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putting the pieces together: theory and practice

Full-Length Paper

An Exploratory Sequential Mixed Methods Approach to Understanding Researchers' Data Management Practices at UVM: Integrated Findings to Develop Research Data Services

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Abstract

This article reports on the integrated findings of an exploratory sequential mixed methods research design aimed to understand data management behaviors and challenges of faculty at the University of Vermont (UVM) in order to develop relevant research data services. The exploratory sequential mixed methods design is characterized by an initial qualitative phase of data collection and analysis, followed by a phase of quantitative data collection and analysis, with a final phase of integration or linking of data from the two separate strands of data. A joint display was used to integrate data focused on the three primary research questions: How do faculty at UVM manage their research data, in particular how do they share and preserve data in the long-term?; What challenges or barriers do UVM faculty face in effectively managing their research data?; and What institutional data management support or services are UVM faculty interested in? As a result of the analysis, this study suggests four major areas of research data services for UVM to address: infrastructure, metadata, data analysis and statistical support, and informational research data services. The implementation of these potential areas of research data services is underscored by the need for cross-campus collaboration and support.

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Keywords: data management, mixed methods research, qualitative research, quantitative research, research data services, academic libraries

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Introduction

In 2014, the Association for College and Research Libraries (ACRL) Research Planning and Review Committee published its biennial review of the top trends in academic libraries. Under the trend of Data: New Initiatives and Collaborative Opportunities, the authors wrote, "Increased emphasis on open data, data plan managing, and 'big data' research are creating the impetus for academic institutions from colleges to research universities to develop and deploy new initiatives, service units, and resources to meet scholarly needs at various stages of the research process" (2014, 294). Two years later, data remained a top trend, explicitly highlighting the development of research data services by academic libraries, who are stepping into the role of service providers for research data management largely as a result of federal funding agency mandates (ACRL Research Planning and Review Committee 2016).

Research data management (RDM) is defined as, "the organisation of data, from its entry to the research cycle through to the dissemination and archiving of valuable results" (Whyte and Tedds 2011, 1), and borrowing from Tenopir et al (2015), "refers to the broad suite of services or processes involving data, including services that assist with data management planning, finding repositories for both accessing and depositing data, metadata description, and preservation" (3). Pinfield, Cox, and Smith (2014) further elaborate, stating that RDM is, "a highly complex set of activities involving an array of technical challenges as well as a large number of cultural, managerial, legal and policy issues" (3).

RDM has become a topic of scholarly interest for academic libraries, with numerous published studies looking at researchers' current data management practices (Table 1). To date, these studies clearly align with either qualitative research methods, including interviews, focus groups, and document analyses, or quantitative research methods, in the form of a survey or questionnaire. The majority of these studies were conducted prior to government mandates requiring grant applicants to account for the sharing and long-term preservation of data, a key stimulus for academic libraries to address RDM (Fearon et al. 2013).

These environmental scans of RDM have provided the impetus for institutional-level decisions on the development of research data services. Extending beyond RDM, research data services (RDS), also referred to as research data management services (RDMS), is defined by Fearon et al (2013) as, "providing information, consulting, training or active involvement in: data management planning, data management guidance during research (e.g. advice on data storage or file security), research documentation and metadata, research data sharing and curation (selection, preservation, archiving, citation) of completed projects and published data" (12).

Several models have been developed to provide structure to RDS. Jones, Pryor, and Whyte (2013) of the Digital Curation Centre (DCC) developed the *Components of RDM Support Services* model that connects guidance, training, and support services to the different stages of research, including: support for data management planning, managing active data, data selection and handover, and sharing and preserving data, including data repositories. Pinfield, Cox, and Smith (2014) developed a library-oriented model of institutional RDM that focuses on Institutional Drivers (i.e. Why should institutions engage with RDM?), Stakeholders (i.e. Who is involved in the institutional RDM program?), Influencing Factors (i.e. How will the program be

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Table 1: Comparison of methods used in data management studies
*Multiple methods used in single study

Method	Author(s)	Institution	Sample Size
Interviews	Diekmann (2012)	The Ohio State University	14 participants
	Lage, Losoff, and Maness (2011)	University of Colorado Boulder	26 participants
	Marcus *et al* (2007)*	University of Minnesota	7 participants
	Peters and Dryden (2011)	University of Houston	10 participants
	Walters (2009)	Georgia Institute of Technology	5 participants
	Westra (2010)	University of Oregon	25 participants
	Williams (2013)	University of Illinois at Urbana-Champaign	7 participants
	Witt *et al* (2009)	Purdue University University of Illinois at Urbana-Champaign	19 participants
Focus Groups	Bardyn, Resnick, and Camina (2012)	University of California Los Angeles	2 groups 8 participants
	Marcus *et al* (2007)*	University of Minnesota	18 groups 65 participants
	Mattern *et al* (2015)	University of Pittsburgh	2 groups 8 participants
	McLure *et al* (2014)	Colorado State University	5 groups 31 participants
Document Analysis	Mischo, Schlembach, and O'Donnell (2014)	University of Illinois at Urbana-Champaign	1,260 documents
	Parham *et al* (2016)	multi-institution	500 documents
	Parham and Doty (2012)	Georgia Institute of Technology	181 documents
Survey	Akers and Doty (2013)	Emory University	13 questions 330 respondents
	D'Ignazio and Qin (2008)	SUNY College of Environmental Science & Forestry Syracuse University	--- 111 respondents
	Diekema, Wesolek, and Walters (2014)	multi-institution	16 questions 196 respondents
	Parham, Bodnar, and Fuchs (2012)	Georgia Institute of Technology	--- 63 respondents
	Scaramozzino, Ramírez, and McGaughey (2012)	California Polytechnic State University, San Luis Obispo	18 questions 82 respondents
	Steinhart *et al* (2012)	Cornell University	43 questions 86 respondents
	Tenopir *et al* (2011)	multi-institution	23 questions 1,329 respondents
	Weller and Monroe-Gulick (2014)	University of Kansas	--- 415 respondents
	Whitmire, Boock, and Sutton (2015)	Oregon State University	29 questions 443 respondents

shaped?), and Programme Components (i.e. What strategies, policies, guidelines, processes, technologies, and services does an RDM program consist of?).

