DATA LITERACY ON DEMAND
Creating a Set of Data Literacy Modules for Remote Instruction

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The case study presented here, from Miami University, demonstrates one approach to designing and implementing a series of online modules covering data management skills. Through collaboration with the Miami Ecological Big Data Initiative (MiEBDI), a research center that facilitates access to and analysis of ecological big data, the authors have created modules that are usable across the STEM departments with which they liaise. Flexibility was built into the modules' design so they can be taken together or separately and can be implemented in multiple situations, from an existing course taught by faculty to a workshop for interested students. The Research Data Management (RDM) modules were created for asynchronous use in Canvas, a learning management system (LMS), making them ideal for remote learning. The modules cover basic data management, data curation, data analysis, and data visualization. By completing the modules, students should have the basic skills necessary to process, archive, analyze, and disseminate the data gathered in their research projects. This instruction format allows for more content to be covered than is possible in a one-shot session. Also, as they can be incorporated into courses quickly and easily, they have the potential to reach a greater number of students than might otherwise be possible, which is particularly important during periods of remote learning.

Miami University is a public institution in Oxford, Ohio, with about 17,000 undergraduates and 2,500 graduate students. There are 120 programs leading to a bachelor's degree and over seventy graduate programs. Research is an important part of the school's mission. Besides the work done by graduate students and faculty, it has a thriving undergraduate research program. The annual Undergraduate Research Forum gives students an opportunity to present their research to their peers and to the world. However, scholarly communication has changed radically in recent years. While it was once sufficient to share results in journal articles and presentations, there is a growing expectation that research data be shared as well in order to enhance reproducibility and create opportunities for future research. Publishers and grant funding bodies want to ensure that the data generated through research is properly cleaned, curated, and stored in publicly available repositories. This requires a new set of skills, such as data curation and management, that may be unfamiliar to researchers. When and how these skills are acquired varies, but there are initiatives in higher education to teach them to students at the undergraduate and graduate levels. Libraries are well-suited to offer instruction in data management and data literacy as they already provide information literacy (IL) instruction and one-on-one research support. At Miami, the Miami University Libraries (MUL) have taken a leadership role in providing instruction in data management through workshops and other training.

The budding micro-credential program at Miami University is a way for students to gain a new set of specific or specialized skills without having to make the huge commitment of time and finances that even a certificate program can entail. Traditional courses take a great deal of investment of time and resources to develop, while micro-credentials can be assembled quickly, which gives them a timeliness that traditional courses and programs sometimes lack. Micro-credentials also have the flexibility to vary in length to meet specific educational needs, to vary in scope, and to be credit- or non-credit-bearing. With the world moving at such a fast pace, it is important to be able to move and adapt quickly. Miami is still in the early stages of creating micro-credential programs, and it was part of the original project plans to solidify the RDM modules into a micro-credential.

LITERATURE REVIEW

Data Management Skills in Higher Education

Data management skills are important for professionals and academics in many disciplines, often starting in graduate school, when students undertake their own research or collaborate with others to conduct research. Some essential questions then become: When and how do researchers learn these skills? Are they generally taught at the undergraduate level or during graduate programs? What form does the teaching take? Who is the instructor? What specific skills need to be taught? By turning to the literature to answer these questions, a few observations can be made.

A team of librarians at Purdue University and the University of Illinois Urbana-Champaign conducted faculty interviews and student surveys on RDM instruction to graduate students.[1] They found the content and training method, as well as the responsibilities placed on graduate students, varied widely. The frequent turnover of graduate students within a lab group both complicates matters and highlights the need for consistency and communication. As a result, graduate students are a natural audience for RDM training, and the faculty interviewed recognized this lack of skills. However, they also expressed hesitancy to provide guidance as many didn't want to become micromanagers.[2]

Similarly, in a study at the University of Oslo's Department of Geosciences' Meteorology Section, academic librarians conducted several rounds of interviews about data information literacy (DIL) with faculty, PhD students, researchers from an outside research institute, and academic librarians.[3] They also found a consensus that these skills were essential for graduate work and that they were being taught in formal and informal ways. Informal methods, including student-to-student conversations, were generally perceived to be preferred as the importance of certain skills was relative and heavily dependent on the specific project or lab group. This study included some questions on library involvement in DIL instruction. It is interesting that out of the small group of ten participants, six indicated that librarians cannot currently play a role, while eight said that by obtaining the skills they presently lack, librarians could play a role in the future. While this study didn't discuss implementing a DIL or RDM instruction program, workshop, or one-shot session, there are others who have.

