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2014

# The Changing Role of Digital Tools and Academic Libraries in Scholarly Workflows: A Review

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# The Changing Role of Digital Tools and Academic Libraries in Scholarly Workflows: A Review

*Research Article*

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## Abstract

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In this paper, we review the literature on how information literacies are manifested in scholarly workflows for undergraduates, graduate students, and scholars, and the need to support integrating library resources into their knowledge practices, and how available tools support their needs. We argue that research is needed on how libraries and digital tools both support, and indeed teach, knowledge-building practices across the entire lifecycle of knowledge. Finally, we advocate for studying researcher and student workflows as a way to both improve the tools we make available, and more importantly, to inform us on the role(s) libraries can play in the shifting practices of research in an information-rich world.

**Keywords:** research workflows, information literacy, technology adoption, libraries, information technology, scholar workflow, undergraduate research, graduate research

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Received: 29 September 2013; Revised: 30 June 2014; Accepted: 25 June 2014

Nordic Journal of Information Literacy in Higher Education, 2014. ©2014 Sharon Favaro and Christopher Hoadley

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## Introduction

With the emergence of new tools and technologies, information practices have changed radically. Libraries, which previously served an information warehousing, dissemination, and search role, now serve patrons whose information habits are continually being reshaped. Increasingly, the work of scholars focuses more on just-in-time retrieval, quick bootstrapping to learn new disciplines, online collaboration throughout the research process, and knowledge construction and dissemination activities unlike traditional publishing. For example, the Association of College and Research Libraries (ACRL) indicated in a 2012 report that their existing standards on information literacies need to be “extensively revised” due to these shifting practices. In 2014, a draft of the Framework for Information Literacy for Higher Education was released, according to ACRL President Trevor A. Dawes, “The revision of the ACRL information literacy standards is vital in order for our libraries and librarians to think about, understand, and use new methods of incorporating information fluency in our curricula.

Similarly, greater access to information increases the need for scholars of all types to learn how to effectively marshal information resources throughout the knowledge construction process. For example, Leckie (1996) identifies gaps between the practices of faculty, students, and librarians, as well as differences in research skills between novice and expert. Although students may be familiar with new information tools such as microblogs, photo sharing, social networking, or filesharing tools, students are unfamiliar with the research process and lack subject domain knowledge, thus implying even a basic search by subject or author is challenging. In contrast, faculty have well established networks for research, i.e. informal communications, citation lists, and domain expertise (Leckie, 1996; Acord & Harley, 2012), but often may not be fluent with Internet-based information retrieval and collaboration tools. An additional barrier is that not only do students lack understanding of the research process, but faculty also lack understanding of the skill level of the student (Leckie, 1996). Information seeking skills are crucial, but are only a piece of the larger overall process of research. Libraries’ role in supporting both novice and expert scholars is changing. In the past, libraries’ information storage and retrieval role was vital, uncontested, yet separated from the core research and learning processes of knowledge-building which took place in laboratories or classrooms. Now, as the Internet subsumes much of the storage and retrieval roles, libraries face a choice. Libraries have an opportunity to become a key partner in the use of information throughout the research process beyond storage and retrieval (including increasing their role in helping new scholars learn to effectively use, share, and disseminate information resources throughout the lifecycle of knowledge); otherwise, libraries risk becoming a less integrated, paywall-filled alternative to the Internet. Although there are many tools to support research, there are profound disconnects between library-oriented resources and tools, and the other tools scholars use to do their work. Scholars increasingly turn to online tutorials and MOOCs (Massive Open Online Courses), Internet search engines, and collaborative sharing and writing environments, in some cases bypassing traditional publishing institutions entirely. Libraries could become increasingly marginalized in the workflow of scholars, where ‘going to the library’ (whether virtually or physically) can be seen as disruptive within the larger context of scholarship and the activities of learning, collaborating, and writing. While online services and tools have attempted to decrease barriers to using library resources, the fragmentation of the tools for library work and the tools for the rest of research instead serves as a disincentive. For example, Gargouri et al. (2010) found that articles available freely on the web are significantly more likely to be cited. Some might argue that this relates to paywalls and subscriptions, but it is also entirely plausible that scholars are more likely to cite work found on the web simply because it is easier from within their workflow. Regardless, clearly technologies have an impact on the practice of scholarship. This is both a challenge, and an opportunity, for libraries.