Beyond the theoretical, numerous articles have been published either detailing the status of RDS implementation across institutions or case studies highlighting RDS within an institution. The plethora of research studies on this topic establish that RDS has been a library-driven initiative to date. Recent studies have provided a somewhat contradictory perspective on the adoption of RDS at colleges and universities. A recent study of ACRL library directors shows that almost 75% of survey respondents were not involved in RDS (Tenopir et al. 2015). These numbers changed little from an earlier study, completed in 2011, that assessed the percentage of libraries that currently offer, plan to offer, or do not plan to offer RDS, and which revealed that there was little or no demand for RDS from patrons at many institutions (Tenopir, Birch, and Allard 2012). Conversely, a separate study of science librarians affiliated with ARL libraries found that approximately 60% of respondents indicated that their university provided data management assistance, and approximately 20% were planning such services (Antell et al. 2014).

Despite the conflicting accounts reported, library directors in Tenopir et al's 2015 study agree that the issues of RDM are important, and that directors at research institutions in particular see that the library needs to participate in RDS in order to remain relevant within their academic institution. In one study, it was suggested that, "the absence of RDS would adversely affect the institution's perception of the library in terms of relevance and prestige, that provision of RDS would augment the institution's research impact, and that the absence of RDS would put the institution at a disadvantage for grants" (Tenopir et al. 2014, 86). MacColl (2010) wrote that, "Without the assistance of the library to curate, advise on and preserve the manifold outputs of [scholarly] activity, while individual scholars may still manage to thrive and build their reputations, they will do so within an impoverished infrastructure for scholarship, using a compromised archive, and their legacy to future scholars will be insecure" (167).

Case studies of current RDS illuminate the role academic libraries have been playing in RDM. Raboin, Reznik-Zellen, and Salo (2012) write about the experiences, challenges, and opportunities of developing institutional RDS at the University of Wisconsin-Madison, the University of Massachusetts Amherst, and Tufts University. Two articles highlight RDS at the Johns Hopkins University: the development of data management services encompassing data storage, data archiving, data preservation, and data curation, and the development of data management consultation services (Varvel and Shen 2013). Rice and Haywood (2011) discuss the University of Edinburgh's process of drafting a university policy related to RDM, while Wilson et al (2011) highlight the implementation of data management infrastructure at the University of Oxford. Fearon et al (2013) include a list of detailed case studies and selected resources in their *ARL SPEC Kit 334: Research Data Management Services*.

What becomes clear through the breadth of articles and case studies published on this topic is that there is no prescriptive, out-of-the-box approach to RDS for institutions to adopt, and that any service developed needs to be relevant to each institution's population. The 2010 ARL report findings state, "There is great diversity in the strategies employed by institutions to address the needs of their researchers. Current strategies range from a decentralized series of data support services in a variety of departments or units to the creation of committees to discuss campus data needs and services along with the creation of centralized data centers to

provide that support. The diversity of response reflects the needs and culture of the institutions, which is to be expected" (Soehner, Steeves, and Ward 2010, 20). Weller and Monroe-Gulick (2014) write, "Rather than adopt a blanket, 'one-size fits' all model, these research data services should be provided with a detailed and nuanced understanding of their users" (467), and Raboin, Reznik-Zellen, and Salo (2012) concur, noting "there is no single foolproof template that will produce a successful service everywhere" (138).

Study Design

Qualitative research methodologies are used to explore why or how a phenomenon occurs, to develop a theory, or describe the nature of an individual's experience, while quantitative methodologies address questions about causality, generalizability, or magnitude of effect (Fetters, Curry, and Creswell 2013). Mixed methods research, frequently referred to as the 'third methodological orientation' (Teddlie and Tashakkori 2008), draws on the strengths of both qualitative and quantitative research. While there is no universal definition of mixed methods research, Creswell and Plano Clark (2011) outline its core characteristics: In a single research study, both qualitative and quantitative strands of data are collected and analyzed separately, and integrated – either concurrently or sequentially – to address the research question. Onwuegbuzie and Combs (2010) concur, writing, "mixed analyses involve the use of at least one qualitative analysis and at least one quantitative analysis – meaning that both analysis types are needed to conduct a mixed analysis" (414). Instead of approaching a research question using the binary lens of quantitative or qualitative research, the mixed methods research approach has the ability to advance the scholarly conversation by drawing on the strengths of both methodologies.

In this study, an exploratory sequential mixed method research (MMR) design was selected in order to broadly explore and understand data management practices, behaviors, and preferences of faculty at the University of Vermont (Figure 1). This research was guided by four research questions:

> **RQ1**: How do faculty at UVM manage their research data, in particular how do they share and preserve data in the long-term? (qualitative and quantitative)
>
> **RQ2**: What challenges or barriers do UVM faculty face in effectively managing their research data? (qualitative and quantitative)
>
> **RQ3**: What institutional data management support or services are UVM faculty interested in? (quantitative)
>
> **RQ4**: How do researchers' attitudes and beliefs towards the data management planning process influence their data management behaviors, in particular, how do they intend to share and preserve their data? (quantitative)

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Figure 1: Exploratory sequential mixed methods research design

In an exploratory design, qualitative data is first collected and analyzed, and themes are used to drive the development of a quantitative instrument to further explore the research problem (Creswell and Plano Clark 2011; Teddlie and Tashakkori 2008; Onwuegbuzie, Bustamante, and Nelson 2010). As a result of this design, three stages of analyses are conducted: after the primary qualitative phase, after the secondary quantitative phase, and at the integration phase that connects the two strands of data and extends the initial qualitative exploratory findings (Creswell and Plano Clark 2011). This article reports on the final integration phase of the research.

