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Developing E-science and Research Services and Support at the University of Minnesota Health Sciences Libraries

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Abstract

This paper describes the development and implementation of e-science and research support services in the Health Sciences Libraries (HSL) within the Academic Health Center (AHC) at the University of Minnesota (UMN). A review of the broader e-science initiatives within the UMN demonstrates the needs and opportunities that the University Libraries face while building knowledge, skills, and capacity to support e-research. These experiences are being used by the University Libraries administration and HSL to apply support for the growing needs of researchers in the health sciences. Several research areas that would benefit from enhanced e-science support are described. Plans to address the growing e-research needs of health sciences researchers are also discussed.

Keywords

e-science; data management; research networking; research support; e-research; health sciences; library administration; health informatics

Background

The development of e-science and research support at the University of Minnesota (UMN) draws on several national and local efforts across the global research landscape. Key initiatives from the national e-science movement have prompted libraries to assume active roles at their research institutions and are examined through the lens of health science libraries. A high-level view of the research landscape at UMN provides the background and foundation to describe how the University Libraries have built library services in response to the changes in research processes.

E-science and Health Science Libraries

The first definitive, US-based contribution to aid in the understanding of the role of libraries in the domain of e-science was made in 2006 when the Association of Research Libraries (ARL) appointed the Joint Task Force on Library Support for E-Science. This group was largely charged with raising awareness and positioning libraries to take advantage of opportunities arising from e-research. The task force leveraged existing definitions of e-science and considered the rapid growth in research data, computational science, aspects of team science and collaboration, and improvements in network technologies (Rhoten, 2007). The work of the task force culminated in the publication of an *Agenda for Developing E-Science in Research Libraries* (Association of Research Libraries Joint Task Force on Library Support for E-Science, 2007).

Although the report recognized that librarians should become “knowledgeable and skilled research library professionals, with the capacity to contribute to e-science and to shape new roles and models of service”, there were no substantive resources currently available to

libraries and information professionals that could assist in building these necessary skillsets. This problem was abated, in part, when the National Network of Libraries of Medicine, New England Region awarded a grant to the Lamar Souter Library at the University of Massachusetts Medical School to build an e-science portal (http://esciencelibrary.umassmed.edu/) to serve as "a librarian's link to e-Science resources" (Creamer, Morales, Crespo, Kafel, & Martin, 2011).

Meanwhile, the National Institutes of Health (NIH) began setting a bold agenda to accelerate biomedical research (Zerhouni, 2003) which led to the launch of the Clinical and Translational Science Award (CTSA) (Zerhouni, 2006; Zerhouni & Alving, 2006). In 2006, a handful of institutions received CTSAs and by 2012, about 60 medical research institutions in 30 states and the District of Columbia became active members of the CTSA consortium. This research program has contributed a major impetus to drive the development of knowledgeable and skilled e-science librarians in the domain of the health sciences.

Prior to developing e-science and research support services in the Health Sciences Libraries (HSL) within the Academic Health Center (AHC) at UMN, several broader e-science initiatives had been undertaken within the greater University Libraries organization. These major UMN research programs provided the University Libraries with opportunities to build knowledge, skills, and capacity to address the needs of e-research. This led the University Libraries administration and HSL to develop and apply support to researchers in the health sciences. This paper also addresses the growing e-research needs of health sciences researchers and HSL's current plans to enhance library resources and support for e-science.

The University of Minnesota Research Environment

The University of Minnesota is among the largest public research universities in the United States. It is part of a five-campus presence in the state totaling 68,400 students and 3,560 full-time faculty and 730 part-time faculty members. The AHC, which is responsible for education and research in the health sciences, is comprised of six professional schools including: the Schools of Dentistry, Nursing, and Public Health; the Medical School; the College of Veterinary Medicine; and the College of Pharmacy. The AHC also includes a number of allied centers and interdisciplinary institutes; one of these is the Institute for Health Informatics (IHI), which serves as the University's hub for health informatics research and graduate training. Personnel in the HSL provide support and services to AHC faculty, students and staff from the Bio-Medical Library, the Veterinary Medical Library, and the Wangensteen Historical Library.

