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1. Introduction

The existing academic research workforce is ill equipped to manage research data using the increasingly complex computing technologies available to them. Despite the availability of ever more powerful desktops, mobile technologies, and high performance cloud computing and storage, universities are failing to provide graduate students with adequate data management skills for research in academia or industry. The challenge for mid- and late-career faculty is even greater, because of the difficulty in changing established research practices for ongoing studies. This skills gap places at risk billions of research dollars, the integrity of vast quantities of research data, and the quality of life for millions of people.

Providing this workforce with the skills they need to collect, manage, and share their data effectively is a challenge many academic libraries are taking on. Though libraries may provide some technological solutions, our most valuable contributions lay in expertise and trust. We have the resources to fill this skills gap by using our information management expertise, teaching ability, ability to facilitate conversation across departmental and disciplinary boundaries, and a uniquely holistic understanding of the scholarly record. At IUPUI, education and advocacy is the foundation of our data services. This choice is shaped by the recognition that many graduate programs are not sufficiently preparing students to manage digital research data. Before we can expect academic researchers to share, preserve, and curate their data, they must understand the value and importance of data management.

This chapter will describe IUPUI's initial foray into data information literacy instruction, the lessons learned, and look forward to the future of such programs. We drew upon best practices in

instructional design and information literacy, the scientific lab experience (Coates, 2014), and interdisciplinary data management expertise to develop the program. The focus is on practical techniques for responsible data management and relies heavily on the data management plan (DMP) as a tool for teaching and research. Our initial trainings have reached a diverse audience, many of whom were not identified as stakeholders when developing the curriculum. This chapter will describe the development of our instructional program, assessment results, and modifications to portray an emerging data literacy program at a high research activity university. As data has become increasingly important in academic research, confusion over terminology abounds. Bringing together researchers from diverse environments introduces uncertainty when similar terms encode different meanings for different communities. The community of library data specialists includes professionals with diverse backgrounds, so it is useful to clarify the terms we use to discuss data skills. I use data literacy to encapsulate the skills related to finding, collecting, managing, processing, analyzing, visualizing, disseminating, and reusing data within the context of a research project. Data information literacy describes the skills needed for data creators, data managers, and data consumers to do their work. This could include activities that take place outside the research process. When I teach, I present these skills as research data management skills. Lisa Johnston, Research Data Management/Curation Lead and Co-Director of the University Digital Conservancy at the University of Minnesota articulates this distinction very well (personal communication, March 31, 2015).

“For me, data management (or RDM if you prefer) is a set of skills or best practices that can be discussed, taught, and put into practice. Other examples might be digital preservation or data visualization. These (and others) are key competencies that can be included in the overarching concept of data information literacy. But I don't tell the students that. Data

information literacy is simply the binding concept that brings all of these skills and ideas into one frame of reference that I can use to define my own research in this area.”

Research is a process of discovery demanding motivation, perseverance, and the ability to learn independently. Being an effective researcher requires a strong foundation of disciplinary knowledge, as well as intellectual curiosity, intrinsic motivation, and metacognitive skills needed to cope with frequent obstacles encountered in the discovery process. The core of our data literacy program includes teaching strategies for managing information and metacognitive skills that enable researchers to overcome difficulties, course correct, and ultimately persevere in the face of repeated failures. Much traditional library expertise can be translated and applied to research data management, given some knowledge and experience of the research process (Lyon, 2012; Pryor & Donnelly, 2009; Swan & Brown, 2008; Tenopir, Birch, & Allard, 2012).

An informal environmental scan of our campus conducted in 2012 revealed that very few programs offered courses in managing research data. The few that existed were very discipline-specific. Although our first step in providing data services was offering support for faculty developing NSF data management plans, conversations during workshops and consultations reinforced the need for training in digital data management. And while faculty are often targeted as high-impact stakeholders, the potential impact of training early-career researchers in more effective data management practices is higher over the long term. These practices are typically passed down from advisor to mentee and staff. Unfortunately, they are often idiosyncratic and based on outdated technologies available during the mentor's training. The significant role of mentorship in graduate training can result in passing on outmoded research practices that

compromise data integrity and reproducibility. Our program was designed to teach generalizable strategies for data management throughout the lifecycle that can be applied to current and future research technologies.