In this paper, we describe a possible way to explore the issue of the changing role of libraries in information literacy as a component of scholarly research. First, we discuss information literacy in the context of the larger generation of knowledge through a lifecycle

model of knowledge comprising research and education. Second, we summarize the literature on how students and faculty use information tools and library resources to accomplish their work in this knowledge lifecycle, and points of friction where tools fail to support these scholars. Third, we explore these points of friction and explore possible new roles and tools for libraries by proposing use cases of researcher workflows. Finally, we describe some of the research needed to carry this agenda forward.

## **The lifecycle model of knowledge**

What is the purpose of library-based information? This question highlights that although information may be valued, it is not intrinsically valuable except as an instrument in the creation and dissemination of knowledge. Historically, the lifecycle of scholarly knowledge was one in which roles were highly distinct. Scholars would create ideas which were written down as information resources. Publishers helped filter and quality check this information, and then replicated the information media and disseminated it through sales networks. Libraries and to some extent bookstores helped curate, preserve, index, and broker these information resources. Then, the information resources would either be used in the context of formal teaching and learning, informal learning (e.g., public libraries), or professional scholarship (student and faculty library research), which helped begin the cycle anew. This description focuses primarily on the information resources represented by media such as books, journals, etc.

Knowledge, however, is not identical with information. In this stereotypical model of research leading to publishing leading to teaching and learning, the knowledge itself follows a different path. First, both philosophy and educational psychology have described the degree to which knowledge is not transmissible directly; rather, a knower must learn knowledge by constructing new understandings based on his or her own prior knowledge (i.e., the constructivist theory of learning, proposed by Piaget (1970). Moreover, this construction of knowledge is intrinsically socially embedded (Vygotsky, 1978). Whether through invention, co-construction through discourse, or through the experience of monologic information resources such as texts (Bahktin, 1984; Enyedy & Hoadley, 2006), the knowledge is not properly considered known until it can be applied in some fashion, and this learning process is demonstrably not mere transmission of information (Dewey, 1897/1954).

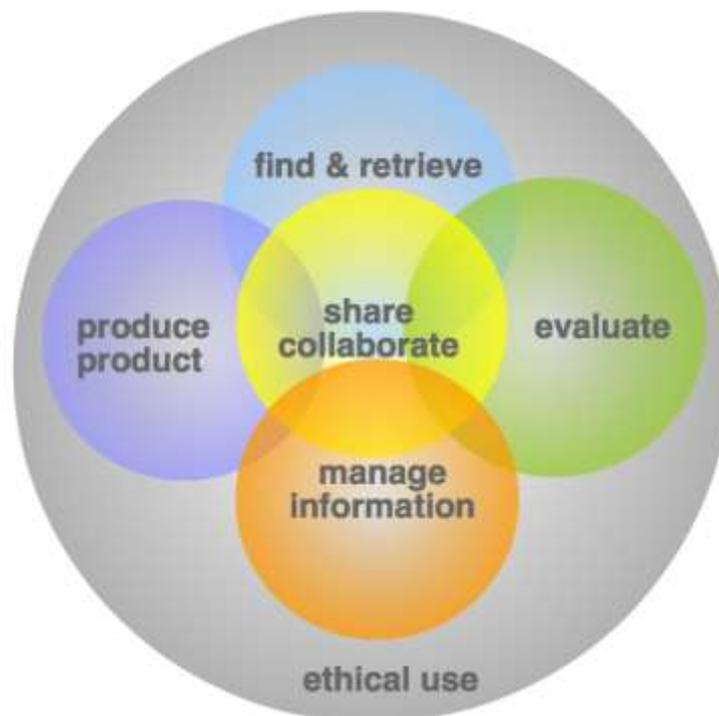
Scholars have a particular stance regarding knowledge; the word has become synonymous with both studying, deliberately cultivating the knowledge of others in oneself; and with knowledge discovery, or creating new ideas or interpretations, often through both writing and teaching. This goal entails a particular set of activities that represent the working lives, the workflow, of scholarship. This workflow encompasses not only reading and writing tomes, but debate, teaching, critique, discussion, exploration, organization and juxtaposition, and application, not to mention any non-literature based research activities such as collecting data in the empirical disciplines.