The University maintains a strong position among the country's top research institutions in attracting sponsored research funding, including $769M for FY2011 (Figure 1; Mulcahy, 2011). The University has sustained an upward trend in funding over the past ten years. As shown in Figure 1, the largest amount of funding comes from the NIH, the majority of which is dedicated to research being conducted in the AHC.

Library Involvement with Grants and Collaborations—In 2006, the University Libraries began a pilot project funded by the Andrew W. Mellon Foundation to focus on developing a virtual community for scholars in the interdisciplinary field of Bioethics. EthicShare is a partnership of the University Libraries, the University of Minnesota's Center for Bioethics, the University's Department of Computer Science and Engineering, and other institutions to allow cross-institutional collaboration between researchers, thus providing a shared database of citation and other bibliographic metadata, along with other information of interest to the ethics community (EthicShare, 2007).

A DataNet grant, Terra Populus: A Global Population/Environment Data Network (http://www.terrapop.org/) was awarded in 2011 to the University's Minnesota Population Center in partnership with the University's Institute on the Environment, and University Libraries; Columbia University's Center for International Earth Science Information Network and the University of Michigan's Inter-university Consortium for Political and Social Research. TerraPopulus research combines two centuries of census data with global environmental data including land cover, land use, and climate records. The primary goals of this project are to integrate information into a common database and to disseminate this data to researchers around the world. The University Libraries' role on this grant includes facilitating key connections between TerraPopulus and scientific communities and to provide insights on organizational sustainability, international collaborations, publisher partnerships, and large-scale production systems.

In 2011, the library became a partner institution on a three-year Institute of Museum and Library Services grant ($500,000) to explore data management needs and disciplinary techniques and will develop and pilot a curriculum for graduate students to increase their data information literacy (http://wiki.lib.purdue.edu/display/ste/Home). This collaborative grant project includes librarians at Purdue University, UMN, the University of Oregon, and Cornell University. Each university is focused on a select discipline to develop unique pedagogical approaches. The UMN team is collaborating with a Civil Engineering faculty and student group to develop an e-learning course on data management (http://www.z.umn.edu/datamgnt). Best practices developed during this grant will be applied to data information literacy programs in the AHC.

Recently, UMN has made investments in research for new infrastructure, collaboration, and data storage, including the Infrastructure Investment Initiative (http://www.research.umn.edu/advance/i3.html#.TzKqc2OXQeA), a program totaling $12M to build research infrastructure funded by the Office of the Vice President for Research (OVPR) in 2011. Research has also been funded to develop geographic information system (GIS) applications, infrastructure, and data archiving services that includes U-Spatial, a project led by the Department of Geography with support from twelve other University of Minnesota collegiate and enterprise-level support units.

The UMN's Supercomputing Institute for Advanced Computational Research (MSI) itself has for decades provided high-performing computer resources and support to UMN faculty and their research groups in all fields. It is a linchpin program in the University's broad-based digital technology efforts, providing a focal point for collaborative research on supercomputing within the University and the State, and an interdisciplinary focus for undergraduate and graduate education related to supercomputing and scientific computing.

Major departmental programs at UMN also offer researchers new services and communities to conduct research collaboratively, including: the UMN Interdisciplinary Informatics Program (http://www.informatics.umn.edu/), which encompasses computational and systems biology, bioinformatics, physical and computational sciences, and biomedical health informatics; and the Academic Health Center Information Exchange (AHC IE) whose mission is aligned with the Clinical and Translational Science Institute (CTSI), OVPR, and OIT to support the conduct of successful research across very large clinical and life sciences data sets. The AHC IE has developed strict data privacy and security standards, provides enterprise-aligned governance, creates robust clinical data repositories containing multi-center medical data, and is designed to integrate and coordinate university-wide research initiatives. The AHC IE also oversees a portfolio of informatics and research tools, including researcher networking systems (RNS), such as UMNProfiles (http://profiles.ahc.umn.edu)

and Experts@Minnesota (http://www.experts.scival.com/umn/), to assist researchers in the discovery of experts and potential collaborators.

