very concerned with the social meaning of literacy. It explores the participatory nature of new means of communicating, which breaks down barriers between academia and the wider community and calls into question standard notions of what constitutes authority by emphasizing the benefits of knowledge sharing via social networks" (Ipri, 2010, p. 533). The author continues, "The social aspects of transliteracy can enhance the workplace by creating robust systems of knowledge sharing and can enhance user experience by granting them a role in the construction of information" (p. 567). In writing about lifelong learning and information literacy in the workplace, Weiner (2011) writes, "Social aspects are involved because people learn together and human relationships have a key role in development of information literacy" (p. 10). It is this recognition that learning, within and across multiple dimensions (information literacy, digital literacy, 21st century literacy, etc), occurs in social contexts that is crucial in the e-Science framework, but resonates far beyond the borders of the sciences.

CONCLUSION

This paper has used the framework of e-Science to discuss the currency and relevancy of ACRL's *Information Literacy Standards for Science and Engineering/ Technology*. While it doesn't go so far as to propose a new model of information literacy in the sciences, it provides a lens through which we can examine the areas in which to seek transformation in information literacy: the role of collaboration and teamwork in an unbounded environment; the recognition of individual-as-consumer and individual-as-producer of information; and an expanded approach that incorporates complementary and interconnected 21st century literacies and skills.

ALA's American Association for School Libraries (AASL) *Standards for the 21st Century Learner* (2007) serves as an interesting model that takes on a broader view of information literacy. The document clearly states that school library programs seek to empower learners by building flexible learning environments, with the goal of producing successful learners skilled in multiple literacies. The learning standards acknowledge that individuals need to acquire the thinking skills that will enable them to learn independently, but also that

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"learning has a social context," and that students need to develop skills in "sharing knowledge and learning with others" (p. 3). The process is as important as the product.

Mackey and Jacobson's (2011) model of metaliteracy, "expands the scope of information literacy as more than a set of discrete skills, challenging us to rethink information literacy as active knowledge production and distribution in collaborative online communities" (p. 64). Further, "metaliteracy provides a conceptual framework for information literacy that diminishes theoretical differences, builds practical connections, and reinforces central lifelong learning goals among different literacy types… The abilities to determine, access, evaluate, incorporate, use, understand, produce, collaborate, and share information are common considerations" (p. 76).

These two models help us think more broadly about lifelong learning and "habits of mind" so that we may better facilitate new approaches to information literacy. The profession has come a long way in its evolution from bibliographic instruction, with its emphasis on skills, to information literacy, with its emphasis on skills and knowledge. We must continue reframing our narrative in order to expand the boundaries of what is "information literacy". It is time to shift the framework away from thinking about information literacy as a complicated, insulated system, and begin thinking about it as a complex system that is interactive and iterative; a system that is diverse, made up of multiple interconnected elements (skills, knowledge and behaviors); and a system that is dynamic, one that can adapt, change and grow through experience.

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