The primary objective of this research study is to understand researchers' current behaviors and challenges related to data management in order to guide the development of research data services at the University of Vermont. As a result, the analysis of RQ4 is not addressed in this article as it proposes the development of a bipolar adjective scale to assess attitudes and beliefs towards the data management planning process in order to measure intention of implementing formal data management plans.

Qualitative Data Collection & Analysis

In the first phase of this MMR study, data was collected from UVM faculty who received National Science Foundation (NSF) grants between 2011-2014, and who had submitted a data management plan (DMP). Primary qualitative data included textual analysis of DMPs (N=35) and semi-structured interviews with a purposeful sample (N=6), reflective of a diversity of academic disciplines and NSF Directorates. An interview protocol was used to guide the semi-structured interviews, using the Data Lifecycle Model as a conceptual model (DDI Alliance Structural Reform Group 2004). The focus of the interviews was on data management planning, including data management activities (e.g. creation and use of metadata; short-term storage of data; long-term data storage and preservation; data sharing practices) and related challenges; and issues of institutional support. Transcripts and data management plans were entered into HyperRESEARCH 3.5 qualitative data analysis software for coding. The qualitative data was then coded using a constant comparative method (Charmaz 2006; Glaser

and Strauss 1967) to elicit themes. A complete description of the qualitative collection and analysis strategies has been described elsewhere (Berman 2017a).

Quantitative Data Collection & Analysis

Data from the qualitative phase were used to develop a survey instrument for the second quantitative phase of the MMR study. The survey measured the following dimensions: data management activities; data management plans; data management challenges; data management support; attitudes and behaviors towards data management planning; and demographics. Questions were built from the salient themes that emerged from the qualitative data analysis, and used the theory of planned behavior (TBP) (Ajzen and Fishbein 2000; Ajzen 2005; Ajzen 1991) as a conceptual underpinning to evaluate attitudes and beliefs towards data management planning. The survey was deployed to all current UVM faculty and researchers in an attempt to generalize the findings from the initial qualitative research, which focused only on successful NSF grantees. A total of 319 respondents completed the survey for a 26.8% response rate. Survey data was analyzed using SPSS version 22 for descriptive and inferential statistics. A complete description of the quantitative data collection and analysis strategies utilized has been described elsewhere (Berman 2017b).

Mixed Methods Data Analysis

The use of both qualitative and quantitative data collection methods in a single study is not sufficient enough to categorize a study as 'mixed methods.' It is in the integration or linking of the two strands of data that defines mixed methods research and highlights its value. Integration can happen at multiple levels of a study – design-level, methods-level, or interpretation-level – and can happen in a variety of different ways – connecting, building, merging, or embedding (Fetters, Curry, and Creswell 2013; Creswell and Plano Clark 2011). In this study, the first linking of data happened at the design-level with the use of a sequential design, where the results from the first phase of the research were used to build the second stage of the research design.

In order to more fully address the research questions interpretation-level integration occurred, connecting the qualitative data from phase one of the study with the quantitative data from phase two of the study using a joint display (Table 2). A joint display allows data to be visually brought together to "draw out new insights beyond the information gained from the separate quantitative and qualitative results" (Fetters, Curry, and Creswell 2013, 2143). As seen in Table 2, sample quotes from the qualitative interviews were compared and contrasted to results from the statistical analyses of the survey data. Points of contention and areas of convergence between the qualitative and quantitative phases were dissected in the final analysis phase in order to form meta-interferences, or an overall understanding developed through integration of data strands (Teddlie and Tashakkori 2008). The connected data was interpreted within the scope of the study's purpose: to understand researchers' current data management behaviors, challenges, and preferences, in order to guide the development of RDS at UVM.

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Table 2: Joint display comparison of data from qualitative and quantitative strands

Theme	In-Person Interviews[1]	DMP Document Analysis[1]	Survey[2]
RQ1a. Data Management Activities: Metadata	"Metadata? I have written some things to help the grad students work with the data more efficiently. Like, 'Here's a standard and here's a script that checks to make sure that your files are conforming to that standard.' It's not very formalized."	• 25.7% (N=35) of DMPs mentioned specific metadata standards	• 28.1% of survey respondents (N= 178) generate metadata • 3.9% (N=178) use known metadata standards
RQ1b. Data Management Activities: Data Sharing	"I like sharing data when it's possible. Sometimes there are NDAs [non-disclosure agreements] on these things. It would be nice to make available once we are able to get some papers out, because there is a notion of being scooped."	• 20.0% (N=35) of DMPs do not share data because of specific data sharing restrictions • 94.3% (N=35) of DMPs share data via publications or presentations	• 4.0% of survey respondents (N=208) 'always' or 'often' do not share data • 25.6% (N=199) are 'significantly limited' in sharing data because of confidentiality concerns • 23.8% (N=199) are 'significantly limited' in sharing data because of lack of time, personnel, or available infrastructure • 15.6% (N=199) are 'significantly limited' in sharing data because of intellectual property concerns • 50.0% of survey respondents 'always' or 'often' share data via publications or presentations
RQ1c. Data Management Activities: Long-Term Data Preservation	"We want to keep [the data] around [on external hard drives], but it's not going to be updated."	• 48.6% of DMPs (N=35) deposit data into repositories • 91.4% of DMPs (N=35) use hard drives or external media to store data long-term	• 7.7% of survey respondents (N=208) deposit data into repositories • 64.7% of survey respondents (N=208) use external hard drives or media to store data long-term

1 Berman, E. A. (2017a). An Exploratory Sequential Mixed Methods Approach to Understanding Researchers' Data Management Practices at UVM: Findings from the Qualitative Phase.
2 Berman, E. A. (2017b). An Exploratory Sequential Mixed Methods Approach to Understanding Researchers' Data Management Practices at UVM: Findings from the Quantitative Phase.