Methods

Library Analysis of E-Science at the UMN

The UMN Libraries have been engaged in studies to explore the evolving needs of researchers for the past several years. Several user-needs studies, organizational strategies at UMN, and a variety of collaborations have informed and influenced the development of resources and support for e-science. The results of this research have been leveraged by HSL to establish priorities for e-science support in the AHC.

User-Needs Assessments—The University Libraries have conducted a number of needs assessments and researcher studies. The first Sciences Assessment was conducted during 2006–07 and included university faculty and graduate students across scientific disciplines. This study was designed to determine the necessary elements of infrastructure to support the discovery, use, and management of information sources and data (Marcus, 2007). Eighteen focus groups and seven individual interviews were conducted with 54 faculty and 18 graduate students from across 32 departments and 19 centers and institutes representing AHC, the College of Biological Sciences, the current College of Science and Engineering, and the College of Food and Nutrition Sciences. Interviews and focus groups comprised the primary methods of gathering information. During the study, researchers were also asked to articulate the role libraries play in their investigations and to describe how they select journals for publishing the results generated from their work.

In 2007, the library became a partner in the UMN's Research Cyberinfrastructure Alliance (RCA), whose goal was to enable intensive computational and interdisciplinary research. One action of the RCA was to task members of a professional development program (the President's Emerging Leaders, or PEL) to study the current state of research support at UMN. This PEL study (Johnston, 2010b) captured survey responses from 780 researchers on the Twin Cities campuses and demonstrated that data storage, data sharing, and data backup were main concerns of researchers.

Biomedical Research Enterprise Needs Assessment—After receiving the CTSA in 2011, the CTSI retained a consulting firm to conduct an enterprise research needs assessment. This study focused on the medical informatics and data infrastructure needs of the AHC and related health care organizations, as well as other areas of life-science research conducted across UMN. The primary recommendations from this assessment included: establish governance by defining roles, responsibilities, agreements and protocols; establish an enterprise clinical data repository; populate the repository with clinical data; and define potential pilot uses for the repository and related infrastructure.

Health Sciences Researcher Needs Assessment—As work to build the infrastructure required to support the CTSI commenced, the information and data management needs of investigators in biomedical research were assessed by HSL liaisons in 2011–12. The data needs of researchers outside of the AHC were generally well understood by the University Libraries, however HSL was not as familiar with the e-science-related needs of biomedical researchers. To address this gap, the enhancement of research support was established as a key goal during the HSL 2011 strategic planning process.

To ascertain researcher needs and the extent that HSL must develop e-science support and services for the AHC, a seven-item survey instrument was designed based on knowledge gained from previous University Libraries needs assessments (Table 1). Questions from the

survey were used during 60-minute, face-to-face interviews with researchers. Notes were collected, and the interviews were also audio-recorded. A total of 13 interviews were conducted. Researchers consistently expressed a strong interest in and appreciation of the library and its resources. No researcher expressed a need for the library to make radical changes. Additional results are presented in Table 2.

Results

Researcher Needs Assessments—Over a period of six years, various needs assessments conducted by the University Libraries, HSL, and informatics-related consultants yielded a consistent set of researcher requirements. Health sciences researchers articulated needs that were consistent with views expressed during previous needs assessments (Johnson, 2012). A summary of results collected from key needs assessments are presented in Table 2 and underscore gaps in researcher e-science support and services. Many of these gaps have been addressed through organizational changes and strategic initiatives undertaken by the libraries at UMN.

Library Responses to E-Science Opportunities—In June 2008, the libraries created an E-science and Data Services Collaborative (EDSC; http://wiki.lib.umn.edu/E-Science/HomePage) to address the needs identified in the Sciences Assessment. The EDSC members articulated concern for the Libraries' capacity to support e-science and research and recognized an urgent need for resources to ensure that library staff members develop expertise in data curation, data preservation, data policies, and virtual organizations. The group focused on education and outreach, and created a campus-facing web site, Managing Your Data (https://www.lib.umn.edu/datamanagement) to provide advice and best practices for research data management. An "Introduction to Data Management" workshop was also developed and offered to incoming graduate students to provide them with a directory of UMN services and policies for the management of research data (Johnston, 2010a).