Traditionally, libraries have focused on supporting and training scholars on the portion of the scholarly workflow that comprises information seeking and supplying and/or locating information, usually under the moniker of 'information literacy'. For example, the Association of College and Research Libraries (ACRL) defines information literacy as: finding, retrieving, analyzing, and using information. Similarly, the Eisenberg-Berkowitz Information Problem Solving model is a six stage process: Identify information requirements, information seeking strategies, location and access, use of information, synthesis, and evaluation (Cortell & Eisenberg, 2001). In both of these definitions, the focus of information literacy tends to be on the front-end process of gathering information for research, rather than on the entire process of doing scholarly work, with much of the work hidden under broad notions of 'synthesizing and applying'. With the changing information environment: ebooks, open access, public search engines such as google scholar, large amounts of information including online research datasets,

and new collaboration tools and technology, the research workflow is changing. Yet, libraries have not fundamentally changed either the role they expect to play in these shifting practices of scholarship, nor in this changed world where libraries are often only one of many sources for information. For instance, scholars might collaborate to write a paper online at a distance in Google docs, may share research data via Dropbox, could explore unfamiliar related topics by starting with Wikipedia or a web search, or publicize their work via social media. These are all information-intensive portions of the research workflow that libraries, library resources, and library-provided digital tools could support, but typically do not.

This is not simply a question of tool integration to make existing research practices more convenient. Rather, as with Internet-mediated shifts in other domains, research practices are becoming more ad hoc, decentralized, and nimble (Brown & Duguid, 2000; Shirky, 2008). It is increasingly important because scholars must learn to locate and integrate resources at all times in the research process; for example, a scholar must be prepared to 'synthesize and apply' a citation suggested by a collaborative author; to 'identify information requirements' in a new way when submitting a prior manuscript to a newly identified journal or a conference in a different subfield; to evaluate or synthesise when reacting to comments on a draft in an open review system; or simply to be able to answer questions that arise during the writing process. Each of these practices is different enough from the traditional model of information literacy that different skills are needed to be truly information literate scholars. We therefore think that libraries should expand their mission from supporting not only the ACRL definition of finding, retrieving, analysing, and using information but also sharing, collaborating, managing, and dissemination, all within the context of ethical use.

**Figure 1:** Life model cycle of knowledge (Favaro, 2012; Favaro & Hoadley 2012).



## **Review of Literature: What are scholars doing and what do scholars need?**

From the perspective of research libraries, how should we support students and professional scholars within the entire lifecycle of the research process? We begin to answer this question by posing another: What are the differential workflows and needs of research library users? Below, we discuss the research on undergraduate students, graduate students, and professional scholars. After exploring these workflows and research practices, we consider how libraries and their tools might better support the emerging practices of scholarship.

### **Supporting undergraduate students**

As previously stated, undergraduate students typically lack knowledge of the entire research and knowledge building process (Head & Eisenberg, 2010; Leckie, 1996). The transition from high school to college research typically leaves a large skill gap (Favaro, 2012). Head and Eisenberg (2010, p. 21) found that undergraduate students had changed their research practices from high school. One way in which these practices change is that undergraduates are required to take ownership of their learning (Smith, Given, Julien, Ouellette & DeLong, 2013). The usual response to the knowledge gaps of students in doing research using library resources is a patchwork of classroom and library-offered training, but rarely do we focus on directly supporting students learning about the research process while enacting it. In addition, Cottrell and Eisenberg (2001, p. 345), found that information communication technology (ICT) failures disrupt the information seeking process. The disconnects between tools may further hinder learning about the process. Cottrell and Eisenberg (2001, p. 345) call for adding “synthesis tools” to support the entire model of the information seeking process. Tools to support students through the entire process could not only reduce cognitive load for students doing (for them) a novel and difficult task which in itself can support learning (Favaro, 2012; Plass, Moreno, & Brünken, 2010), but such tools could also directly scaffold best practices in the complex task of writing a research paper (Favaro, 2012). Students do try to use digital tools to make their work easier: Eisenberg and Head (2010, p. 22), found that approximately half of the 25,000 undergraduate students they surveyed made use of citation managers, digital highlighters, and document sharing (i.e. Google docs). It is discouraging that these three categories of tools which were found to be the most used research tools by undergraduates typically have no integration with each other. For instance, imagine the loss of focus and the distraction created whenever a student needs to move from a highlighted PDF to typing the metadata into EndNote or Zotero, and then additionally needs to manage moving the document and inviting collaborators into a space such as Google docs or Dropbox. There are ubiquitous disconnects between tools; between tools and the library; and between tools and research process. These disconnects not only have productivity costs, but also have learning costs. Research in software to support scientific inquiry in primary and secondary school students shows that explicitly scaffolding a model research process can improve how students learn not only the disciplinary content but also the research process itself (Quintana et al., 2004; Schwartz, Brophy, Lin, & Bransford, 1999).