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Table 2 *(continued):* Joint display comparison of data from qualitative and quantitative strands

Theme	In-Person Interviews[1]	DMP Document Analysis[1]	Survey[2]
RQ2. Challenges/ Barriers to Data Management	"What do you really get in terms of research support? One of the things I always wonder when I get these big grants and I see the overhead taken off is, 'What does my overhead fee go towards, exactly?' It's not my desk. It's not these computers. It's not a fancy mahogany locker at the gym. And it's not for storage, right? So what infrastructure and support do we get from ETS?"	n/a	• 68.6% of survey respondents (N=191) found it 'easy' or 'somewhat easy' to store data short term (5 years or less) • 44.5% (N=191) found it 'easy' or 'somewhat easy' to store data long term (more than 5 years) • 45.0% (N=191) found it 'difficult' or 'somewhat difficult' to track updates to data (i.e. versioning) • 42.4% (N=191) found it 'difficult' or 'somewhat difficult' to describe data • 18.0% of respondents who have submitted a DMP (N=50) experience no challenges with data management
RQ3. Interest in Data Management Support & Services	"Is it expensive to [deposit data in a data repository]? Because I'm riding high on these grants now, but ten years from now? Is there a permanent fee? If it's free, of course that would be great." "I think the challenge of all these data repositories is your chances of making everyone happy are slim. Slim to none."	n/a	• 69.6% of survey respondents (N=188) found it 'very important' for UVM to spend resources on statistical/data analysis support • 55.9% (N=188) found it 'very important' for UVM to spend resources on long-term data storage • 53.7% (N=188) found it 'very important' for UVM to spend resources on short-term data storage • 51.6% of survey respondents (N=192) are interested in DMP tools and templates • 36.5% (N=192) interested in institutional data repository
RQ4. Perceptions of/Attitudes towards DMPs	"I've been on review panels, and nobody says anything about the data management plan. Everybody reads it to check that they're there, but nobody makes any comment."	n/a	• Bipolar adjective scale data to be analyzed in future publications

1 Berman, E. A. (2017a). An Exploratory Sequential Mixed Methods Approach to Understanding Researchers' Data Management Practices at UVM: Findings from the Qualitative Phase.
2 Berman, E. A. (2017b). An Exploratory Sequential Mixed Methods Approach to Understanding Researchers' Data Management Practices at UVM: Findings from the Quantitative Phase.

Results

Institutional and Study Demographics

The University of Vermont is a public land-grant institution with a student enrollment of 12,000 undergraduate and graduate students and a faculty of 1,200 (University of Vermont 2017). UVM is a higher research activity Research University (The Carnegie Classification of Institutions of Higher Education 2017), regionally comparable to Boston College, Drexel University, Northeastern University, University of Maine, and University of New Hampshire. UVM Libraries is comprised of two libraries – the Bailey/Howe Library and the Dana Medical Library – with a FTE of 81.70 and an annual collection budget of approximately $7 million (UVM Libraries 2015).

Qualitative interview participants were drawn from fields connected to the NSF Directorates or disciplinary areas that support science and engineering research: Biological Sciences; Computer & Information Science & Engineering; Education & Human Resources; Engineering; Geosciences; Mathematical & Physical Sciences; and Social, Behavioral & Economic Sciences (National Science Foundation 2017). Faculty in the sciences represented 80% of the document analyses (N=35) and 66.7% of the interviews (N=6); the remaining faculty were from the social sciences. Quantitative survey participants were drawn from across the campus, with STEM faculty representing 68% of the survey respondents and social sciences and humanities each representing 16% (N=319). Descriptive statistics comparing these samples can be found in Table 3.

RQ1. How do faculty at UVM manage their research data, in particular how do they share and preserve data in the long-term?

Research data management, structured around the Data Lifecycle Model (DDI Alliance Structural Reform Group 2004), focuses on a variety of activities, including: types of data collected, data file size, generation and use of metadata, short-term (five years or less) data storage, long-term (more than five years) data storage and preservation, data retention, and data sharing practices and limitations. Combining the results from both the qualitative and the quantitative phases provide a detailed understanding of researcher behaviors at UVM, most notably that there is no 'typical' researcher. Because quantitative and qualitative research methods are "not inherently linked to any particular inquiry paradigm" (Greene, Caracelli, and Graham 1989, 256), researchers collect a variety of data sources and demonstrate a variety of behaviors in managing it, and this diversity has been documented in similar research studies (Weller and Monroe-Gulick 2014; Whitmire, Boock, and Sutton 2015). For the purposes of this study, it is worthwhile to focus on three RDM behaviors that are central to federal data sharing mandates, a prime driver for RDS: the creation and use of metadata; data sharing; and long-term data preservation.