In 2010 the University Libraries' administration undertook a strategic goal setting process that included a rigorous speaker series; as part of the series, Clifford Lynch, Executive Director of the Coalition for Networked Information, visited UMN to speak and consult about e-science and e-scholarship. The speaker series and subsequent work performed during the strategic planning process resulted in the creation of an e-scholarship strategic goal which was articulated and adopted for 2010–2012: "The Libraries will provide life-cycle management solutions for digital content and support of researcher networks through engagement in strategic partnerships, leveraging of Libraries' (and campus) assets, developing and sharing our expertise, and collaborating to develop essential infrastructure." This goal provided a foundation for HSL's work to support e-science in the AHC.

In April 2011, the Libraries' Research Support Services Collaborative (RSSC; http://wiki.lib.umn.edu/Staff/RSSC) was launched and leveraged the former work of the EDSC and the e-scholarship strategic goal to guide its work. The RSSC advanced broad support programs for e-science and research and was organized into three work groups: Data Management, Access, and Archiving; Research Communities and Networks; and Digital Arts and Humanities. The RSSC provided relevant direction for HSL, particularly in the areas of data awareness and research networks and communities.

Translational Science and Biomedical Informatics—The CTSI (http://www.ctsi.umn.edu/) was created at UMN in spring, 2009 to improve the health of Minnesotans and to position UMN to aggressively compete for a CTSA. The IHI was formed virtually in 2005 to link the growing health informatics-related research, teaching, and outreach functions at the UMN. Full recognition of the important role of informatics in

biomedical research was realized in 2009 when a portion of the HSL was converted into space for the IHI (http://www.bmhi.umn.edu/ihi/aboutihi/). In June 2011, UMN received $51.2M to fund a 5-year CTSA. This program has offered significant library opportunities to support research needs across the translational science spectrum. Library support to the CTSI and IHI has been provided since 2009 when two new roles were created in HSL. These roles include a Translational Science Information Specialist and an IHI Library Fellow (Johnson, 2010) and have been augmented by other roles, including the HSL Outreach Librarian, HSL subject liaisons, and the University Libraries Research Services Librarian.

As library services were being developed to support the UMN research enterprise, CTSI and the AHC IE, it became apparent that there were several gaps that could be filled. The e-science and data needs of researchers performing early discovery and translational research were not well supported. The workgroups of the AHC IE possessed various needs that could be addressed by librarians. Not all workgroups require major support from HSL, but the Researcher and User Needs Work Group, the Informatics Workgroup, and to a lesser extent, the Data Governance and Security Committee, have benefited from expertise provided by librarians.

Current Library e-science Services

Services provided by the UMN Libraries include training efforts around data management, research data curation and archiving services, and a role in advocacy for sound data practices and openness in research. A review of e-science and data support services (Association of Research Libraries, 2010) and the University Libraries participation in the ARL/DLF E-Science Institute in 2011–12 provided additional knowledge and stimulus to support the evolving e-science environment at UMN and to produce a strategic agenda to address e-science and researcher needs.

Research Networking Systems (RNS)—The University of Minnesota has implemented two RNS tools (Elsevier's SciVal Suite and UMNProfiles) to assist in expertise identification, locate potential interdisciplinary collaborators locally and globally, and facilitate community-engaged research collaborations. The UMNProfiles RNS was implemented in the AHC during 2010 and contains 4,000 researcher records. In 2012, SciVal Experts was implemented as Experts@Minnesota and will eventually include profiles for 4,400 UMN-Twin Cities faculty, research associates, postdocs, and librarians. This work has spawned interest in coupling the need for developing a scholarly identity registry and the migration to linked open data, resource description framework, and semantic web versions of UMNProfiles and Experts@Minnesota. Neither RNS is yet compatible with research networking recommendations adopted by the CTSA Consortium Executive and Steering Committee in October 2011 (https://www.ctsacentral.org/best%20practices/research%20networking), however, one strategy under consideration is to link UMNProfiles and Experts@Minnesota to permit cross-system search capabilities that leverage the VIVO ontology. Both UMN RNS tools are part of the national direct2experts network (Weber, 2011).