Additionally, students may lack ICT skills generally and overestimate their “research skills” (Buschman & Warner, 2005). For students with low access to technology before entering universities and colleges, the lack of technology skills can be crippling. Even if students have prior technology skills, they are generally not integrated with the practices of good scholarship. Furthermore, when ICT skills training is provided at the undergraduate level, it is just as fragmented as the toolsets. While libraries are a natural place to provide technology training, they tend to focus on only limited parts of what students need to learn, usually database search and retrieval. Within libraries, information literacy training tends to be disconnected from the tools that support it (Tuominen, Savolainen, & Talja, 2005). Students might be given training in study skills and reading skills by student affairs; in database access and retrieval by a librarian; and in appropriate scholarly reading and citation practices by a subject matter professor.

## Supporting graduate students

There is a growing need to support graduate students in research workflows; their need tends to be less on information seeking, as typically at this point they are advanced users, and more on information management. According to a report published by Association of Research Libraries (Covert-Vail & Collard, 2012) graduate students will not only need skill-sets for finding resources, bibliographic management, basic technical skills, knowledge of discovery and delivery tools, but also the ability to use advanced technology for analytical and methodological skills (i.e., data mining or data visualizations).

A study, "Researchers of Tomorrow: The Research Behaviour of Generation Y Doctoral Students", conducted a survey of 17,000 doctoral students and 70 higher education institutions across the UK on a variety of topics, including their use of digital tools (JISC, 2012). Key findings of their study indicated that generation Y students and older doctoral students adopt technology, such as alerting tools (RSS), text and data mining tools, and social bookmarking, at similar levels; access and authentication to resources are problematic; open access and copyright is a point of confusion; doctoral students are not fully using innovative technology nor are they trained or informed of opportunities within digital landscape. In general, tools are adopted when there is an immediate fit within their research workflow (JISC, 2012). While many explanations of this are possible, one is that institutions are providing access to tools that are less likely to fit into the research workflow of the modern graduate student. An alternative is that specialised tools come from institutions while more general-purpose tools come from the consumer Internet. A study of 45 humanities doctoral students at Columbia University and Cornell University, found students had frustrations with online citation tools, e-book formats, and managing their own personal libraries and the needs for tools to support their work including linking bibliographies and note taking (Gessner, Jaggars, Rutner & Tancheva, 2011). Additionally, most students relied on advice from peers and advisers, rather than asking a librarian or technologist (Gessner et al., 2011). Several graduate student blogs reviewed describe a need for writing tools to be integrated with document, annotations, and citation management. Graduate student bloggers' recommendations of tools and workflows, sometimes held together with custom scripts or code, seem to be a growing theme, further evidencing the need to have better integration of tools between the library and the research process (Lawson, 2009). One doctoral student advocates for a space or "one-stop shop" for annotations, writing, storing documents, citing, during the dissertation writing process and for use later as a searchable database (Schafer, 2011). An important point made by Schafer is that 'a searchable database' is pertinent for later use in the dissertation writing process, later use as faculty member, researcher, etc.

Often, when confronted by disconnect between the tools and the research and writing goals, typical practices can consist of piecing together software and sometimes with code to make them connect. This code can be developed directly by the scholar or made open source and searchable so that researchers can download and use it. However, this brings with it issues of access for those not as information literate or programming savvy.

An example of the disconnects caused between the research and the writing process is illustrated by Lawson (2009):

(...) I presume to be the more common, is that if one has a very large quantity of notes on many different sources, when one shifts into the writing mode, one has to hunt through one's notes looking for the information relevant to the claims one wishes to make in that particular section of the dissertation. This is the problem of the lack of the "middle layer" of organization that I referred to in my first posting and for which I have presented a temporary and imperfect solution for in the second posting.

Lawson laments about tools that do not support the process in cohesive manner. To flip back and forth between notes then shifting to writing impedes workflow and thought process as one must sift through material for the writing process.

