Teaching Research Data Management: It Takes a Team to Do It Right!

Mr. Larry Schmidt, University of Wyoming

Larry Schmidt is an associate librarian at the University of Wyoming and is the current Head of the Brinkerhoff Geology Library. He holds BS degree's in Chemistry and Biology, MS Degree in environmental engineering from Montana State University and received an MLS from Emporia State University in 2002. His interests lie in providing undergraduate and graduate students with information, data and science literacy skills that will allow them to succeed in a global economy.

Dr. Joseph H Holles, University of Wyoming

Associate Professor, Department of Chemical Engineering

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Introduction:

Research Data Management (RDM) is an important competency that is beneficial for graduate and undergraduate students across the disciplines. Not only are many funding agencies requiring a Data Management Plan (DMP) for new grant proposals [1,2,3,4], there is also a shift toward data driven research, data driven analyses, data visualization and new distributed computational systems that use "big data". One piece of data management is metadata and the problems that insufficient or bad metadata can cause. Take, for example, a recent article in Science "Engaging over data on fracking and water quality"[5]. The authors discuss both the political and scientific side to the complexities of gathering disparate data sets and merging them into one online public database for high-volume hydraulic fracturing in Pennsylvania. A major problem with merging data sets is often related to a metadata issue, "Water data is particularly complex in comparison to …". In this case, they are describing the problem of disparity in metadata; they found 13 different reporting conventions used for reporting nitrate. This is one example supporting the need for good data literacy and management, especially with the move to make data freely available to facilitate data verification, data reuse and duplication of experimental results.

Universities are addressing data issues for their campuses in a number of ways. Some universities are hiring informatics faculty and other data management professionals to facilitate RDM and big data needs on campus [6]. Although this will help with certain research programs at an institutional level, it may not support every RDM need that researchers and students have. In fact, to address this growing demand, articles and books on the topic are being published. In *Data Management for Libraries*, Krier and Strasser provide a guide on how libraries can develop a data management consulting service [7]. They also stress building such a service is not something librarians can do on their own. It takes teamwork that includes administrators and researchers along with institutional support to create a successful service. Another example written for researchers, and a resource for librarians interested in developing RDM skills is *Data Management for Researchers: Organize, maintain and share your data for research success* [8].

As librarians continue to provide traditional help in information literacy and scholarly communication, now is the time to expand and take on another role: providing RDM services to students and researchers. Krier and Strasser discuss RDM training in their book and how data literacy fits in with the role librarians already fulfill in teaching and assisting students in information literacy and scholarly communication instruction [7]. Many of our libraries have the structure in place for librarians to provide assistance for multiple disciplines including the social sciences, engineering, humanities, medicine, biological and physical sciences, and education disciplines. However, RDM is not a topic that lends itself being taught or managed by any one group or discipline on campus. Researchers approach RDM through the eyes of their specific discipline while librarians take the broader view looking at RDM through the lens of scholarly communication as a whole. Rather, it is a set of skills and knowledge that takes an interdisciplinary approach to address properly.

There is a growing evolution in libraries to support RDM that includes helping their institutions with RDM plans for grants, supporting their data storage and preservation needs and, finally, looking to teach RDM to students and faculty. Teaching RDM skills to students is an important academic competency that the students will need as they progress through school and into their

professional careers. Carlson et al. in their assessment of data information literacy needs of students and research faculty state, "Although faculty and students do consume research data, our analysis indicates that we have to address their roles as data producers as well." [9]. With the growing emphasis on data reuse, interdisciplinary research and multi-institution collaboration, the next generation of researchers will need RDM skills to navigate and excel in this shift toward big data. Librarians are well equipped to take on this role as libraries are now teaching data information literacy skills to audiences that may include faculty, graduate students, undergraduate students, and librarians [10].

RDM instruction approaches depend on the audience to be taught and the instructors doing the teaching. Additional factors include the time available for the instruction, whether it is mandatory training, or if it is a credit class through a specific department or the libraries. RDM teaching approaches include seminars, workshops, workshop series, noncredit courses and credit courses and, in some cases, pre-course interviews of researchers, research groups or departments. Instructors for these approaches vary as well. Individual instructors have taught credit classes while some classes are co-taught by multiple librarians or as a librarian and faculty member team. For the workshops and other shorter instruction sessions, instructors are chosen for the topic that is being taught. There are even cases of the material being made available online via a YouTube. So, not only are the types of instruction variable, there are also multiple methods instructors can utilize to teach a session.