The CTSI and the AHC IE are sponsoring work to construct a web-based catalog of research resources. Initially, the catalog will highlight resources for clinical researchers and future plans include interoperability with eagle-i (https://www.eagle-i.net/), CTSAconnect (http://ctsaconnect.org/), and other standard RNS resource tools. Several HSL staff are contributing to the development of this tool.

Education and Outreach—A major outcome of the Libraries' early investment in e-science was the production of the "Creating a Data Management Plan for your Grant Application Workshop" (https://www.lib.umn.edu/datamanagement/workshops/dataplan). This training has been offered since December 2010 to ensure that all NIH and NSF grant proposals from UMN include a data management plan. The libraries have hosted 22 sessions and have trained over 300 graduate students and investigators. These discussion-based sessions are often supplemented with one-on-one consultation services for creating a plan and using the DMPTool (https://dmp.cdlib.org/), an online resource that includes a template for creating data plans that are compliant with the NIH data sharing requirements for grant proposals over $500,000/year.

Research Support Services—Additional data services, such as the productivity tool assistance (https://www.lib.umn.edu/capim), include web-based tools for collaborative writing, electronic note-taking, sharing citations, and assistance with mobile devices. These services demonstrate the role of librarians and their impact on many areas of research, including the role as advocates of scholarly communication related to e-science, open access policies, open data, and the benefits of metadata standards. Finally, library personnel also raise awareness about intellectual property issues such as copyright and ownership of research data.

Data Curation and Metadata Services—Researchers and administrators at UMN have developed a growing respect and appreciation for long-term access to digital research data because many funding agencies require investigators to preserve and share research results through publications and the submission of underlying data. Since librarians understand the principles of information dissemination, archiving, and preservation, they are in a good position to provide services related to managing research data as it flows through the research process (Jacobs & Humphrey, 2004). Familiarity with the data-related aspects of the life-cycle of research has been facilitated by the use of the research process model developed by Humphrey data visualization, analysis tools, and collaboration networks will also allow librarians to become valuable partners with researchers throughout (Figure 2; Humphrey, 2006). Several types of current and future e-science services and support from HSL to the AHC, CTSI, IHI, and other biomedical research groups are listed in Table 3.

Library Roles and Staff Development

Organizational structures; building knowledge and skill sets—Research support in the health sciences requires liaisons and librarians to possess a fundamental understanding of the scientific method, the basic principles of biology and the life sciences, health care, and related subject expertise. This can present a challenge to the development of a research service-based health science library organization. Librarians and information professionals possessing scientific degrees are rare and can command higher salaries which impact the financial resources required to support a scalable e-science services model. However, for many researcher needs described in this document, an undergraduate degree in the sciences can be sufficient and is enhanced by a graduate degree in the life sciences combined with a library science degree or relevant experience.

High functioning organizations ensure effective planning and execution, accountable goal setting, optimizing performance and growth of staff and, here, the potential to develop highly effective communities of practice to support researchers and e-science. One building block towards these organizational aims was the expansion of all librarian liaison position descriptions at the UMN in 2009 to include "E-Scholarship" objectives to support research and scholarship (Williams, 2009).

In 2010–11, several new library positions were created to support e-research, including a Research Services Librarian, a Digital Arts & Humanities Librarian, a Metadata Strategist, and a Digital Preservation Strategist. During 2011, the University Libraries made several organizational changes to gain efficiencies and to adapt to changing needs of user communities. One such change was made in HSL to bolster resources applied to the growing needs of clinical and translational scientists and the biomedical health informatics community. To effectively meet the needs of researchers in these disciplines, a listing of performance objectives are presented in Table 4. A number of library services and related roles to support translational science at UMN are listed in Table 5 and additional tools, resources, and projects that demonstrate how librarians can collaborate with researchers in e-science have been described by Gore (2011).