Other issues cited by graduate students include understanding best practices along with technology. Another graduate student blogger (eCommunitas2.0, 2011), consults with other researchers for best practices for technology to support research. Researcher recommendations included using a Mac for ease of use and including Mac software, rather than using the advice from the University's help desk. First, the fact that the student would contradict the explicit recommendations of a university help desk on which he was depending for advice shows that there is likely a strong motivation for using the platform and tools assembled. Second, the students' choice of tools demonstrate how activities can cross the phases of information behaviour specified by ACRL information literacy definition: communication or brainstorming are not the types of activities that neatly fit into find, retrieve, analyse, use categorisation. Third, this example highlights the high bar necessary for library resources in that robust interoperability with these tools would require modification of a huge swath of software across a wide variety of developers and application areas. Finally, the case shows that graduate students seek counsel of other researchers and informants such as the IT help desk, to help them better understand how to do research using digital tools, supporting the idea that learning and scaffolding could be provided in the context of those tools.

The study "Researchers of Tomorrow: The Research Behaviour of Generation Y Doctoral Students study" (JISC, 2012), found that doctoral students were not quick to take up technology unless it readily integrated with research work practices, and preferred tools to alert for new resources rather than having tools to organise their research. Doctoral supervisors and peers influence technology adoption, and technology offered by institutions may not always be appropriate, flexible, or may "lock-in to proprietary systems" (JISC, 2012, p. 69). An important point in this study is that libraries did not play a key role facilitating technology in the research workflow, and librarians were seen more for information seeking consultations. Could the role of the librarian be more visible in supporting the technology of the research workflow? Hence findings go on to include comments from students of what they wish they had learned: Many of the student cohort wished they had known about certain technologies and applications that they realised might have eased the workflow and research process; Google Scholar, cloud computing, EndNote and Mendeley were all mentioned as things researchers did not know about until too late. (JISC, 2012, p. 71).

Thus, we see that while graduate students may have mastered basic research skills and have nascent workflows for scholarship; those workflows are still fragile and subject to inappropriate tool selection and fragmentation. Furthermore, graduate students face scaling issues as their scholarship workflows come to encompass not only isolated research projects, e.g., for a course paper, to a potentially lifelong cumulative scholarship and knowledge base, containing a mix of primary sources and metadata, personal notes and annotations, and shared resources from peers and faculty. Again, this workflow provides opportunities for us not only to support their information use, but to provide a nexus to scaffold their learning best practices in the research tradition for which they are being trained. For example, Rutner and Schonfeld (2012) found in a study of historians and graduate students of history that the best practices of information use from archives and libraries are missing from traditional training. A graduate student was quoted as saying,

One of my big issues with graduate education in general right now is that there's almost no training with methodology and what you actually do in the archive and why that matters. You don't always know how to ask someone for help. There are larger philosophical questions about what an archive is. I haven't gotten systematic training. I had done some archival work through previous education.

I'd been to an archive and I kind of knew how to use one on a basic level. A lot of it is figuring it out as you go. (Rutner & Schonfeld, 2012, p.37).

Another student said even more simply, "I would be interested in attending a session about organizing information and writing [it] up." (p. 37). While the first quotation focuses more on learning needs related to tasks traditionally done in a library, and the latter focuses more on learning needs related to tasks traditionally done outside a library, both connect directly with library-related resources. What both of these quotes demonstrate is that successful information practices, workflows, and learning the inquiry methods of the discipline are intertwined, reinforcing our idea that if we can support workflows across the lifecycle, we may also be able to support learning about the entire lifecycle of scholarly knowledge.

Thus, we see that graduate students are using a wide variety of digital tools to accomplish their work. Increasingly, those tools include not only university-or library-provided tools, but also a variety of tools from the broader Internet. Commercial and free software providers on the Internet have advanced beyond libraries in designing tools that explicitly support social information flow, collaborative writing and data analysis, and low-threshold sharing and publication. What does this imply for how libraries can conceptualize the research process of their users? How can we envision the role of libraries in a much broader process of knowledge building that extends beyond a trip to the library or constructing a bibliography?