This paper presents a collaborative interdisciplinary approach to RDM instruction using current literature and the authors' insight on their own recent course. Reviewing the successes and lessons learned from credit classes, seminars and workshop styled courses provided guidance for the creation of a 3-credit course for graduate students in the engineering and physical science disciplines [11, 12]. Results of student outcomes from this class along with examples from previous instruction efforts provide good reasons to take a team approach when teaching RDM to graduate students. Along with our RDM instruction experience and literature review two trends seem to be coalescing: teaching RDM credit classes, and using a team approach for instructors. The goal of this work is to illustrate best practices, promote an interdisciplinary collaborative approach to RDM instruction, make the case for credit classes and provide suggestions to help make it a viable and sustainable option for other universities.

Methods:

Most RDM instruction fall into two primary structures: 1) the individual workshop or seminar, and 2) a series of seminars or a term long class. Librarians have a culture of seminars and workshops to teach information literacy skills and often take this approach to RDM instruction. Research faculty, on the other hand, teach credit classes as a part of their teaching load. Data literacy is a topic that can be approached two ways: workshops for focused content, and courses to cover a subject in both breadth and depth. The authors chose to teach a credit course to provide in-depth coverage of RDM topics. In developing a graduate course to teach engineering students RDM skills, the authors utilized material developed by Whitmire, a librarian, from her 2-credit course taught during 2014 [13]. Briney's "Data Management for Researchers" was the textbook used for the class [8].

The 3-credit class was held three days a week for 50 minutes each for a total of 42 class periods. A semester long credit course allowed for in-depth coverage of a large range of topics, room for numerous guest speakers and ample time for discussion without having to rush through the material. The flexibility of a three-credit class seemed to be more easily adopted for our goals even though some of the literature suggests a one or two-credit class would suffice [13, 14, 15]. The course was taught under the special topics heading offered by the Department of Chemical Engineering during the Fall Semester of 2016.

Guest lecturers with expertise in library and information technology were targeted to teach the students on a number of topics where the practitioners have more knowledge and experience than the course instructors. Librarian and IT experts were targeted to teach concepts on metadata, researcher ID's, DOI's, storage, and data preservation. It was important for the students to learn how to manage current experimental data for their group work in a way that allows them to store and share their active data as needed. The Advanced Research Computing Center (ARCC) informaticist is knowledgeable in this area and agreed to provide a lecture along with the digital collections librarian to help with this aspect of RDM. In order to expose the students to the other aspects of RDM, four guest lecturers visited the class, including a humanities researcher, a manager of data acquired purposely for reuse, a PI from a multi-institution research group, and an administrative lawyer from the Research Office.

The course work was based on topical discussions with lectures followed by interactive question and answer sessions. Along with the textbook, additional resources including the DMPtool [16] and the Data Curation Profile [17] were used as assignments and additional readings. Exercises for the class were created to expose students to a broad range of concepts dealing with data management to build skills to apply to their own research projects. To provide students with a broader view of managing research data we selected a diverse set of guest lecturers to speak about their experiences. These lectures were followed by discussion sessions that brought to light the complexity of dealing with research data in real world situations. A more complete methods discussion for the class can be found by reading the authors articles "A Graduate Course in Research Data Management" [11], or another example prepared for as an ASEE presentation, "Implementing a Graduate Class in Research Data Management for Science/Engineering Students" [12].

Literature review:

As described earlier, RDM education at universities is offered in a variety of ways and targets multiple audiences. Target audiences range from the undergraduate student learning how to manage their individual research project to librarians learning a new skill to help provide a needed service at their university. Instruction style can vary as well with seminars, workshops and stand-alone courses being used to teach RDM skills. Who teaches RDM can vary just as much as the audience: librarians teaching alone or in teams, librarian and faculty combinations, librarian and IT professionals, and any combination of the above including guest speakers. Often, there is preparatory work that may include interviews, laboratory reviews, surveys or other tools that aid in getting informative information to facilitate the work toward RDM instruction. In order to illustrate the benefits of the team approach to RDM instruction and the trend toward credit classes, Table 1 compares the course type, date, instructor method, preparatory work and

the target audience. There is a large body of work out there showing multiple ways to teach RDM skills to students but there is a consensus developing supporting using the team approach to teach credit courses.