Evidence from both the qualitative and quantitative strands confirm a general lack of metadata creation to describe the primary data, very much in line with findings from other published research (Akers and Doty 2013; Diekema, Wesolek, and Walters 2014; Qin and D'Ignazio 2010; Scaramozzino, Ramírez, and McGaughey 2012; Steinhart et al. 2012; Tenopir et al. 2011; Whitmire, Boock, and Sutton 2015). While approximately half of the data management plans mentioned metadata, only one-quarter of those directly referenced a known standard,

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Table 3: Descriptive statistics of participants in MMR research study

	Population	QUAL Sample: DMP	QUAL Sample: Interview	QUAN Sample
Discipline				
Arts & Humanities	177 14.9%	0 0.0%	0 0.0%	38 16.0%
Social Sciences & Business	236 19.8%	8 22.9%	2 33.3%	38 16.0%
STEM	777 65.3%	27 77.1%	4 66.7%	162 68.0%
TOTAL	1,190	35	6	238
College[3]				
BSAD	31 2.6%	0 0.0%	0 0.0%	5 2.0%
CALS	60 5.0%	4 11.4%	1 16.7%	14 5.6%
CAS	314 26.4%	15 42.9%	2 33.3%	85 34.1%
CEMS	77 6.5%	12 34.3%	2 33.3%	18 7.2%
CESS	64 5.4%	0 0.0%	0 0.0%	19 7.6%
CNHS	54 4.5%	0 0.0%	0 0.0%	12 4.8%
COM	551 46.3%	0 0.0%	0 0.0%	86 34.5%
RSNER	39 3.3%	4 11.4%	1 16.7%	10 4.0%
TOTAL	1,190	35	6	249
Rank[4]				
Full professor	308 25.9%	n/a	2 33.3%	59 23.4%
Associate professor	364 30.6%	n/a	2 33.3%	81 32.1%
Assistant professor	298 25.0%	n/a	2 33.3%	80 31.7%
Other	220 18.5%	n/a	0 0.0%	32 12.7%
TOTAL	1,190	35	6	252
Gender				
Female	493 41.5%	6 17.1%	2 33.3%	129 51.2%
Male	697 58.5%	29 82.9%	4 66.7%	123 48.8%
TOTAL	1,190	35	6	252

3 BSAD = Business Administration; CALS = Agriculture & Life Science; CAS = Arts & Science; CEMS = Engineering & Mathematical Sciences; CESS = Education & Social Services; CNHS = Nursing & Health Sciences; COM = Medicine; RSENR = Environment & Natural Resources.

4 Rank at time of DMP submission was not available.

such as Darwin Core (DC) or Ecological Metadata Language (EML). These numbers were even lower in the survey results, with only seven out of 319 total respondents indicating that they use known metadata standards; these seven respondents had all successfully submitted DMPs for grant funding. The remaining study participants who used metadata described their data using standards individually developed, often in the form of ReadMe files or codebooks.

Independently, both strands of data indicate that respondents are willing to share their data with others outside of their research groups. Despite this willingness to share data, both phases of the study demonstrate particular obstacles – internal and external – that limit the sharing of data. For researchers who have submitted DMPs, the issues focused around fear of misinterpretation, intellectual property concerns, and a variety of legal issues, including confidential, proprietary, or classified information. The major limitations from the quantitative phase of the study focused on the ability to maintain confidentiality, the lack of time, personnel, and tools/infrastructure to make data available, and intellectual property concerns.

The most common data sharing method in both phases of the study were via publications and presentations; almost one-third of the DMPs were exclusively sharing research data via these scholarly pathways. Data repositories, which serve a dual function for data sharing and data preservation, were an infrequent response in both phases of the study. Seventeen out of 218 survey respondents and 17 out of 35 DMPs mentioned depositing data into specific repositories, such as GenBank or the Long-Term Ecological Research Network (LTER). More common methods for long-term preservation of data included external hard drives or other media and campus network servers.

RQ2. What challenges or barriers do UVM faculty face in effectively managing their research data?

The quantitative research respondents were directly asked to rate their level of difficulty with specific data management activities, while qualitative participants were prompted to indirectly discuss challenges they have faced with managing research data more generally. Qualitative research participants were more likely to focus outward on the lack of University-level support and infrastructure available for preservation of their data – in particular, storage – while quantitative survey respondents were more likely to focus inward on organizational issues, such as tracking updates to data (i.e. versioning), describing data, and ensuring the data were secure. One discordant finding when integrating the data is that, while interview participants focused on the lack of short-term storage options for their data, the majority of the survey respondents (68.6%, N=191) found short-term data storage easy or somewhat easy. In line with the findings related to use of metadata, approximately 12% of the survey respondents (N=191) found it easy or somewhat easy to describe data.

Focusing on researchers who have submitted a DMP, the quantitative results expand upon the results of the qualitative phase. The top challenge identified via the interviews was a lack of institutional research support, while survey results were more nuanced, showing that a lack of guidance from the institution on data management and lack of appropriate infrastructure for long-term data storage were the top challenges. It is also worth noting that of those who have submitted a DMP, 18% of survey respondents (N=50) indicated they experienced no challenges managing their data.

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RQ3. What institutional data management support or services are UVM faculty interested in?

While the questions in the qualitative interviews focused more on an institutional data repository, the survey instrument was used to expand on potential institutional RDS. Using a structure proposed by Tenopir et al (2014), RDS can be categorized into either *informational/ consulting services*, such as identifying data repositories or providing DMP templates, or *technical/hands-on services*, such as building an institutional data repository or providing metadata. Table 4 organizes the quantitative data into these two categories.