### Supporting scholars

Scholars, faculty and professional researchers, expect tools to support them in their research process, but these tools are lacking and rapidly changing. As noted by other scholars, the changing nature of research due to both the explosion of information and the increasing interdisciplinary nature of scholarship has heightened the need for collaboration in research (Harley, Acord, Earl-Novell & Lawrence, King, 2010). Rowlands, Nicholas, Russell, Canty, and Watkinson (2011), found the main use of social media within the research workflow is used for collaborative authoring, conferencing, and scheduling meetings. Rieger (2010) found that humanities scholars wanted their institution (i.e. libraries, academic learning centers, digital humanities centers) to support the ICT, thus allowing them to focus more on research rather having to 'understand, manage and sustain' new technologies. Bauder and Emmanuel (2012) conducted a survey on technology use in faculty workflows and found that the preference was for customized web portals thus showing only relevant content. Burke (2011) blogged about the type of tool needed for his research, which would "generate several kinds of notes as I read through it: a) direct quotations; b) summaries of the argument or analysis or content of a particular section or part of the source; c) my own commentary on or responses to what I'm reading."

Scholar workflow may involve high level of collaboration, in some cases working with scholars at several different institutions. An example of workflow for writing a paper is illustrated in Kim and Crowston (2011):

We conceptualize cyber-infrastructure as an assemblage of diverse technologies, as a collection of computing elements and software-based systems assembled to address an individual's diverse computing needs. For example, in writing this paper we used Google Docs, Microsoft Word, EndNote, Google Scholar and a range of library databases, a collection of articles as PDFs in various folders on a laptop, email, ManuscriptCentral, not to mention more infrastructural technologies such as the Internet, Mac OS X, Windows and laptops. The conception of an assemblage emphasizes that digitally-enabled work is increasingly done by drawing on multiple systems that are rarely well-integrated and often not formally planned, designed, delivered or governed. (p. 2)

Further evidence of workflow, provided on Chad Black's blog "Parezco Y Digo" (Black, 2011), is a list of nine steps in his workflow and a compilation of 13 tools, occasional use of five more tools, plus scripts. One thing that is very apparent in Black's workflow is the emphasis on "Ubiquitous access and backup" as he notes working from multiple locations and creating archives. Being able to access work from multiple locations and creating archives, are key features for designing software, to facilitate ease in access during the research process and proper storage techniques to ensure access.

### **Workflow Differentiations**

It's important to note that as students become scholars, their workflow may be more and more differentiated by discipline; thus the workflow needs of a historian using medieval central Asian primary sources is likely to differ significantly from that of an experimental psychologist referring primarily to her own datasets and published articles, from that of an astrophysicist whose work relies almost exclusively on large shared datasets and/or collaboration with dozens of co-authors on each paper. One set of tools to support scholars in certain fields is the concept of a 'collaboratory' (Finholt, 2002). While collaboratories may provide shared support for data gathering, analysis, and writing, they traditionally have not provided any integration with the types of resources libraries manage.

Increasingly, libraries are beginning to be asked to participate in supporting the data management and archiving functions of the research lifecycle. Libraries can provide stewardship, archiving, preservation, and access (Delsereone, 2008), as funding agencies such as the National Science Foundation (NSF), National Institute of Health (NIH), and Institute of Museum and Library Services (IMLS), have included data management plans and access to data as part of the application process. A memo released by the Obama administration calls for expanded access to federally funded research (White House, 2013).

There is a need for libraries to also partake in training scholars in best practices for data management. An Ithaka study (Long & Schonfeld, 2013) found that chemists need data management support as they do not have sufficient training in data management practices including proper data storage in formats and metadata standards. They also identify a shift in the custodianship of shared information repositories from libraries to discipline specific databases, such as databases of information on specific chemicals, or repositories of experimental data on chemical structure (p. 39). However, again, these tools typically would not be deeply integrated with the tools and resources used elsewhere in the research workflow. It would be easy to mis-conceptualise this type of support as simply supporting and making more efficient the scholars' research practices, but even here there is a learning role that can be played. Williams (2002) describes the role of technology in not only accelerating but fundamentally changing disciplinary inquiry across the humanities and sciences in her role as a dean at MIT, and similarly Long and Schonfeld (2013) identify collaboratory, discovery, and knowledge management as functions that are lacking in the information practices of experienced chemists. We anticipate, building on the collaboratory idea, that even experts are always learning new knowledge-building techniques as technology advances in its ability to provide new lenses on disciplinary knowledge.

### **Research Tools integration with research lifecycle and the library.**

If so far as there are tools, the ones that support library work rarely integrate with the whole research lifecycle or even each other. The previously cited workflow cases from Ithaka (Long & Schonfeld, 2013; Rutner & Schonfeld, 2012) both explicitly identify a need for tools to be integrated to facilitate better research practices, both for students and expert scholars alike.