Author(s)	Time	Preparation Methodology	Instruction approach	Audience	Team Member(s)
J. Adamick et al.	2017	Focus group	Workshop 90 min.	GS	Librarians
C. Borgman	2015	Course Syllabus	Course – 4-credit hrs.	GS, MLIS PhD, Med. S	Librarian - PhD Library Science
J. Carlson M. Sapp Nelson	2012	Environmental Scan (DIL)	Embedded approach	GS, L	Librarians
J. Carlson M. Stowell-Bracke	2013	Interview, Environmental Scan (DIL)	Embedded approach	GS, L	Librarians
R. Clement, et al.	2017	Planning Group - Librarian Facilitators	Workshop - 1.5 days	F, GS, UG, L	Librarians, Faculty
B. Fong M. Wang	2015	Data Profile for research groups	Seminar 90 min., Workshop 1 day	GS	Librarians
L. Johnston J. Jeffryes	2012	Environmental Scan (DIL)	Course - not for credit, 7 sessions/YouTube	GS, L	Librarians
J. Muilenburg, et al.	2014	Survey and Interviews	Course - not for credit, 7 sessions	GS	Librarians
M. Piorun, et al.	2012	National Experts, Literature Review, Interviews	Curriculum development - no class	UG	Librarians
L. Schmidt J. Holles	2018	Course Syllabus	Course – 3-credit hrs.	GS	Librarian, Faculty
J. Thielen, et al.	2017	Literature review, Environmental Scan (DIL)	Course – 2-credit hrs.	GS	Librarians, Faculty
M. Valentino M. Boock	2015	Faculty and Student Interviews	Workshop - multiple, duration unknown	GS	Librarians
B. Westra D. Walton	2012	Environmental Scan (DIL)	Embedded approach	GS, L	Librarians
A. Whitmire	2015	Course Syllabus	Course – 2-credit hrs.	GS	Librarian - PhD Oceanography
S. Wright C. Andrews	2013	Environmental Scan (DIL)	Workshop - 1 hr. / Course – 1-credit hr.	GS	Librarians

Table 1.

In our literature reviews, we came across a number of cases where it seemed that the librarians were learning both data management and discipline specific information while teaching or reviewing cases. This is especially apparent in some of the Data Information Literacy (DIL) case studies where librarians worked with individual departments to understand their RDM needs and then directed the instruction sessions to address these issues. Westra and Walton discussed how their group worked on a literature review for the RDM practices in the field and how they then interviewed the researchers to learn how they currently handled their data [18]. In this case, the librarians came up with a RDM training plan tailored for the graduate student's research project. They also mention that while the librarians learned a lot about the discipline's research needs and had good conversations on approaches to help them, the approach is time intensive and might not be sustainable.

At the University of Minnesota, librarians working with civil engineering faculty discussed their team approach [19]. This is another example of a DIL case study that incorporated an environmental scan and other elements of preparatory work. The work by Johnston et al. also led to a 7-session course complete with YouTube video recordings [19]. One faculty member in

particular provided them with a reality check on the material they chose to cover and teach to ensure that the skills taught were appropriate for the discipline. This team of faculty and librarian instructors came out of the experience with the belief that this kind of partnership is mutually beneficial as the faculty can address any gaps in coverage allowing the librarians to engage with the students and address their needs in new ways [19]. Clemet et al. in the development of their course for undergraduate students, mention that the librarians often needed to learn the discipline subject matter in order to feel confident with their RDM instruction [20].

Clement, et al. in their paper make a case for including librarians as important team members as professionals in organization, scholarly communication, records management and digital preservation [20]. Librarians are also able to speak the language of data management and preservation working with faculty to facilitate a broad based understanding of many elements in managing data [21]. Thielen et al. mention that librarians bring diversity to the instructional effort by providing multiple methods and approaches that facilitate an understanding of the complexities of RDM, often new to the researcher, that can be selected when managing research data for a project [15]. Corti and Van den Eyden mention that librarians are amplifying lifelong learning skills in information and digital literacy and that adding data literacy is within librarian professional skills, so this is a good fit for them to help with RDM instruction [22].