2. Data Management Lab

2.1 Background

This program began as an informal lab pilot, but has since taken the form of a workshop series, standalone workshops, and tutorials. The scope and format were informed by a scan of available courses on campus, discussions with graduate program directors, and a review of data management curricula available at the time (DataOne, 2012; EDINA and Data Library, 2011; RDMRose, 2013). Throughout the design process, input from the Data Management group at the Indiana Clinical and Translational Sciences Institute (CTSI) provided useful guidance and targets. Tolerance for innovation within IUPUI University Library is high; we are encouraged to experiment with new services. Thus, this program began as a grassroots effort.

While the Center for Digital Scholarship was recently established (2014), our staff have been creating digital collections of cultural heritage materials, electronic theses and dissertations, and open journals for nearly fifteen years. Over the past four years, three librarians were added to expand open access initiatives and to develop support for research data and digital humanities. Current staff members include an Associate Dean of Digital Scholarship, five librarians, three full-time staff, and several part-time student employees. These services and systems are supported by an internal IT team (6 FTE), who also provide support for the library website,

archives, and special instructional initiatives not maintained by other institutional or campus services.

The Data Services Program, established in 2012, has been shaped strongly by the context and strategic priorities of University Library, the campus, and the institution. The library's Strategic Directions include two items relevant to data: enhance the ability of IUPUI students and faculty to make their scholarly output widely accessible, and ensure its preservation (Lewis, 2015). The IUPUI Strategic Plan for Research (*Research Strategic Plan, Indiana University - Purdue University Indianapolis*, 2014) incorporates several priorities suggested by University Library: encourage wider access to findings and applications from research at IUPUI. More specific action items include the following:

- 5.2. Facilitate and increase dissemination of research and scholarship;
- 5.3. Support new metrics to assess research impact at all levels;
- 5.4. Facilitate data management reuse and archiving.

These statements emphasize data as a valid scholarly output and highlight the parallels between public access to publications and data sharing issues. Within this context, data management is viewed as a cluster of skills crucial for the production of high quality data, the responsible conduct of research, and long-term access to the products of academic research. The Center's mission supports the dissemination, reuse, and evaluation of data as a valuable scholarly product alongside our support for publications.

2.2 Approach & Audience

The ultimate goal of this program is to provide researchers with the skills to manage their data responsibly to produce better results. Five broad priorities were identified: 1) building awareness of research data management issues; 2) introducing methods to facilitate data integrity and address common data management issues; 3) introduce institutional resources supporting effective data management; 4) building strategic skills that enable researchers to solve new data management problems; and, 5) building proficiency in applying these data management methods. These priorities emphasize the importance of data management within the research process and its role in the integrity of the scholarly record. Framing the content in this way demonstrates the relevance of data management strategies to the products of their research, which is an important motivational tool for encouraging researchers to implement these strategies.

The program was designed to be learner-centered by using outcome-based planning and incorporating active learning strategies. Initially, the intended audiences were faculty, graduate students, and research staff. Unexpectedly, several staff from administrative units such as the Office of Research Compliance (ORC) and clinical production labs like the Indiana University Vector Performance Facility attended the fall 2014 workshops. This connection with the ORC has led to the creation of a working group established to develop institution-wide guidelines for research data management that will inform policy development and adoption.

2.3 Structure & Content

Content for the data management lab was gathered from literature spanning multiple disciplines. Selected resources ranged from practice manuals like *Good Clinical Data Management Practices* (Management, 2013) to data processing texts such as *Best Practices in Data Cleaning*

(Osborne, 2013) to guidelines from the Office of Research Integrity (Steneck, 2004) as well as articles from computer science, library and information science, ecology, and statistics. Other key resources included reports from the National Academy of Sciences (Committee on Science, Medicine, Affairs, Sciences, & Engineering, 2009), the UK Data Archive *Guide to Managing and Sharing Data* (Corti, Van den Eynden, Bishop, & Woollard, 2014), and the ICPSR *Guide to Social Science Data Preparation and Archiving* (2012). It took nearly a year to conduct the literature review and develop the curriculum and instructional plan.