Physical Space and Facilities—Because the HSL Bio-Medical Library is located on an urban university campus, space comes at a premium. Fortunately the library is located centrally to the AHC and the partnership of HSL and the IHI demonstrates HSL's commitment to use library space to best support research. The AHC Learning Commons is another large space in the Biomedical Library that is currently under review with the intent to repurpose the space to meet the rapidly evolving needs of health informatics graduate students, e-learning, and interdisciplinary professional education efforts.

Conclusions

The rapidly emerging needs of the e-science research community have begun to redefine the knowledge and skillsets needed by health science librarians moving forward. In response, the professional development of HSL staff in the realms of data management, translational science, informatics, and the research life-cycle will allow for the delivery of support and services that provide value to researchers. It will also be important to develop a basic knowledge of medical terminologies, ontologies, and bioinformatics to support the full spectrum clinical and translational science. Relevant e-science (and e-learning) development and training opportunities for HSL professionals will ensure that valued library contributions to research will continue well into the future.

The ability to provide adequate resources to meet researcher needs is a challenge that many academic institutions experience. Intra-institutional coordination, if not collaboration coalescing the major support services provided by campus information technology, library, and sponsored research office seems critical to executing a strategic agenda at the enterprise level. Additionally, consortia like the CTSA, the Committee on Institutional Cooperation (CIC, which comprises 13 universities including those represented in the Big 10), and participation in the ARL e-Science Institute allow cross-institutional relationships to develop, thus resulting in efficiencies through the sharing of best practices and e-science resources.

But these are still relatively early days for e-science in academic libraries. Although most subject liaisons and library professionals strain to develop the knowledge and skillsets necessary to provide reliable e-science support and services to researchers, a high level of interest and desire to meet researcher needs persists among HSL staff. Through prudent distribution of resources, HSL and UMN libraries are well poised to build an engaged and knowledgeable cadre of e-science librarians. Such building will ensure a continued commitment to the ultimate goal of improving human health.

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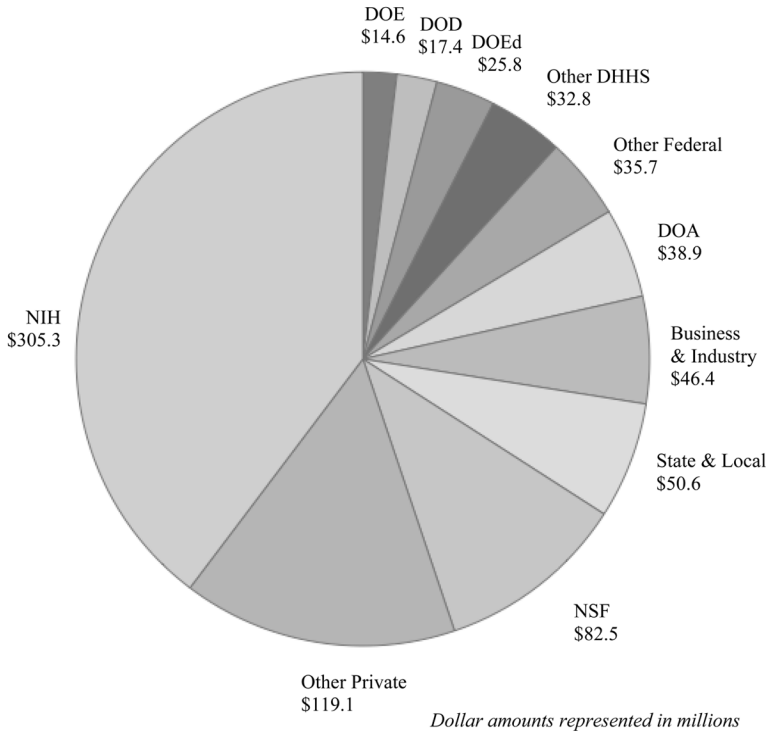

Figure 1.