A team approach including both research faculty and librarians is supported by a number of recent articles on DMP instruction. Thielen, et al. in their paper discussing the creation of a two-credit class, suggest a co-taught model provides legitimacy and real world experience to the students [15]. Graduate students and their faculty supervisors need to believe the course or training is important before they will support it. A discipline specific faculty member can provide this legitimacy. In an approach to craft a curriculum for RDM, Piorun, et al. built a team of information technologists, librarians and research faculty to create "case studies" based modules for instructors [23]. Another reason for having a team approach including a faculty member is the graduate student's desire for discipline specific examples [21]. Johnston and Jeffryes had a civil engineering faculty member review the material to make sure it was within the disciplinary norms that students could expect to see [19]. Three more examples support an integrated teaching approach based on student feedback: 1) Wright and Andrews, also a librarian and faculty-teaching team, reported their students felt real examples would be useful [14], 2) Whitmire mentioned students would like to have more real world examples [13], and 3) Students attending workshops developed by Johnston et al. mentioned the time devoted to the material was not adequate and more time could be put to case studies with concrete examples [19]. Getting faculty buy-in and help in creating discipline specific RDM instruction may not be easy, but by approaching faculty using workshops, attending seminars in departments and getting the word out will eventually create a body of advocates on campus. In this way, the framework has been created that can be built on to create more opportunities to provide instruction to multiple disciplines and thus reaching more universities graduate students.

For graduate student RDM, multiple instructional methods have been used with some degree of success. Another approach to RDM training and a way to address these needs are to focus on discipline specific requirements. Fong and Wang collaborated with the Department of Earth & Environmental Science to provide the mandatory RDM skills course required by the department for their graduate students. The authors describe the challenges and concerns that students and

faculty have related to backup, data storage and secure data sharing. In this example, although the IT professionals were not included initially, the authors facilitated a meeting with their computing services department to address these concerns [10].

Wright & Andrews discuss their RDM workshop series at Cornell and the one-credit, six-week course they developed for graduate students in their natural resources department co-taught by a faculty member and librarian [14]. The workshops had low attendance as the semester continued and the six-week course did not allow enough time to cover some of the topics thoroughly. Another course that ran for 7 weeks taught at the University of Washington was a modular based structure that met once a week [24]. Attendance in this modular class started out well but by the end of the series very few students attended. This points to the problem of creating workshops, classes and other instruction sessions for which there is not incentive to take the class [24]. These examples further support the creation of credit classes while still using a team teaching approach.

Similar to the one credit course discussed previously is Whitmire's 2-credit course taught at Oregon State University Fall 2014 [13]. In this general RDM course, students came out with a framework to use for their research projects. Most of the feedback indicated the course could have had more discipline specific examples or case studies and a desire to work with metadata and data manipulation tools such as Excel. Another credit class example, also 2 credits, was a discipline specific course taught to Climate and Space Sciences and Engineering Department (CLaSP) graduate students [15]. For this class, Thielen et al. visited with faculty in the department to learn how they worked with and managed their discipline specific data. They also attended the American Geophysical Union meeting to learn how others in the profession managed data along with what tools and resources were already in place for RDM researchers. This approach allowed for more in-depth discussions and broader coverage of topics. The students in their evaluations wanted more topical material even though the instructors had worked with the CLaSP faculty to learn more about the disciplines research methods and data.

Fong and Wang found that their 90-minute workshop in which they covered a full range of RDM subjects somewhat confused the students [10]. Adamick et al. found students did not have time to fully understand metadata and also wanted more discipline specific coverage [21]. Students commented that the overview of data management across disciplines was useful and they learned elements of basic data management. Due to the limited time, there were a number of students who asked for more information on various aspects of RDM including metadata, versioning, backup and specifics for certain practices. Fong and Wang in their approach started with a talk at one of the department's weekly seminars [10]. After the meeting they were invited to lead a workshop to create Data Profiles with the researchers that then led to a graduate class on RDM. Fong and Wang mention the importance of having a buy-in from the students and faculty to build a good relationship with an advocate in the department is critical to a successful outcome. Clement et al. in their team-based approach to RDM instruction agree there is a need for collaboration between researchers, IT professionals, students and librarians [20].