Several examples of library-facilitated RDM or DIL instruction show the variety of forms they can take. A librarian DIL project team, with members at several universities, reported on sessions they conducted at their institutions.[4] One of two projects at Purdue University was focused on electrical and computer engineering students and took an embedded librarian approach. The second at Purdue was a workshop aimed at agricultural and biological engineering students. At the University of Oregon, the team created a facilitated discussion group centered around assigned readings for ecology students. An online self-paced course was implemented at the University of Minnesota for civil engineering. At Cornell, the librarian DIL project team crafted a semester-long, one-credit-hour course on RDM targeted toward students in the natural resources, which was able to cover more than a one-shot session but less than a full course. This sampling demonstrates a variety of educational approaches a library can take with DIL as well as the different disciplines that may benefit.

Parallels between Data Literacy and Information Literacy

DIL is a natural extension of IL, and it encompasses other literacies such as data literacy, statistical literacy, IL, and science data literacy.[5] Previous studies mentioned have highlighted a gap in higher education where there is little or very informal instruction on these much-needed skills. It can be argued that libraries are well-suited to provide guidance and instruction on DIL, as they have long been teaching IL.

Libraries have adapted continually over time to serve their users in new ways; e.g., shifting from print resources to electronic resources. A similar and current shift involves data. Data production hasn't previously been viewed on the same level as other scholarly products such as books and journal articles, but it is now beginning to be as indicated by the development of standardized ways to cite them, including unique identifiers.[6] Another indicator of this shift in data production becoming akin to other scholarly products can be seen in the P*roposal and Award Policies & Procedures Guide* from the National Science Foundation (NSF). This guide includes a section on drafting the project description that says, "Plans for data management and sharing of the products of research, including preservation, documentation, and sharing of data, samples, physical collections, curriculum materials and other related research and education products should be described," and further explains

that research products can include but are not limited to "data, publications, samples, physical collections, software, and models."[7] The NSF is not alone in elevating the importance of data in research. A 2013 White House memo mandated a data management plan (DMP) for extramural researchers receiving federal grants and contracts for scientific research and currently covers any federally funded research.[8]

With this changing landscape comes an awareness that data created in one discipline could be useful to others, within or outside the discipline. Ideally, the data would be clean and have associated metadata. This is not always the case, unfortunately, in the modern data collection deluge, thereby requiring new proficiencies. The RDM and DIL competencies are part of the current efforts to teach these skills.[9]

However, pinning down what exactly these DIL or RDM skills ought to be is the challenge. Carlson et al. (2011) conducted faculty interviews and student surveys and examined them alongside the ACRL's Information Literacy Competency Standards for Higher Education (the precursor to the current Framework for Information Literacy for Higher Education) in order to triangulate a set of data literacy competencies.[10] They discovered some practical skill deficiencies and some conceptual and ethical topics unfamiliar to students, including the following:

- Standardizing the documentation processes with organization and file naming conventions
- Maintaining relationships among data such as masterfiles and versioning
- Quality assurance
- Metadata
- Database skills
- Preservation, such as file backups
- Analysis
- Visualization
- Intellectual property
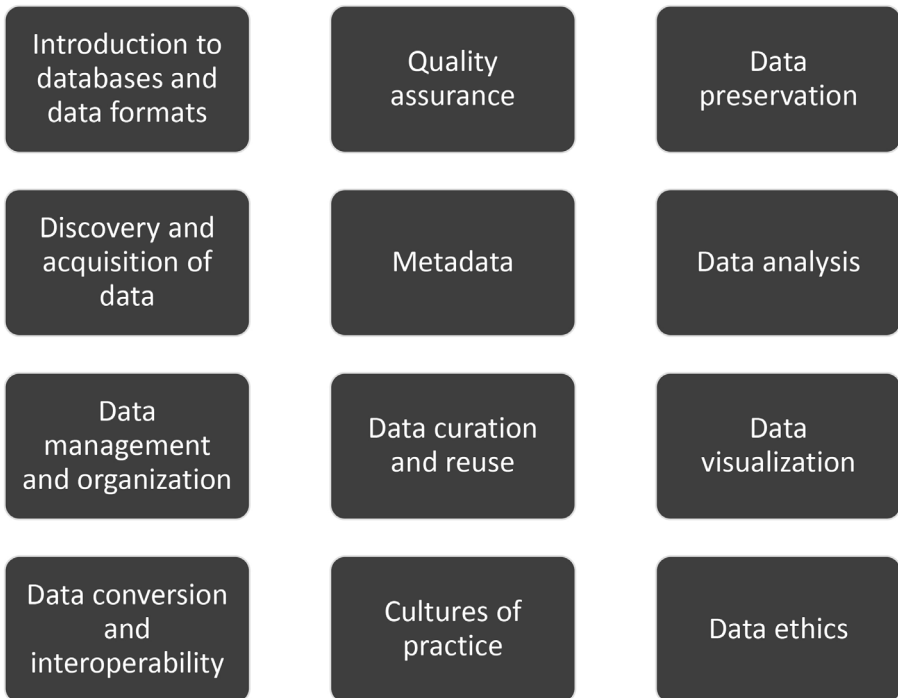- Confidentiality
- Attribution

Compare these to the ACRL Framework, which provides "conceptual understandings that organize many other concepts and ideas about information, research, and scholarship into a coherent whole."[11] Each aforementioned

skill or topic could comfortably nest under this broad definition, so long as the case could be made that data is in fact information. Another similar definition comes from ACRL's Information Literacy Standards for Science and Engineering/Technology, which defines IL in STEM as "a set of abilities to identify the need for information, procure the information, evaluate the information and subsequently revise the strategy for obtaining information, to use the information and to use it in an ethical and legal manner, and to engage in lifelong learning."[12] For librarians, these useful frameworks are in place, but they need some adaptations with specific competencies for DIL instruction. Carlson and coauthors have proposed a DIL framework of twelve competencies (figure 5.1).[13]

To tailor instruction to each circumstance, audience, and institution, not all the competencies need to be present in every session, just as not every ACRL

FIGURE 5.1

The twelve core competencies for data information literacy as identified by Carson et al. (2011)

Introduction to databases and data formats	Quality assurance	Data preservation
Discovery and acquisition of data	Metadata	Data analysis
Data management and organization	Data curation and reuse	Data visualization
Data conversion and interoperability	Cultures of practice	Data ethics

IL frame is included in every instruction session. Some examples of these instruction sessions have been mentioned already. Currently, the authors are exploring the possibility of a micro-credential in RDM as a way to introduce students to a handful of these skill sets.

Micro-credentials and Digital Badges

Higher education institutions and libraries have been establishing micro-credentials and digital badges for an array of subjects and scales. One definition of micro-credentials is "transferable forms of metadata-encoded, performance-based educational credits," which are the same as digital credentials or digital badges.[14] Others state that a digital badge is a form of micro-credential, similar to a certificate but with more information behind it in the form of metadata, and that badges usually have a pictorial depiction of the skill learned.[15] The pictorial element is reminiscent of physical scout badges, which are similar to digital badges in that they share the flexibility to be created for different levels of education.[16] The difference is metadata, which provides information on what was done to earn the badge, when and where it was completed, who granted it, how the learning was assessed, and more.[17] This communicates and tracks skills learned to badge-holders and outside evaluators.

There are several examples in the literature of libraries of creating micro-credentials or digital badges. Many of these are for IL skills. Eastern University Library, in response to a university-wide initiative for undergraduates, including one for IL, partnered with a required writing class and created a badging system to demonstrate competencies.[18] Previously, the library had done many one-shot sessions on IL, but it needed a formal way to assess student learning on a scale that large, with added accountability. This took time to grow into; it was at first a certificate the students received upon completion of the modules, which they could show the professor. With different software over time, including a new LMS, the badging became more feasible. Similarly, Portland State University Library responded to a provost challenge to the university to respond to current higher education challenges; at first, they sought an IL curriculum, which later evolved into a badging system.[19] Another example comes from Penn State University Libraries, who created online, asynchronous instruction modules at a scale that made individual feedback unfeasible; these modules were to teach students granular library and research skills.[20]

THE RESEARCH DATA MANAGEMENT MODULES

The project the authors' team has undertaken involves first creating online RDM modules and later, with future developments, transforming them into a micro-credential. With RDM and DIL both still in their infancy at Miami, the data literacy modules created by the authors' team are an important first step to more broadly introduce these topics to students across several disciplines.