University of Minnesota sources of sponsored research awards granted in 2011 by source (Mulcahy, 2011; Total=$769M), including 40% from the National Institutes of Health (NIH) and 11% from the National Science Foundation (NSF). Abbreviations: Department of Energy (DOE), Department of Defense (DOD); Department of Education (DOEd); Department of Health and Human Services (DHHS); and Department of Agriculture (DOA).

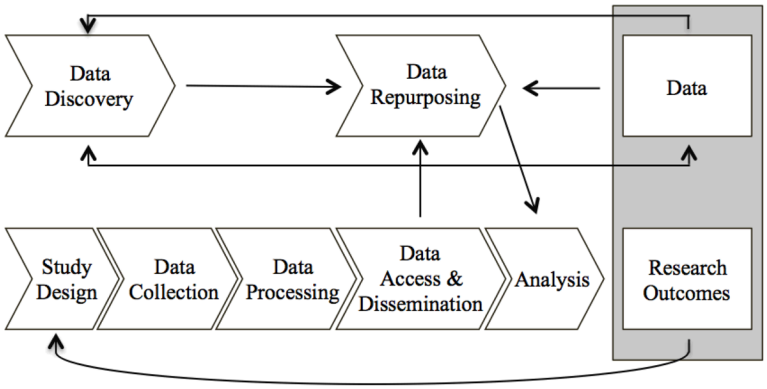

Figure 2.

E-science and the life cycle model of data, information, and knowledge creation in the research process (adapted from Humphrey, 2006). This model displays stages in the research process that assist in understanding data and information needs. Several resources have been developed at UMN to help address the data and information management needs related to research and e-science, and are based on this model.

Table 1

Health Sciences Libraries Researcher Survey Instrument used to conduct AHC researcher needs assessment at UMN during 2011–12.

1	Please give us a quick overview of your research.
2	As a researcher you use and produce data. What kinds of data do you work with? How do you store your data during your research projects? Do you have needs for long-term preservation of the data you produce, and if so, how do you meet them? How is your data organized or described? Are there formal, set organization schemes [for data management] or do people create their own?
3	We are now going to ask you some questions about collaborative research, which we define as multiple researchers (from the same or different disciplines) working together within a single research project. Are you ever involved in collaborative research? (If no, skip to 5) If yes: what challenges do you confront when working collaboratively (with colleagues at Minnesota or at other institutions)?
4	Do you have trouble locating other scientists to collaborate with? Potential follow-up: how do you discover collaborators outside of your discipline?
5	Do you have any experience sharing research findings outside the avenues of traditional journals or conference presentations? For instance, do you post articles on a personal website or in an institutional repository; have you posted a video to YouTube or have you shared research findings on a science blog, Facebook, or Twitter? Do you share preprints?
6	What aspects of finding and using information do you find to be most difficult?
	i. Finding and retrieving articles
	ii. Managing your library of electronic articles
	iii. Creating bibliographies
	iv. Staying current
7	Do you feel well informed about the resources that the libraries offer?

Table 2

A compilation of results collected during several researcher and user needs assessments conducted at the University of Minnesota during 2006–2012.

Name of Study	Date	Group Responsible	Description	Major Findings
Sciences Assessment: Understanding Scientists (Marcus, 2007)	2006–07	UMN Libraries	Interviews and focus groups; 70 University faculty, deans, and graduate students	Difficult to keep current; online resources indispensable for collaborative research; Collaborative research is challenged by time, distance, language; digital collections mitigate physical boundaries; data curation and storage are haphazard and in need of attention; student and faculty needs similar.
PEL Study (Johnston, 2010b)	2007	UMN Libraries, President's Emerging Leaders	Survey responses from 780 researchers at UMN Twin Cities	Inconsistent data storage patterns; limited public data sharing (8% of users); inconsistent or insufficient data backup support.
Biomedical Research Needs Assessment	2010–11	Independent Consulting Firm	Interviews with 58 individuals at UMN and outside groups; identification of assets and gaps	Institutional needs result in creation of AHC IE; need to establish governance; establish enterprise clinical data repository; populate repository; establish pilot projects for repository and infrastructure.
Health Sciences Libraries Researcher Needs Assessment	2011–12	HSL liaisons	Interviews with 13 AHC researchers using 7-item survey instrument	Inconsistent data management practices, institutional guidelines requested; knowledge of collaboration tools lacking; enterprise backup required; data sharing and policies not understood.