Identified strategies were reviewed for curriculum inclusion based on feasibility, value, and relevance to as many research methods and contexts as possible. The tentative curriculum was compared to curricula available at the time, such as Research Data MANTRA, RDMRose, and the DataONE Educational Modules. This comparison was helpful for identifying gaps in the evidence base as well as the curriculum and in balancing the needs of diverse research methods and tools. Unsurprisingly, the curriculum developed for IUPUI is very similar to those developed by other academic libraries (Coates, Muilenburg, & Whitmire, 2015; Johnston & Jeffryes, 2014; Kafel, Creamer, & Martin, 2014). This convergence reflects significant consensus across the community about the data management skills researchers need to succeed.

The assembled practices and strategies were organized around the DataONE data life cycle to relate them to the research process as experienced by study personnel. This approach was selected to reflect the needs and expertise of researchers who are engaged in ongoing studies. The program includes a broad introduction to the research data management and scholarly communication issues with the recognition that people learn what they regard as relevant. This

introduction explicitly describes the connections between data literacy skills and the quality of research products, their professional reputation, and the importance of quality evidence for scientific progress.

Key program take-aways emphasize the importance of thorough planning before embarking upon data collection. Specific planning events should include (Society for Clinical Data Management, 2013):

- defining expected outcomes and quality standards for generated data;
- identifying legal and ethical obligations as they affect data management, protection, security, and ensuring confidentiality/privacy;
- selection of tools, formats, and standards;
- a sound storage and backup plan, including the use of data locks or master files;
- developing an index of project and data documentation to support efficient and accurate reporting;
- identifying relevant best practices for data collection, entry, and coding; and,
- identifying key expertise needed at the institutional and research community levels for informed decision-making.

These considerations and decisions are documented in the data management plan and updated as the project progresses.

2.4 Evidence-Based Instructional Design

The format of data management and literacy training has typically consisted of one-shot workshops and stand-alone courses. At IUPUI, we are currently limited to providing non-credit

bearing workshops. In order to move quickly into the gap in data management education, we chose to start by offering a variety of workshops, both stand-alone and series. The January 2014 pilot was offered as a one-day 8-hour workshop. Since then, the program format varies depending on the specific audience and content that is targeted each semester. In the spring of 2014, it was offered as a 4-week workshop series of weekly 2-hour workshops. We scheduled evening sessions because our target audience, graduate students in the health and social sciences, often work. This proved to be less popular than expected, so subsequent events have been scheduled earlier in the day. Three key topics from the curriculum were selected for the fall 2014 line-up. Stand-alone workshops were offered on three topics: practical data management planning, preventing data loss, and ensuring data quality. Other formats for the curriculum are planned. First, activities that are relatively straightforward and procedural will be adapted into tutorials and flipped classroom sessions. Additionally, we are exploring the feasibility of offering a for-credit course as well as embedded instruction tailored to the needs of particular departments or research centers. A long-term goal for the program is to offer tiered and progressive instruction across the curriculum, similar to integrated information literacy programs.

Learning outcomes for each topic were developed from best practices and recommended strategies when available. While there are gaps in the literature, the challenge in this phase was to prioritize the long list of learning outcomes into a cohesive and feasible program. Once a reasonable list was developed, the next steps were to identify instructional design and assessment strategies. The guiding approach for this phase was to minimize lecture as much as possible in order to provide sufficient time for application through active learning exercises. This was a fairly complex and messy process, so structure was imposed through the use of an instructional

design spreadsheet (see Table 1). The primary form tracked modules, topics, learning outcomes, activities, assessment products, use of case study, and examples. More specific sheets contained details about instructional timelines, assessment, and instructional materials.