Table 4: Support for and interest in RDS

	Q39 How important do you think it is for UVM to spend resources on providing the following services (Very Important)? (N=191)	**Q40 Would you be interested in any of the following data management support activities? (Yes) (N=192)**
Informational/Consulting	Guidance on privacy/confidentiality (46.3%)	Data management plan templates and tools (51.6%)
	Guidance on writing data management plans (38.9%)	Informational website with best practices and campus resources (46.9%)
	Guidance on depositing data into data repository (37.8%)	Data management consultation (33.9%)
	Guidance on intellectual property issues (36.8%)	Data management plan workshops (27.1%)
	Guidance on how to use appropriate metadata standards (36.1%)	Tools for sharing research data (26.0%)
		Compliance with policies, legal requires, and ethical standards (24.0%)
		Help identifying repositories to submit data to (9.9%)
		Assistance finding and accessing secondary data (6.8%)
		Information about citing data resources (3.5%)
Technical/Hands-On	Provision of statistical and other data analysis support (69.6%)	Data storage and preservation (50.0%)
	Data security support (58.7%)	Institutional data repository (36.5%)
	Long-term data storage (more than 5 years) (56.8%)	Assistance meeting data sharing and/or data management requirements of funding agencies (28.1%)
	Short-term data storage (5 years or less) (55.2%)	Producing metadata (13.5%)
	Provision of advanced computing options (41.5%)	Data set purchasing (9.4%)
	Acquiring unique identifiers for data sets (26.5%)	Assistance in selecting data to preserve for the long-term (7.8%)

Combining qualitative and quantitative results, faculty at UVM show high levels of interest in and support for technical RDS. The need for storage infrastructure has been enumerated above, and is confirmed with 50.0% of survey respondents showing interest in "data storage and preservation." For services that the institution should devote resources to, more than two-thirds of the respondents mentioned "provision of statistical and other data analysis support," followed by "data security support," "long-term data storage," and "short-term data storage." Approximately one-third of survey respondents showed interest in the creation of an institutional data repository; this neither confirms nor contradicts the attitudes expressed during the interviews regarding data repositories, but provides a complicated view of the data to consider in the development of RDS. And while metadata has proven challenging for participants in the study, there was little interest in guidance on metadata creation or in services that produce metadata.

The survey also elicited data on informational RDS. Approximately half of the survey respondents indicated interest in both "data management plan templates and tools" and an "informational website with best practices and campus resources." While these do-it-yourself tools were rated highly by respondents, educational opportunities – including consultations and workshops – yielded far less interest. Likewise, assistance identifying data repositories, finding secondary data, and citing data prompted negligible interest as well.

Discussion

In line with the pragmatic impetus for this research study, it is useful to discuss the significance of findings in relation to the ultimate aim of the study: to develop research data management services at UVM. RDS includes a wide range services from informational, including data management plan support and data management best practices, to technical, including metadata, data sharing and access, data storage and backup, data security, research file organization and naming, and data citation. Martin (2015) writes, "[Research data] services need to go beyond helping researchers and grant writers develop required Data Management Plans. Services must extend beyond the planning phase to ongoing education about how to organize and manage the data, and offering services for preserving and archiving, as well as analytical and other statistical consultation services" (3). As a result of the integrated analysis, there are four major research data services to be considered by UVM: infrastructure, metadata, statistical support, and informational services.

Infrastructure

Uncertainty and confusion were pervasive in the qualitative and quantitative results as to what storage infrastructure is available to UVM faculty. The volume of data being created by researchers for a single project is typically quite small, with the majority of projects averaging less than 100 gigabytes; only a small subset of researchers routinely handle more than 1 terabyte of data. A particular outcome of this 'small data' research is an over-reliance on computer, laptop, or external hard drives both for short- and long-term storage solutions, a concern noted elsewhere in the literature (Pinfield, Cox, and Smith 2014; Whitmire, Boock, and Sutton 2015). The cost of data storage, for any length of time, appears to be a driving factor when considering data storage options. The qualitative interviews demonstrated concerns about costs of data repositories and confusion about the amount of 'free' storage campus IT provides. One respondent from the survey commented, "Data is stored on laboratory

computers. This is indefinite storage and doesn't require any funds." This is a naïve, but common, belief that doesn't account for data expiration or technical failure.

Storage is seen as both a high priority that UVM needs to address, but also a relatively easy activity for the majority of researchers to manage. This contradiction has several potential causes: the blanket use of the term 'storage' by researchers represents both short-term and long-term storage (preservation), conflating the issue; the relatively common practice of researchers to buy additional storage space using personal funds; and confusion as to what infrastructure resources are currently available through UVM. It could also suggest that, while storage is easy to manage, compromises are being made in how data is stored and that researchers are envisioning a system that better meets their needs.

For grant-funded researchers, the issue of storage becomes more acute. As one survey respondent wrote, "We as researchers are the stewards of the data on NIH grants but in fact the University owns the data and is responsible for its backup, storage, and maintenance for the length of time required by federal regulations," while another directly stated, "I believe the university should pay for the data storage if they want to associate their name or claim co-ownership of the data. They like when the UVM affiliation appears on a high profile paper but they do not currently contribute to the preservation of that data or research." Underlying these statements is a key question: What infrastructure needs should be guaranteed to researchers at UVM?

Based on the mixed responses in both strands of data, developing an institutional data repository – which would help account for long-term data preservation as well as data sharing – is not a priority solution for UVM at this time. UVM's institutional repository, ScholarWorks @ UVM, was launched in 2013 and is still gaining traction within the academic community; the lukewarm support for a data repository observed in the integrated analysis suggests that creating a data repository would have a negligible effect towards addressing researchers' challenges and concerns. Yet it should remain an area for the University to pay particular attention to; several interview participants who had submitted DMPs were excited by the idea of an institutional data repository, and as more faculty are required to submit formal data management plans, the scales may continue to tip in this direction.

A more pressing matter seen in the two strands of data is the overall state of UVM's technological infrastructure. The qualitative interviews highlighted how "woefully understaffed" campus IT was, which parallels a comment from the survey: "The fragmented and understaffed nature of UVM IT offices is another major hurdle to research and data management. I think UVM would do well to work on improving its basic technology infrastructure and IT staffing before, or at least in conjunction with, more specialized opportunities." Multiple survey respondents commented on the difficulty of sharing files and research data within research groups due to inadequate infrastructure – a sentiment also expressed during the interviews – noting it would be near impossible to share the same files externally. While there are no easy or immediate solutions for UVM, addressing infrastructure and storage issues has proved to be a major leverage point at other institutions to garner support and action around RDM activity (Pinfield, Cox, and Smith 2014; Raboin, Reznik-Zellen, and Salo 2012).