Inception and Planning

There were four developments that converged around the same time, and each was important to the successful launch of the project:

1. Interest from a biology research program in incorporating librarian-led DIL instruction.
2. Desire from a separate biology program in collaborating with MUL to expand in-house RDM workshops.
3. Encouragement from Miami administration for faculty and staff to propose and create micro-credentials.
4. Expansion of data-related programs on campus, which necessitated the expansion and creation of library services to meet their needs.

The biology department at Miami has had a long-running, NSF-funded Research Experience for Undergraduates (REU) program.[21] This ecology-focused, intensive summer research program has maintained a productive relationship with MUL, including librarians leading IL sessions on and off since 2007. The co-PIs on the grant had been wanting to incorporate DIL topics into the program's curriculum; when the grant was up for renewal for the 2020 cohort, library-led DIL instruction was written into the proposal with the full support of MUL.

The plans were well-supported by a collaboration with MiEBDI. Beth Mette, the center's data management specialist, had previously led both a workshop series and an elective course on DIL topics. However, both offerings were targeted solely to biology students and suffered from low enrollment. Mette was interested in expanding these programs beyond the biology department and felt, as did the authors, that MUL was a natural partner.

Concurrently, in fall 2019, the Miami administration began encouraging faculty and staff to create micro-credentials. As originally pitched, these would take the form of a short series of modules or seminars, with each grouping

focused on a central topic and ultimately leading to some sort of digital badge or certificate. The authors' team, including Mette, decided that a series of modules based around DIL would fit very well within this micro-credential framework while also meeting the needs of the REU program and the goal of MiEBDI's DIL expansion.

The overall success of the project relied on the support and interest from within MUL in expanding data-related services. In recent years, Miami has created a new data and analytics research center and a handful of new data-focused educational programs, and it is working to incorporate data and related topics more thoroughly into curricula at both the undergraduate and graduate levels. MUL has also expanded existing data services and created new ones, but they are based around a reference model of engagement, with one-on-one consultations forming the bulk of the interactions. There was very little in the way of formal DIL instruction for students to learn about these topics in a more broadly applicable way. MUL administration recognized this gap in service and gave their full support to the authors when the opportunity to create DIL instruction presented itself.

By the end of fall 2019, it was decided that the REU students would serve as an excellent pilot group for a fully online, general-purpose, modular DIL instruction program that could then be assessed, modified if needed, and rolled out, either as part of a micro-credential or as several standalone modules to several introductory graduate student seminars beginning in fall 2020.
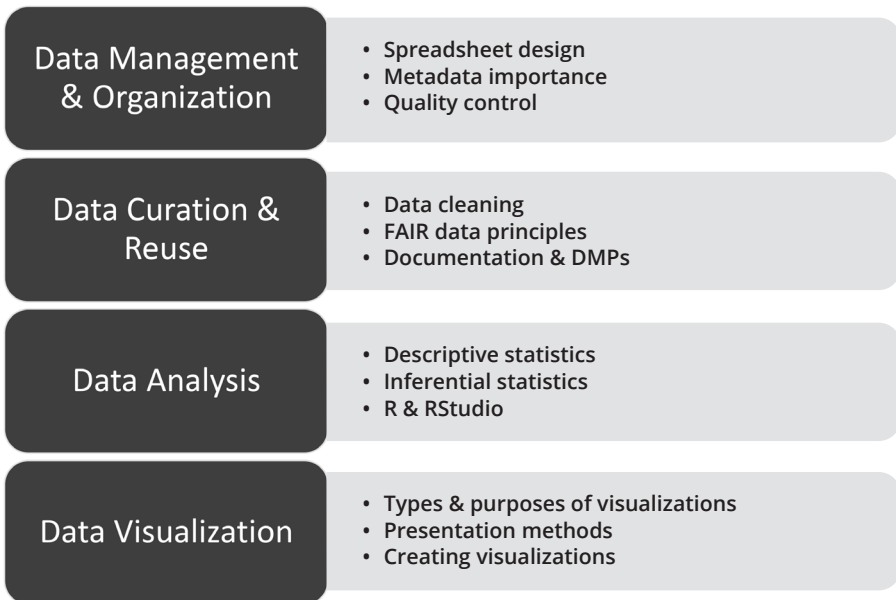
Module Creation

The twelve core competencies for DIL as put forth by Carlson et al. (2011) have been generally accepted by data and instruction librarians.[22] The library-led DIL instruction that was written into the NSF grant renewal proposed covering four of these: data management and organization, data curation and reuse, data analysis, and data visualization (figure 5.2). These four were selected because they were thought to be the most relevant to new student researchers.