The goal of creating a learner-centered classroom that engages students with active learning techniques was accomplished using outcome-based planning. In selecting recommended instructional design strategies (Clark, 2010; Nilson, 2003), four areas of focus emerged: lecture, discussion, examples, and exercises. Keeping these in mind, specific activities were created to address motivation, procedural skills, strategic skills and metacognitive skills. Strategic and metacognitive skills in particular are crucial for researchers to be successful in the uncertain world of research. But teaching these skills will be ineffective if students are not motivated to learn the material. We can help motivate them by making the material relevant to their day-to-day experiences, future careers, or real-world problems. The primary method we used was explaining the connection between learning outcomes to the ultimate goal of ensuring research integrity. Similar to information literacy instructional programs, our data literacy curriculum attempts to develop strategic skills for solving new data management challenges and enable researchers to become self-regulated and self-directed learners.

2.4.1 Lecture

Used appropriately, lecture is a valuable component of almost any instructional program. However, the weight of evidence for recall and application favors active learning strategies such as those that are inquiry-guided, problem-focused, and collaborative (Nilson, 2003). Since it was not possible to eliminate lecture completely, the amount of time spent on lecture was minimized

by focusing only on content that was strictly necessary. In general, this was realized by following established best practices based in neuropsychology. Each lecture component was brief, limited to 20 minutes (Nilson, 2003). This ensured that content was kept concise, focused only on the information needed to accomplish the learning outcomes (Clark, 2010). Each lecture began with a statement of learning outcomes and ended with a review to reinforce the connection between the content and how attendees could implement it. Presentation slides utilized a combination of text and graphics and incorporated examples whenever possible (Clark, 2010).

2.4.2 Discussion

Discussion, the second core component of the instructional plan, is most effective when it is activity-based, encourages reflection, and provides for formative assessment. It provides an opportunity for learners to practice self-regulation of their learning through application of metacognitive strategies. Nilson (2003) clarifies situations in which discussion is particularly effective. Those relevant to data literacy instruction include examining and changing attitudes, beliefs, values and behaviors; problem-solving; exploring unfamiliar ideas open-mindedly; and transferring knowledge to new situations. Discussion often requires more upfront planning than expected. Students need to be primed for discussion. One goal is to have them engage with each other, rather than talking through the instructor (Nilson, 2003). Specific strategies to facilitate productive discussion include waiting for responses, starting with a common experience, brainstorming what students already know about a topic, using good questioning techniques, and concluding with a wrap-up (Nilson, 2003). The wrap-up ensures some closure and provides a summary; it is most effective when led by students (Nilson, 2003). We used discussions to share diverse perspectives and research experiences, build rapport and community, and address

complex topics such as ethical and legal obligations and choosing what data to retain for preservation.

2.4.3 Examples

Examples were used to make lectures and exercises more engaging and to provide concrete examples for how broad data management concepts are applied across disciplinary boundaries. Effective examples enable learners to integrate new information into a coherent structure, such as their mental model. They are especially effective when worked and partially-worked examples are provided and discussed (Clark, 2010). These can facilitate procedural learning by modeling the process, which provides support for learners through each step (Clark, 2010). This can present challenges for a mixed audience of novice and experienced researchers, so it is important to remember that while novices learn better with examples, experts do not. They benefit more greatly from time to practice (Clark, 2010). Our program embedded examples into the lecture content and used them to support the exercises, described next.

2.4.4 Exercises

People learn through elaborative rehearsal and by connecting new knowledge to what they already know and believe (Nilson, 2003). In the classroom setting, exercises provide opportunities for this rehearsal. We designed exercises to be relevant, meaningful, contextualized, and targeted to a particular skill. Each activity provided an opportunity to practice the strategies introduced during the lecture. Activities in the spring workshops were designed with the graduate student thesis or dissertation project in mind, to make them meaningful and contextualized. This approach met the need to provide exercises requiring

application rather than recall (Clark, 2010). One effective practice we were unable to implement is distributed practice of skills over time to promote retention (Clark, 2010). Including exercises that meet all of these criteria is challenging, but implementation has improved with each iteration of the program. Specific improvements will be discussed later, along with challenges and next steps.