Metadata

Metadata proved to be a significant challenge for researchers in both phases of the study, whether directly acknowledged or not. In particular, there is a notable discordance between direct questions about researchers' use – or disregard – of metadata standards, challenges researchers face in describing data, and researchers' desire for metadata support or services. In looking at the connected results for RQ1, it is worthwhile to note that the requirement of DMPs as part of the grant proposal process has raised the awareness of the need for describing data and available metadata schema; as more granting agencies require formal DMPs, it is reasonable to assume that awareness will continue to grow.

At the same time, it is clear that the 'why' of metadata – not just the 'what' of metadata – needs to be further contextualized and supported for researchers to understand that structured metadata is essential to helping others find, access, and make sense of data. This study's ambiguous understanding of metadata suggests that researchers are either unfamiliar with the term 'metadata' or are unable to adhere to the protocols of metadata schema for any number of reasons. This latter point, in particular, may be better understood by further analysis of the bipolar adjective scale measuring attitudes and intentions towards data management.

The issue of unfamiliarity with metadata generally or metadata schema specifically has provided opportunity for outreach and engagement for some institutions (Whitmire, Boock, and Sutton 2015), yet it's notable that a study at Cornell University found that nearly two-thirds of survey respondents would not use a metadata service, regardless of cost (Steinhart et al. 2012). Given personnel constraints within the UVM Libraries, the low levels of interest demonstrated in the survey, and a lack of RDS at even the most basic level, this would not be a productive area for UVM to address in the near-term. Survey respondents indicated that funding agency websites were their main source of guidance when they had questions about creating DMPs; it is fair to suggest that these agencies bear greater responsibility in providing sufficient information so that researchers can successfully meet funding requirements. And, as study participants indicated, the RDM needs of researchers are so different across – and even within – disciplines that a top-down approach to metadata education and support may be a moot point if metadata is not being addressed in a meaningful way from the bottom-up within communities of practice.

Data Analysis and Statistical Support

An unexpected finding of this research was the high level of importance survey respondents gave for the University providing data analysis and statistical support. UVM currently offers a free Statistical Consulting Clinic (SCC) for faculty and students, providing a range of services across all stages of research. For 'big data' users, the institution also established the Vermont Advanced Computing Core (VACC), a research facility offering high-performance computing for complex data sets, with three tiers of service that move from free to fee-based. While the latter is promoted by the Office of the Vice President for Research and is heavily utilized by specific disciplines, including complex systems, computer science, physics, and health sciences, it is unclear the extent to which campus constituents are aware of the SCC. In an informal interview with the director of the SCC in the first phase of this study, he said: "For the most part, I depend on word of mouth. Since it's just me and I'm really very busy anyway, if I were to advertise… I'm afraid I would go crazy."

While not explicitly addressed in the interview protocol, during the qualitative phase several researchers mentioned their use of external statistical consultants, paid for by their grant; the expectation of external funds covering such auxiliary services was likewise reiterated in conversations with UVM's Vice President for Research. Yet this expectation is not a reality for many researchers. During the interview with the director of the SCC, he shared that he works with faculty across a broad spectrum of disciplines - psychology, social work, geography, agriculture, natural resources, and engineering were all mentioned – who conduct research without grants or newer faculty who haven't secured grant funding yet.

Separately but interconnected, institutional support of high performance computing, potentially to the detriment of more basic support and infrastructure, was critiqued by one survey respondent who wrote, "We shouldn't forget that Humanities, Arts, and Social Scientists have technology needs, too, and they should, arguably, be more easily supported because their needs are more modest." This is a fair critique: the director of the SCC said, "I'd love to have some help, but I don't see that happening. But I could really use more assistance." They continued by stating that when they retire in a few years, they are concerned that their positions will not be replaced, leaving a noticeable void in statistical support on campus. As UVM grapples with RDS now and into the future, it will be important to address and serve the needs of all faculty researchers, and it is clear from the survey data that data analysis and statistical support is an area to pay particular attention to.

Informational Research Data Services

Demand for informational RDS, typically provided by academic libraries, was notably lower than demand for technical RDS, as outlined above. While data management consultations and workshops had lukewarm support, do-it-yourself services such as an informational website or data management (DMP) templates and tools were popular. In particular, the latter could be addressed by a local installation of DMPTool, a software solution that would provide UVM-specific sample documents and language that allow researchers to create high-quality DMPs to meet funder requirements. While the Office of Sponsored Programs website offers some information related to data management, the Biology researcher noted the difficulty in locating relevant information during their interview:

> There's no coordination, and there's no information about who to go to when you have [questions about data management]. If you go to the UVM web page about research it's all about the money. How to get the money. How to get the patent. How to spend the money. It's not about the support that people need once they're doing the research or to do what they need to do after they get the money.

The development of an informational website specifically geared towards data management, that pulls together information from these disparate stakeholders and focuses on support, could prove an effective foundation for establishing future RDS. This same website could serve as a portal to educate researchers on relevant federal data sharing mandates, as well as available disciplinary or other data repositories.

At UVM, there is a strong possibility that the library is not currently perceived as a key stakeholder in RDS. A top challenge reported in Fearon et al's 2013 multi-institutional study showed faculty non-engagement in data management activities was due to a lack of

awareness of library RDS. Similarly, Whitmire, Boock, and Sutton (2015) noted that one of the biggest challenges at Oregon State University has been a lack of visibility on campus of library -provided research data services, such as reviewing data management plans. In a study at Cal Poly, San Luis Obispo, Scaramozzino, Ramírez, and McGaughey (2012) found that faculty were interested in RDS but the library was not perceived as the resource to provide such services. One survey respondent wrote in this study, "It definitely would be helpful to have [data management] resources available. I wrote my DMP unsure of what support UVM could offer in writing the plan and ultimately storing and sharing the data. If any support or guidance is available, it should be accessible through SPA and/or IRB where researchers need to go anyway for funded research."