Thus, we see that while tools are either extant or coming into existence to support a wide variety of aspects of the entire research cycle, nothing supports scholars across the entire

process. What this table fails to show is the dismally poor integration of these tools with each other. Even in cases where there theoretically is interoperability, the difficulty of moving information from one tool to another is great, requiring advanced technological skills and tediously lengthy procedures. This lack of interoperability can be a real barrier in the networking and production of knowledge (Hoadley & Pea, 2002). Again, we additionally believe that tools can not only reduce barriers to research, but can explicitly scaffold good research processes.

What can be done? Hoadley and Pea (2002) advocate a seven stage process to support knowledge networking in communities: defining the scope of the community, examining existing practices, identifying potential improvements, identifying potential technologies to support those improvements, designing and building technology for the community, cultivating a community of use around those tools, and finally understanding and evaluating the outcomes. Treating the community of researchers, from undergraduates through faculty, at universities and colleges as our scope, there is much work to be done on each of these stages. At this moment, we especially advocate investigating the existing practices of research workflows among faculty and students.

### **Constructing use cases of researcher workflow**

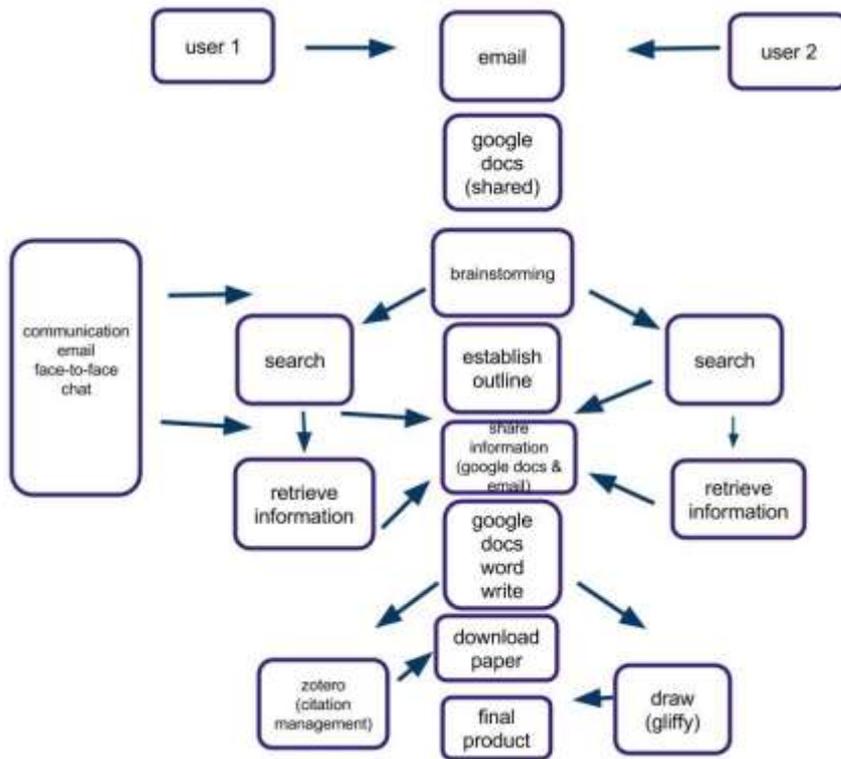
We believe the first step in re-imagining the role of libraries is to examine the workflows of researchers, both novices and experts, and identifying ways not only to streamline how tools might support integration of information resources beyond the retrieval phase of research, but more importantly identifying ways to support novices to learn best practices about the uses of information resources across the knowledge lifecycle.

The research workflow is still relatively poorly understood. To understand research workflows, we draw on the tradition of use cases as a research tool from the Human-Computer Interaction literature (Preece, Rogers, & Sharp, 2002). Information systems design often relies heavily on user research, in particular workflow analysis and development of use cases, to help identify needed information supports. The purpose of a use case is to describe a full scenario of use of the relevant tools within the context of a particular task or subtask. They act as generalized stories, in which actors, tools, actions, and outcomes are described. In short, use cases are simply descriptions of sequences of events that, taken together, lead to a system doing something useful (Bittner & Spence, 2003). Use cases can be empirical records of actual user behavior, hypothetical activities of prospective users, or an abstraction or generalization of typical behaviors. Use cases are not only a research tool, but also can be used as a mechanism to involve users in a design and development process. While some research has been done on researcher workflow and probing scholars for the types of supports they might need in different disciplines (Harley et al., 2010). Acrod and Harley (2012) note changes in scholarly workflow with web 2.0 tools, as tool adoption is discipline specific (Crotty, 2011). We undertook an analysis of specifically how a researcher workflow might suggest use cases that would be helpful in designing tools across the research lifecycle.