2.5 The Data Management Plan

The content and meaning of a data management plan (DMP) varies widely. For funding agencies, a DMP serves as a data collection tool to identify common practices. Researchers use the DMP as a planning tool, a part of the project startup process, a communication mechanism throughout the project, and a resource for writing results. It is effective for both planning and implementation. However, a DMP is just one piece of good study documentation. Data management plans are functional, living documents that reflect both planning and study conduct, encompassing information that can be used in articles, reports, and subsequent proposals. A DMP should reference existing standards and norms for the field. Several professional and research communities have established standards for data management and interoperability (CDISC Submission Data Standards Team, 2013; Clinical Data Interchange Standards Consortium (CDISC), 2008; Federal Geographic Data Committee, 1998; Knowledge Network for Biocomplexity, 2011). One such group is the Society for Clinical Data Management, which produces a guide to *Good Clinical Data Management Practice* (2013) that is updated biannually. It is both comprehensive and focused, covering all aspects of project management for clinical research.

The DMP is extremely valuable in the instructional context. It is a real-world product that enables authentic assessment of learning outcomes; it is an effective instructional tool because it relies on strategic skills (i.e., performance of tasks that are not routine and require problem-solving to adapt to the unique circumstances of the situation). The DMP provides an excellent opportunity for engaging learners with relevant examples and exercises. The challenges lie in developing rich cases or scenarios from which detailed DMPs can be developed if learners are not at a point in their own research to develop one. These characteristics make the DMP a uniquely powerful activity and product for assessment.

Its value as an actionable document for planning, startup, active project phases, and project completion make it worth the time needed to explain how a DMP can be used. A functional plan articulates outcomes that can be measured to identify successes and failures; it also helps researchers to anticipate problems and prevent them, gathers information needed for team communication and reporting, and enables extension, secondary use or reuse, and reproducibility of results. Perhaps most importantly, the planning process helps researchers to clearly link data quality standards to study processes, thereby producing higher quality research outputs. This is perhaps most clear in the highly-regulated clinical research environment. Although the current emphasis is on its use in planning, an effective DMP, like all study documentation, should be viewed as a living document that is used frequently and updated periodically (Society for Clinical Data Management, 2015).

2.6 Strengths

Overall, evaluations for both the pilot and spring workshop series were positive. Responses to the examples were strongly positive, in session and in the evaluations. Time for discussion was appreciated and many asked for more time to continue them. Learners also appreciated the resources provided, particularly institutional services and resources, and links to further information. When asked what topics were most valuable, responses varied. Topics identified include data management plans and planning, file organization and naming, storage and backup, master files and versioning, documentation, and data citation. The evaluations also provided constructive criticism that was used to improve later offerings. During the pilot, even the experienced staff stated that a full 8-hour day was too much; they felt overwhelmed. In the spring, content was separated into four workshops of 2 hours each. This format provided sufficient time to engage students with exercises, while alleviating the weight of providing all the content at once. It also provided students time to reflect between sessions, which enhanced discussion because they were better able to make connections between the topics.

2.7 Challenges & Next Steps

Although the evaluations spoke to the relevance and utility of the program to their research, there remains substantial room for improvement. In particular, there is much to be done to optimize instructional design and delivery and expand its reach to the research community at IUPUI. Possibly the most significant challenge was not knowing where students are starting from (Nilson, 2003). Within the graduate student population alone, there is a wide range of experience with research. Some are professionals seeking education to advance or change careers, while others have just finished their undergraduate work. Teaching researchers with such a diverse range of experience is difficult; some strategies are more effective for novices than experts, and

vice versa, making it difficult to develop learning outcomes, choose exercises, and select relevant examples. One option is incorporating topic-specific pre-assessments into the beginning of each session to prime learners and target instruction more effectively. Another is to have learners complete a broad pre-assessment prior to the program. Unfortunately, no such assessment currently exists.

Despite positive evaluations, attrition was high throughout the spring series of workshops. While 23 attendees registered, only slightly more than half (12) attended the first session. By the fourth and final session, just four students remained. It may be possible to improve this with better timing, but retention is generally a problem for non-credit bearing workshops on our campus. We are exploring other incentives to promote retention, as well as the possibility for partnering with an academic department to provide a for-credit graduate course.