Discussion

As is often the case in a developing a new field of study, there are a variety of options available to apply, although none of them will be a perfect approach. Taking what was learned from our

course and comparing with the lessons and observations from other RDM courses, workshops, and seminars from the literature, one element repeatedly occurred. Instruction models incorporating a team approach of mixed professionals that include research faculty, librarians, information technologists and other professionals tend to be more effective. Using the faculty and librarian team approach at our institution worked very well. The librarian was familiar with resources available on campus including the librarians in the digital collections department and the IT department resources, personnel, and facility. The faculty member had experience in discipline specific research methods related to specific metadata, data sharing expectations and funding agency data preservation expectations. Having two instructors with different backgrounds and campus contacts proved to be useful as our list of possible guests was more diverse and offered more options than if the class were taught by either individual. Not only were the instructor disciplines different, their approaches to instruction varied as well. Librarians tend to teach one hour topical instruction sessions or workshops while the research faculty often teach semester long credit courses.

During planning for our course it was determined that 50 minute discussion based learning classes held three times a week was appropriate to cover interdisciplinary and engineering specific data management topics. The instructors knew they brought different points of views and experience in dealing with research data. Both instructors had backgrounds in science and engineering issues and research with one in the library field as a science and engineering librarian and the other a researcher with an active chemical engineering research group. The team teaching for-credit course approach has distinct advantages over workshops, tutorials and individually taught courses. Students desire real life examples and want to see examples from outside their field of study. They also would like more hands on time to look at their particular data management needs and mentioned they would like to learn about tools that can help them be more efficient.

Another advantage to teaching students using the team approach is the fact that there are many stakeholders on campus who need to be aware and have a say in how RDM at the university is conducted. In the collaboration for this course in this manuscript, there were benefits for the instructors as well. The instructors learned new material from each other as the course progressed making it easier to teach the next time with another instructor or subject. An added benefit for this team approach was the creation of a network of guests and participants willing to advocate for a RDM course across campus. Our students, in their post-assessment, mentioned they would like to learn more about ethical aspects of data management. With the guest speaker approach and knowing whom to approach on campus, we will be able to include ethical treatment of data in future classes. Thus, there is a need to communicate with all stakeholders and bring units together to keep the overall mission whole rather than each individual unit doing it on there own [15].

Research faculty, librarians and IT professionals have observed there is a need to develop a graduate RDM course. With the increased emphasis on big data and computational analysis there, is a need to follow best practices to manage the scholarly outputs from these efforts. At our institution librarians and IT professionals have found that faculty and students are unaware of some or our RDM services. These included the libraries' ability to help with DOI's, researcher ID's and in collaboration with IT access to the DMPtool to aid in grant submissions. Another

outcome from the class came from the student work using the DCP to develop RDM plans for a selected faculty member's participants. Some faculty members mentioned they were not familiar with ARCC services for data storage and preservation. Another point many of them made was that they were changing some data filing systems in their labs, further supporting the integrated approach to DMP instruction.

Our students mentioned they appreciated the digital collections and information technology joint seminar for the information provided and the contact information if they were to need further help. In addition to the student support, our Advanced Research Computing Center professionals were excited about this opportunity to build their relationships with librarians, research faculty and students. These interactions allow the IT personnel to demonstrate their usefulness to the university. This supports the need to include IT professionals who support RDM by providing guidance, instruction and university support where they are able. IT and library collaboration is essential for any university when it comes to supporting RDM through tools, resources and instruction. The need for IT professional participation helps make the case for credit classes that have enough sessions to add what students would like and lectures by IT professionals to teach them coding and other data management tools [13]. These observations illustrate and support the need for an interdisciplinary approach including not just librarians and researchers but also the professionals in IT who actually provide data services on campus.