With four team members, it was decided that each person would work primarily on one module, with everyone providing feedback and suggestions along the way. The hope was that faculty would encourage or require their students to complete all four modules in sequence; the reality was that some faculty would be more interested in some modules than in others, depending

FIGURE 5.2

Overview of the four modules that make up the RDM micro-course

Data Management & Organization	• Spreadsheet design • Metadata importance • Quality control
Data Curation & Reuse	• Data cleaning • FAIR data principles • Documentation & DMPs
Data Analysis	• Descriptive statistics • Inferential statistics • R & RStudio
Data Visualization	• Types & purposes of visualizations • Presentation methods • Creating visualizations

on the needs of the class and/or the students. Therefore, the team planned for both scenarios from the start. Created fully in Canvas, Miami's primary LMS, the four modules were organized sequentially, progressing from one topic to the next based loosely on the data lifecycle:

- Students should have an understanding of data organization and management before they begin collecting and/or processing their data.
- Many of the REU and graduate students at Miami work with longitudinal data or datasets created by others, so proper curation and reuse is essential to cover next.
- Once proper data management and curation are understood, students can then move on to data analysis.
- Data visualization created a natural caboose.

However, for flexibility, the content for each individual module was created to be self-contained, with minimal references to the other modules and assuming

little to no prerequisite knowledge. While there was the chance that some students would already be familiar with much of the content, the team's goal was to provide a true introduction to each of the topics.

Each module was designed to take roughly four hours to complete. This allowed for more in-depth coverage than would normally be possible in a typical one-hour workshop while also not being too much of a burden on already-busy students.

Since the modules were being created with the intent to have them continuously available to all faculty who wanted to use them, the team had some difficult decisions to make during the planning stage. The format necessitated an asynchronous model, and the unknown future responsibilities of the team made it virtually impossible for the creators to plan on having any direct interaction with the students. Thus, the modules had to be self-sustaining. There was room built into the modules for interested faculty to mold the content and activities if desired to better fit the particular needs of their classes, but the team anticipated that most faculty would be interested in "plug-and-play" type modules that would require little-to-no modification for each class.

With a non-interactive, asynchronous instruction model, authentic and engaging learning is extremely difficult to achieve, and much discussion was centered around creating such content. To keep learners as engaged with the material as possible, the modules were created to be multimodal.[23] A variety of formats were incorporated into each module to address different learning styles and learner preferences. The modules contained a mix of readings, videos, quizzes, unmoderated discussion boards, and other activities. Care was taken to ensure all material was as accessible as possible: videos were captioned, alt-text was added to all images, and readings were made screen-readable. The activities were designed to present learners with practical situations based on the material from the readings and videos while also encouraging as much critical thinking as possible, again without requiring much interaction from the module creators. For example, in the Data Management and Organization module, students are first given a mostly theoretical foundation on data collection and organization, after which they are given some sample datasets and asked to participate in an unmoderated discussion about them (figure 5.3). They are asked to: 1) provide some examples of problems within the datasets, 2) make recommendations for how they would go about correcting the identified problems, and 3) reply to at least one other post with further discussion of problems and/or solutions identified by their