Table 3

A partial listing of current and future e-science services provided to UMN, AHC, CTSI, IHI, and other researchers by HSL liaisons, librarians, and information professionals.

Current Services	Potential Future Services
Data management plan training & consultation	Research Networking training (UMNProfiles, Experts@Minnesota) to aid in grant preparation, expertise identification and collaborative research
Education and awareness of data sharing requirements	Data archiving services to enable search and discovery of data sets
Citation management and digital article storage	Training for health information and data privacy and security
Use of subject-based data repositories	Linked open data services, ontology services, semantic web support
Bibliometrics and evaluation	Creation of expanded research networks including experts, core laboratory services, research resources, clinical expertise; training of related services
Community engagement, outreach, and health literacy	Collaboration with informatics consulting services, including terminology, meta-data, and indexing support

Table 4

A list of performance objectives for HSL subject liaisons, librarians, and other information professionals to meet the e-science needs of researchers and users.

1	Apply e-scholarship, e-science, and data management principles to support the research programs of the AHC, CTSI, IHI, and other projects.
2	Develop proficient knowledge of the data life cycle, interdisciplinary research, translational science, science of team science, and other relevant research models.
3	Perform data audits, researcher and user needs assessments and develop actionable plans to address the needs of the research community.
4	Connect researchers to research resources and assets including local and national datasets and researcher networks.
5	Advise researchers on the use of metadata standards and terminologies relevant to the life sciences and biomedical health informatics communities.
6	Understand and communicate relevant granting agency and publisher policies on data management, sharing, and preservation. Be proficient in knowledge about public access policies, open data, and open access publishing.
7	Describe and illustrate how HSL staff currently support data management, access, and preservation.

Table 5

A listing of library services and roles to support translational science research activities.

Stage of Research and Related Activities	Relevant Library Services	Suggest Support Roles
T1 translational; basic scientific discovery; preclinical and animal studies; proof of concept; first in humans; early Phase 1 clinical trials.	Funding databases; information about core facilities, research tools and assets; subject consultation; literature searches and citation management; research networking; data management and sharing plans; metadata services; privacy and security training; information and data dissemination; evaluation.	Subject liaison, evidence-based medicine expert; database searcher, cataloger, collection development expert, reference expert, data management expert; bioinformatics expert.
T2 translational; Phase 2 and 3 clinical trials; translation of research findings to patient care	Health disparities consulting, research ethics consulting, health informatics training and related library training, evidence based medicine support, grant support, collaboration, expertise and research asset identification through research networks, clinical data collection and clinical trials management (setting up these systems requires meta-tagging, taxonomy, ontology and identity support from libraries)	Subject liaison; database searcher; data liaison; collection development; role familiar with clinical trials management systems and clinical data repositories; taxonomist or ontologist; semantic web expert.
T3 translational; Phase 4 Clinical trials, Translation for Practice, where knowledge is gained in real-world settings	Dissemination and communication of results; data sharing; researcher networking; ethics consulting; data repositories; clinical outcomes support	Data consultant; ontologist; database searcher.
T4 translational; Community-engaged research and population health; health disparities.	Outcome studies; community based participatory research; community engagement; outreach; health literacy; social network analysis; research networking; funding sources for community partners; research ethics	Outreach librarians; subject liaisons; health literacy experts; community librarians; technical experts for social and research networking.

Note: Translational Science stages (T1-T4) adopted from Trochim, 2011.