In this article, we review existing studies of technology in research workflow practices and offer design considerations for academic libraries for supporting research workflows for undergraduate students, graduate students, and faculty, with a special interest in how such support may scaffold learning to research. According to Barry (2005, p. 103) "libraries have an important obligation to support the building of quality, academic resources that are accessible via the Internet". It is important to note that while mere access is one portion of accessibility, ease of use within existing practices is equally, perhaps more, important. There is need to examine research workflows and how the shift in the information landscape impacts workflow and the ways libraries can best support all phases of research--not only a self-contained and planful literature review phase. We will review existing work and suggest ways libraries could design/support research workflows.

Below, we provide an example of a use case to identify areas where library tools could be better integrated to support library resource use throughout the lifecycle of research. The purpose of constructing this hypothetical use case was to examine commonly performed steps in collaborating on a research paper as experienced by faculty and/or graduate students.

**Figure 2:** Collaboration workflow example (Favaro, 2011).



In this use case, user 1 and user 2 email to start a project, and start a shared document in Google docs for brainstorming. Users individually search for material at the library and the Internet, retrieve information, and store information. User 1, for instance, might use primarily searches in google scholar, and cutting and pasting URLs into the shared Google doc. User 2, on the other hand, uses the library catalog database, and cuts and pastes metadata information as formatted by the campus library catalog website into the google document. Collaboratively, the two work synchronously in the document to start an outline, chatting with the embedded google chat. They begin to write the paper asynchronously within google docs. One user manages citations using her own personal Zotero library, and the other creates a conceptual diagram for the document - tasks are done individually. Throughout the process communication is occurring via email, face-to-face, and chat.

During the information seeking process, there is not an easy way to co-browse and share retrieval results virtually, robbing the participants of an opportunity to learn search best practices by watching each other, and distracting them from the intellectual core of writing the paper and instead encouraging them to focus simply on collecting citations. There are several pieces to the research process after information seeking. Once the information is retrieved it must be exported to a format suitable for the researcher (i.e. pdf, doc, scan), and stored. The metadata must be exported to a citation management tool (i.e. Zotero, EndNote, RefWorks) and then re-exported out and formatted for within the writing software (i.e. Google docs, Word). The collaborators need a space for annotations, and then the ability to reference those during the writing process, which they might do in a separate google document. Once in the writing phase

for the collaborative project, it is possible for them to use a google doc for asynchronous writing while being able to comment and chat, however it is difficult to share all documentation and annotations during this process, as there is not a shared workspace to do so, and their fallback of copying and pasting information into the shared documents destroys digital formatting for their structured tools like their personal bibliographic database.

Again, not only is this hodgepodge a barrier to efficiency, but it is also a lost opportunity to scaffold nascent and expert scholars alike in attending to the hard problems of doing good research. Designing a tool to scaffold this process could be very effective for librarians when teaching the research process. For example, digital tools could provide reinforcement of a holistic research process; they could scaffold the details of managing information resources across that process; and they could allow direct collaboration with mentors and librarians alike from beginning to end. Instead, the current workflow provides ample opportunity to lose the forest for the trees, and to run up against best practices while working around technological limitations.

### **Future research**

Future studies are needed to examine how existing library tools sync with existing workflows; types of tools and technology libraries should offer within physical and digital spaces; types of tools do researchers need to conduct work and how can libraries integrate library tools within the across the research lifecycle and future planning for connecting users to the library resources and disconnects between new technology.

### **Conclusion**

Thus, we can no longer focus only on the retrieval aspects of the research cycle. Design research techniques such as workflow analysis, use cases, and scenarios can help us explore new possibilities. We need to think about how our information resources are used in context and not just during a library research phase. We need to think about the research will be able to retain lifelong access to their information works (i.e. once they graduate and/or move to another institution) they should be able to retain access (the researcher is the owner) without having to migrate another system.

### **Acknowledgements**

We gratefully acknowledge the helpful comments and feedback of colleagues. Portions of this paper were originally presented at emtacl 12 in Trondheim, Norway.

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