FIGURE 5.3

General outline of the Data Management & Organization module
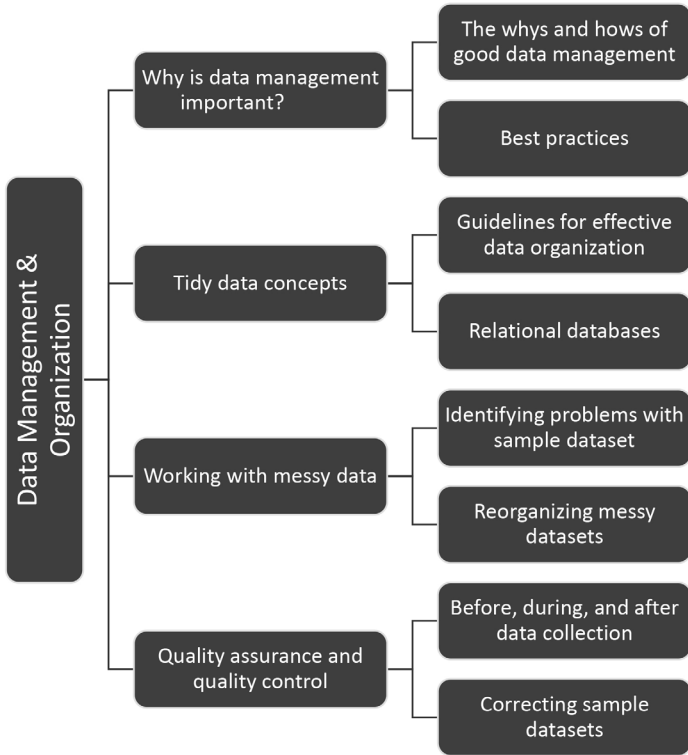
classmate. The discussion board is hidden until a learner creates a post, thus ensuring that learners are forced to apply themselves to the question and are not (easily) able to plagiarize from their classmates.

Pilot Testing to Full Rollout

It wasn't until the team was well into the planning process that they were notified that, due to the COVID-19 pandemic, the REU program grant would not be renewed. Since the team had already decided that the modules would be fully online and that the REU students would have just been beta testers, this wasn't as much of an impediment as it might have been. Simply, a new group of pilot testers would need to be found.

The team created a promotional flier describing the planned content of the modules as well as overall learning outcomes. The authors are all liaison librarians with departmental responsibilities in STEM and some social sciences, and it was decided that the initial promotion would be limited to these departments and to other librarians, with one exception: an economics professor who heard of the project and expressed interest in helping. Some of the faculty to whom the flier was sent forwarded the information to their graduate students, many of whom suddenly found their summer schedules open due to the cancellation of their planned research activities. Interested faculty and students were added to the Canvas course in the role of students. All in all, the initial summer pilot group consisted of twenty-seven faculty, staff, and students across seven departments, not including the four members of the authors' team (table 5.1).

Two modules were made available to pilot testers beginning in May 2020, with a third module being made available in July. The fourth module was

TABLE 5.1

Departmental breakdown of pilot testers

Department	Number of pilot testers
Biology	3 faculty 8 students
Chemical, Paper, and Biomedical Engineering	1 faculty 2 students
Chemistry and Biochemistry	1 faculty 3 students
Economics	1 faculty
Geology	2 students
Library	4 librarians
Mechanical and Manufacturing Engineering	1 faculty 1 student
Total	**27**

unfortunately not available during the initial pilot phase due to time constraints and an extended learning curve for the creator but was completed in the fall.

Each module contained a survey that pilot testers were encouraged to fill out following the completion of the module's content. Each survey was slightly different, including some questions specific to each module, but some questions were the same; e.g., how long it took students to complete the module and how basic or advanced they felt the content was. The initial promotional materials also encouraged those who signed up to be pilot testers to provide their feedback at any point, either by directly contacting the creator of each module or through the end-of-module surveys. The goal was to solicit constructive feedback about each module that could be incorporated before the full rollout in the fall of 2020. However, only one piece of formal feedback was received during the summer pilot phase.

The pilot phase had no set end period, but it was decided that the modules should be made more widely available in Miami's Canvas Commons (the online repository built into the LMS consisting of modules, activities, and full courses that faculty can browse and import into other courses) at least one month prior to the start of fall classes. The three modules that were ready at that time were published to the Commons and more broadly advertised to faculty, with the last module published the following month.

Using Canvas Commons has distinct positives, but it also comes with some drawbacks. Because any faculty is able to access the Commons, it's an ideal repository when seeking to make content widely available. Material published to the Commons can be assigned several descriptors and identifiers (including a range of Creative Commons licenses), which aids faculty in discovering potentially useful content. However, the Commons does not allow content creators to see exactly who has downloaded or otherwise used their material, so assessment data is difficult to collect without the active participation of the users. In addition, the Commons makes it difficult (though not impossible) to publish updates to content without republishing the entire module, which resets the limited usage statistics.