This evidence builds towards the necessity of outreach in RDS, and particularly engaging with administration and faculty researchers about the role libraries can play in data management, as well as the need for collaboration with more 'visible' stakeholders on campus. Any successful endeavor at UVM would need to be the result of strategic collaboration between various stakeholders, including the Office of the Vice President for Research, campus IT, legal counsel, sponsored projects administration, and the libraries. This need for collaboration is underscored by the literature. Fearon et al (2013) reports on potential challenges with collaboration: "In order to provide comprehensive RDM services and to support scientists throughout the data lifecycle, libraries need to collaborate, either formally or informally, with other units at the institution… Forming these partnerships is listed as the biggest challenge by respondents, and in some cases has led to uncertain roles at the institution-level over which units have primacy over RDM" (20). Tenopir et al (2014) present such work in a more positive light: "Working with others on campus, as both teachers and joint learners of research data service specifics, will help the library play a shared role in building the future of research data at their universities" (89).

This collaboration is key for a pragmatic reason: limited available resources, be it personnel, time, skills, money, or institutional support (Tenopir et al. 2015). Raboin, Reznik-Zellen, and Salo (2012) discuss how limited RDS can be without funding, administrative champions, or appropriate IT infrastructure, while Pinfield, Cox, and Smith (2014) suggest that a lack of institutional support may be a key reason RDS hasn't been adopted faster, especially by academic libraries. Because libraries tend to be the initiators of RDS at higher-education institutions, Fearon et al (2013) found that academic libraries are absorbing the costs of most RDM services overall. The key challenges facing many research libraries are both tangible and social in nature: lack of money and resources, lack of faculty interest, lack of shared campus values, and the unwillingness of library staff to be retrained to manage data (Scaramozzino, Ramírez, and McGaughey 2012).

It perhaps is to the institution's benefit that there is minimal demand for informational RDS at this time because it begs the question, Who would be providing such services? Like the majority of academic libraries (Steinhart et al. 2008; Cheek and Bradigan 2010; Fearon et al. 2013; Raboin, Reznik-Zellen, and Salo 2012; Soehner, Steeves, and Ward 2010; Tenopir et al. 2015), UVM Libraries does not have a dedicated data librarian to provide RDS. Instead, any services would be provided by individual subject librarians, who may or may not have the specific skills to meaningfully assist with data management. To this end, the breadth and depth of services offered will be significantly influenced by the available technical skills, advocacy skills, and research expertise of the librarian. Heidorn (2011) underscores this point: Because

RDM is heterogeneous in nature, it is very difficult for any single individual to have all the required knowledge and skills to provide RDS. While the role of outreach – educating faculty about available RDS – is important, equally important is the notion of 'inreach,' educating librarians about data management (Hswe and Holt 2011). Any consideration of future informational RDS would therefore need to be accompanied by opportunities for professional development, both within the libraries but also among campus stakeholders.

Conclusion

The need for data management support and services will continue to grow, especially as more faculty are being required to directly address RDM in grant applications. While there remains a question as to whether DMPs are taken seriously within the grant application process – either in actuality or in perception – there is some evidence to suggest that DMPs are being critically evaluated on some level: one survey respondent wrote, "I recently submitted an NSF proposal and was told my data management plan was inadequate but it was the one UVM provided. The institution needs to catch up as it was a factor in my rejection." While not all researchers will be required to submit data management plans, attending to the needs of this subset of the population will benefit the entire institution. But it remains equally important to not focus myopically on just federally funded researchers, and stay attuned to the needs of all researchers, in particular those who do not have funding to support the range of their data management activities.

The development of research data services at the University of Vermont will requires both a top-down and bottom-up approach: it needs to respond to need and demand by the researchers at the institution, but also needs to have leadership and resources provided by top-level administration in order to be successful. Hopefully, this research will also prove to be a tipping point internally, clearly demonstrating the need at UVM, not just for collaboration, but for support of research data management at every level and for every researcher.

The study is not without its limitations. The samples for both strands of data were not fully representative of the populations of study, and there was potential confusion about key terms in the study, namely the conflation of data storage and data preservation/curation. Additionally, one of the more interesting themes to arise from the qualitative phase of the study was the perception of data management plans and attitudes towards data management planning. This theme resulted in the creation of a bipolar adjective scale, based on the Theory of Planned Behavior, to assess attitudes and beliefs towards the data management planning process in order to measure intention of implementing data management plans. This data has yet to be fully analyzed, and may uncover new understandings of the impact of DMPs and research data services, and provide interesting directions for future research studies.

By using an exploratory sequential mixed methods research design to uncover UVM researchers' data management practices and the challenges they face in managing digital data, this study allows for a deeper understanding of UVM researcher needs and to develop a robust plan to implement research data services that meet these needs. In particular, the strength of the mixed methods approach allowed for a deep dive into understanding the lived experiences of researchers' data management practices via qualitative methods, while using the results of the qualitative analysis to build a survey instrument to more accurately measure data management activities at UVM, including behaviors and attitudes toward data

management planning. The integration of these two strands of data has been crucial to unpack the salient themes UVM should address through research data services. To date, related published studies have reflected either a qualitative or quantitative research orientation; this study successfully provides a model to strategically and systematically link qualitative and quantitative data into a truly mixed methods research design.

Supplemental Content

An online supplement to this article can be found at http://dx.doi.org/10.7191/jeslib.2017.1104 under "Additional Files".

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