Many librarians are concerned the time commitment required to develop and teach RDM courses for graduate students is too great. It seems to be the nature of the work that RDM instruction is time intensive and difficult to do correctly as there are many general and specific topics to cover. Adamick et al. specifically mention this in their working group assessment, that both broad-based data management overviews and tailored discipline specific workshops should be used in any RDM instruction program [21]. They mentioned this approach will likely be hard to sustain as targeted workshops take time to prepare and if there are multiple disciplines to teach, the number of sessions increases as well. The two-credit course developed by Thielen et al. took a significant amount of time investment by the libraries and they mentioned that if they did not have the support of their library administration, the course would not have taken place [15]. Although there was some redundancy covering content in our class, especially with some of the guest speakers, students did not seem to be to concerned with this duplication. Student post-assessment also demonstrated the importance of including guest speakers in the course. The students mentioned they enjoyed the sessions and learned about issues different disciplines and projects have when dealing with their data. We feel our model of multiple guest speakers could help with the time commitment for future classes. In the future, as more courses are developed and a pool of speakers willing to contribute to RDM instruction will help make the team approach sustainable.

A well-developed course including research faculty for discipline specific RDM protocols such as metadata and file naming conventions, discipline specific standards and archives, and general RDM and university resources (DMPtool) as provided by librarians will help students in their research projects and carry them past their school years. Although this may be time consuming for both the librarian and faculty member, the burden can be spread broadly across campus as guest speakers and incorporated specialized workshops taught by others relieve some of the time commitment from the individual instructors. A team-taught course also lends itself to discussion-

based learning as interactions between the instructors often provides healthy dialog that students are more likely to participate in [20]. Clemet et al. mentioned they were excited to see that students valued the skills and concepts they were taught in the class [20]. Discussions in our course with our students supported Muilenburg's observation that the students learned from each other and brought up concerns to each other that the instructors could then address [23].

It is becoming apparent the teaching RDM courses evolve over time as did information literacy education. Information literacy education evolved into a tiered approach that takes place as a part of the student curricula. This may also be the future of RDM education. There are a few cases where curricula are being developed at some institutions illustrating RDM is important to be included throughout a students career as an undergraduate student especially in the medical profession as illustrated by the Massachusetts Medical School and Worcester Polytechnic Institute [23]. In another example of undergraduate data management instruction, multiple small liberal arts colleges collaborated to develop workshops to teach their students data management practices [20]. From these discussions, the librarians gained valuable insight on some of the data management issues students were having based on their current research examples, thus highlighting where some of their knowledge gaps were. This supports development of credit classes with discussion sessions and a team approach, as expertise from librarians, IT professionals and faculty are often complimentary.

Conclusion:

The need for more than librarian, research faculty and IT professionals as guest speaker or instructors is apparent. There is a growing consensus in the literature that team teaching is the appropriate approach to take for RDM instruction. There are a number of institutional stakeholders at universities for which having an active program in RDM instruction is a useful enterprise. Faculty with active research programs, interdisciplinary research groups, Office of Research, Legal Affairs, Libraries, and University Information Technology Departments all have a role and a stake in making sure students are taught RDM skills. Graduate student instruction includes multiple approaches that have been used with varying degrees of success. Most RDM instruction methods include a mix of professional backgrounds comprising research faculty, librarians, information technologists, legal experts or data managers. The ability to include multiple stakeholders and perspectives for RDM instruction supports the growing effort toward the creation of for-credit RDM courses. We are also seeing a trend in the literature on RDM instruction that is moving toward the team teaching approach. Teaching RDM courses as credit classes with a team approach will support the growing need to support data sharing across the disciplines as mandated by government agencies and other stakeholders in research funding.

We believe the success of our team-taught RDM course will provide an additional example for the development of more team taught classes at our university. After the course was completed, Dr. Holles took the step to get the course in the University Catalog and cross-listed as a graduate, library and chemical engineering credit course elective. Depending on who takes the lead in teaching the course and what the structure is, the team approach provides flexibility to teach to any number of specific disciplines. With all the examples of RDM instruction to chose from we believe progress will continue and the merits of the team approach will allow this method to evolve. We believe collaboration and team teaching is the key to success for any research data

management instruction program. It takes advocates in libraries, research faculty and information technologists to get the word out to create successful RDM courses and services on campus.

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