However, there is some utility in the statistics the Commons provides. During the fall of 2020, the modules were downloaded into other Canvas courses a total of twenty times, broken down as follows: Data Management and Organization, eight; Data Curation and Reuse, four; Data Analysis, two; and Data Visualization, six. The authors know of only a single course that incorporated all four modules, so the initial assumption that some faculty

would pick and choose which they wanted to use has been shown to be correct. However, the identities of all other faculty and courses for which the modules were used remain a mystery.

Considering the extremely low response rate during the summer pilot phase, the team decided to keep the surveys in the modules for the fall term in an attempt to collect additional feedback from future classes. However, the modules only gathered one more survey response during the fall semester, although one of the authors received some informal feedback from two additional people through direct correspondence. The feedback received, both formal and informal, was positive and constructive but was not enough to prompt any major revisions. Therefore, the surveys will remain in some form, and the authors' team will be exploring additional methods to collect future assessment data.

Future Plans

The modules will remain available to faculty in the Canvas Commons and will continue to be marketed and promoted to all those who may be interested. Initial efforts were targeted to STEM and some social sciences disciplines, so future efforts are likely to involve promoting the modules to additional disciplines in the social sciences and some data-focused faculty in the humanities.

A large part of the original vision for these modules was their incorporation into introductory graduate seminars since, as already discussed, knowledge of RDM topics is often expected of incoming graduate students but inconsistently taught to undergraduates. The authors anticipate holding targeted conversations with the instructors of these seminars, as well as a number of graduate student advisors, to try to effectively and efficiently scaffold this information into existing courses and programs.

One such conversation has already begun. One of Miami's largest graduate programs is a distance program in biology called Project Dragonfly (PD). This master's program is geared toward non-traditional students who are pursuing careers in conservation, ecology, education, and/or sustainability. The program administrators were part of the initial pilot group and are interested in fully scaffolding the RDM modules within the PD curriculum. However, two of the current modules, Data Analysis and Data Visualization, need to be altered to better fit the needs of PD's students. The Data Analysis module focuses on conducting statistical analyses using R, which has a steep

learning curve and can often be intimidating for learners who don't have a strong background or interest in technology, while the Data Visualization module focuses heavily on theory. The creators of these two modules are now working to create parallel modules to better fit the needs and backgrounds of the PD students. The parallel Data Analysis module will focus on conducting the same statistical analyses but will use Microsoft Excel and Google Sheets instead of R; the parallel Data Visualization module will add practical applications, also using Excel and Sheets.

Lessons Learned

For libraries interested in trying a similar model of DIL instruction, there are some considerations that need to be made. The authors, like many others, have found that the creation of asynchronous instruction is far more time-intensive than synchronous instruction. However, if scalability is a primary concern, then asynchronous instruction a clear advantage. Planning for flexibility in the modules' usage from the beginning of the project made pivoting due to unforeseen circumstances possible without derailing the project. This flexibility has also allowed for new future plans for the modules not originally anticipated.

Because of the size of the project—roughly sixteen hours of coursework in this case—the authors also recommend working with a diverse team with people of different experiences and backgrounds in the topics, even if they are from outside the library. This not only divides the workload but also enables discussions on student needs, teaching practices, technical skills needed to create the modules, and topics covered in the modules.

CONCLUSION

Although there were several stumbling blocks throughout the creation and implementation of these online modules—the loss of the REU students who were to form the initial pilot group, the lack of feedback from the subsequent pilot group, the lack of assessment data from the implementation of the modules, and a change to the overall structure of Miami's micro-credential program that postponed solidifying the modules into a micro-credential—the authors' team considers the project's first semester an overall success. The initial goal of incorporating the modules into several introductory graduate seminars was not met, but several of the smaller goals were. With the help of MUL, MiEBDI

was able to expand its RDM instruction beyond the biology department, and with the help of MiEBDI, MUL was able to expand DIL instruction beyond the typical one-on-one reference interaction or one-shot instruction session. The authors have also been able to use the modules to build new working relationships with faculty who have previously not taken advantage of library services for their classes. Overall, the team is excited about the success the modules have had so far and are hopeful about how they may be expanded in the future.

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