The third significant adjustment is to provide better support for relating data management skills to existing knowledge and experiences. As Nilson (2003) reminds us, we need to teach students how to learn the material. We hope to accomplish this by explicitly connecting individual learning outcomes with the broader goals and skills they will gain. For each session, we will provide an empty outline of the key points for students to fill in along with a background knowledge probe. We will facilitate attendees relating new ideas to their existing knowledge by providing time for reflection and explicitly discussing the connections between the learning outcomes and the students' area of research. Tools like concept maps are time consuming to use, but the burden on the instructor could be alleviated by using peer review to provide helpful feedback.

There are many minor adjustments to be made. We have already begun to try workshops that cover fewer topics (Clark, 2010) in order to delve more deeply and provide more opportunities for application. While the design for the spring workshop series attempted to build in plenty of assessment opportunities (Nilson, 2003), execution in the classroom was less than ideal. We will further examine the activities and assessment products to ensure we provide adequate motivation and clearly state the connection to learning outcomes. Specifically, formative assessment of data management plans and documentation will be incorporated primarily through peer-review (Whitmire, 2014). Ideally, summative assessment will be added to gather evidence of behavior change and implementation of learned strategies. We will build in additional time to complete the formative assessments, review them, and respond to them. There are also plans to more explicitly teach metacognitive skills to promote self-regulation of learning within their own research.

3. Future of data literacy instruction

3.1 Opportunities

We face several important questions as the demand for these skills within and outside the academy increases. When do we provide data literacy instruction? When is it most relevant and useful for students? Information literacy research has found that support and instruction are most powerful at the point of need, but there are many such points that arise throughout the research process. How do we reach students during those times? And how do we help students identify when they need support? Further research into these questions is necessary for instruction to proceed beyond a trial and error approach to meeting the needs of our researchers.

I see two immediate opportunities. If we want to better adapt data literacy instruction to students, we need to develop pre-assessments that accurately gauge their knowledge of disciplinary research practices as well as the research process. The most pressing needs for data literacy instruction are authentic, engaging examples and activities. While many participants have pre-existing projects, students who are novice researchers need the support of relevant examples and well-structured exercises. Such resources rely on real-world datasets that are curated for instruction purposes, rather than for reuse. Developing scenarios and case studies are time-consuming and can be difficult to tailor to specific fields of research if the instructor is unfamiliar with them. Just as librarians have developed rich resources for information literacy instruction, we need a repository for instructional materials, cases, scenarios to effectively teach data literacy. This should include activities and assignments relevant to disciplinary practices and which provide opportunities for authentic assessment. The data management plan is just one of these activities. Second, we need to identify foundational data management skills and determine the optimal sequence of learning outcomes that enable students to practice responsible data management within their own discipline. This will require the data librarian and specialist community to leverage the expertise of our instructional and liaison colleagues.

Moving forward, the community of instructors teaching data literacy, including faculty and librarians, has several issues to address in order to develop sustainable models for instruction. We should explicitly acknowledge the many roles through which people interact with research data – creator, manager, and consumer. In these early days, we can simply build in support for data literacy alongside existing information literacy services such as reference and instruction,

content guides, citation tools and training, first-year experience programs, discipline-based programs. Rather than creating new models for service, it may be more sustainable to train library staff to deliver data content and instruction in the context of their daily work. For those data specialists or managers tasked with developing or coordinating support for researchers, this could take several forms (Tenopir, Sandusky, Allard, & Birch, 2013). However, models which simply extend existing services (such as reference, instruction, and liaison activities) to include data are less well-documented.

3.2 The future of data literacy instruction at IUPUI

The future of our program will include broadening the range of formats by offering targeted materials and activities for use by faculty in discipline-specific courses, a for-credit graduate course, self-paced tutorials, as well as general workshops and on-demand instructional sessions. In particular, we need to develop mechanisms to deliver point-of-need support alongside embedded support within particular academic courses. Of course, the ultimate goal for data literacy instruction is to demonstrate long-term impact and application of these skills in the research happening on our campuses. For that, we can look to the literature on demonstrating the value of academic library for examples and strategies. People learn when they are motivated to do so by the inspiration and enthusiasm of others (Nilson, 2003). Instructors can tap into their own passion and energy by finding the aspects of data literacy that are compelling to them, and can in turn help students connect with their interests by sharing stories of failure and success.

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