Librarian Support in Teaching Open Science Research Practices in Higher Education

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Abstract

This exploratory study examines trends in librarian teaching support for open science (OS) practices in higher education. The study was conducted through semi-structured interviews with academic librarians and a survey that was distributed through academic librarian interest groups. The results indicate that academic librarians have varied approaches to teaching OS and different opportunities to collaborate within institutions. There were common pedagogical OS topics and perspectives on teaching OS practices in higher education. The findings also include insights regarding professional development needs and opportunities for librarians.

Keywords: Open science, Open scholarship, Reproducibility, Replicability, Librarian support, Librarian instruction, Pedagogical trends, Curriculum integration

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Introduction

Open Science (OS) is made possible by a wide variety of systems and implemented and supported by professional practices. Concepts like open access, open data, open source, open educational resources (OERs), open methodology, open peer review, reproducible analysis, and replicable research (Abele-Brehm et al., 2019; Crüwell et al., 2019) are part of an ethos designed to increase transparency in science, foster collaboration, and facilitate the generation of new discoveries through the reuse of existing knowledge.
The need for OS practices has been an ongoing conversation in higher education. While the practices are recognized by researchers and academics working at higher education institutions, there is a shift to bring more of the conversation and practice into student learning (Azevedo et al., 2021; Chopik et al., 2018; Hanna et al., 2021; Strand & Brown, 2019). More specifically, there have been efforts to integrate OS into pedagogical practices, as there has been a disconnect between OS practices in research and what the students are being taught (Azevedo et al., 2022). The implementation of assignments that either talk about OS practices, analyze openly available past methodologies, or attempt to reproduce or replicate methodologies has been sporadic in many institutions. Nevertheless, there is a potential to strengthen OS practices by integrating the principles of OS into the higher education curriculum and instilling the practice within the next generation of researchers (Azevedo et al., 2022). Librarians have been involved in leading the ongoing change in OS including support for open access publishing, data management and archiving, guidance on pre-registration of studies and so on (Sayre & Riegelman, 2018; Sayre & Riegelman, 2019; Stodden et al., 2013). However, there is still a need to understand how collaborations are forged and supported between librarians and faculty, including the role librarians play in developing instructional support related to OS in higher education.

Open science and open scholarship are used interchangeably throughout this article.

**Literature Review**

There are variations of topics related to OS practices that are taught in the curriculum. Examples include teaching the reproducibility crisis, transparency in research, questionable research practices (QRPs), preregistration of research, replication projects, writing data management plans, and tools and workflows for transparent research (Lane et al., 2020; Strand & Brown, 2019; Toelch & Ostwald, 2018). There are studies from various disciplines that focus on teaching a specific OS topic. One example is teaching transparency in research and statistical errors as the first step of teaching OS practices (Jekel et al., 2020; Pownall et al., 2021; Sarafoglou et al., 2020). Acquiring that background knowledge is crucial, particularly for those who do not have direct experience with research. Some other examples include integrating replication projects into courses, and undergraduate or masters’ theses (Jekel et al., 2020; Marshall & Underwood, 2019; Toelch & Ostwald, 2018; Wagge et al., 2019). Engaging students in hands-on research through replication projects offers valuable learning opportunities especially for students who may not have learned about the research process otherwise (Jekel et al., 2020). It enables them to gain practical knowledge of the scientific process, research designs, methods, statistical analysis, and the overall research cycle, with the emphasis of open and transparent research.

The value of "openness" is highly regarded within the library profession. Some common examples of libraries promoting OS in higher education include demonstration of Open Educational Resources (OERs), open access resources, and research data management (Hanna et al., 2021) with latter examples being more tied to those conducting research required by funders to use OS practices. Libraries have an opportunity to collaborate in supporting and teaching transparency in the research lifecycle (Lyon, 2016). However, limited research exists that investigates how librarians collaborate and provide
instructional support on OS practices that go beyond the topics of open access publishing or using OERs. Several studies analyzing librarians supporting OS focus on the support through the research lifecycle and vary in educational level from undergraduate and graduate students to post-graduates. (Medeiros & Ball, 2017; Read et al., 2022; Sayre & Riegelman, 2018). Examples of topics of OS classes and workshops include preregistration, data curation, tools and research workflow, reproducibility, OS curricular plans for student research experience, and so on (Medeiros & Ball, 2017; Read et al., 2022; Sayre & Riegelman, 2018). Hanna et al. (2021) describe a collaborative librarian and faculty OS curricular plan for undergraduate students. Their example outlines strategies used in the program that focus on teaching students OS practices at various stages of the curriculum to promote transparency, collaboration, and reproducibility in research. Their plan provides a description of the curricular design and instructional methods used (Hanna et al., 2021). The challenge here is that the examples of teaching aspects of OS practices in the curriculum vary between disciplines, faculty understanding of OS, and faculty willingness to adapt OS practices in their own research. As a result, the ways librarians can help support teaching OS is still emerging. Current policy changes are creating a path for OS to be instilled not only in research but into student learning, and as such, this may create a greater need for instructional collaboration between faculty and librarians. This exploratory study aims to provide a deeper understanding in pedagogical trends of librarian support of OS practices in higher education.

Methodology

Sample and Recruitment

This study used a mixed methods sequential exploratory design (Creswell & Creswell, 2023; Creswell & Plano Clark, 2011). The qualitative approach used an interview instrument that was followed by a survey that included closed and open-ended questions. The information collected during the interview phase, one year before administering the survey, informed the development of the survey questionnaire.

A non-probability sampling method was used. The participants for the interview and survey were recruited through the ALA Members group and interest groups in divisions like ACRL (Association of College & Research Libraries), and Physics-Astronomy-Mathematics (PAM) Division of the SLA (Special Libraries Association). The estimated membership within the ALA Members group is 44,000 individuals, which is an approximate number of individuals who may have received an invitation to participate. Another recruitment approach for the interview used contact information from various Library Guides covering the topic of open science, open scholarship, and reproducibility. Following the interviews, a survey in Qualtrics was administered. The interview and survey focused on academic librarian experience in providing instructional support on the topic of OS research practices. Participants were not provided with incentives to participate. The study was approved by the Institutional Review Board at the University of Missouri, Columbia.
Data Collection

A total of five semi-structured interviews were conducted over Zoom. The interview followed a set of questions but allowed for the participants to share additional information that was related to the study topic (Appendix I). Each interview lasted from 60-90 minutes. The transcribed document produced in Zoom was proofread while the recordings were re-watched. Then the data was anonymized, reviewed, and themes were identified in an Excel document. Themes were identified by reading the transcripts multiple times, highlighting passages that relate to specific topics, and combining similar topics into themes.

The interviews informed the design of the survey questionnaire, more specifically the interview questions focused on the ways OS practices were conducted in the undergraduate curriculum. The interview analysis revealed that the participants provided instruction to undergraduate and graduate students, with some focusing solely on graduate students. This insight helped with constructing the questionnaire by including questions asking participants to provide examples of how they teach OS practices to undergraduate and graduate students. The survey included closed and open-ended questions (Appendix I). The survey was open for four weeks and was completed by 26 librarians working at academic institutions. Toward the end of the survey there was a slight decrease in response rates, with most questions garnering between 20 and 26 responses. Several questions allowed respondents to select multiple answers.

The author used credibility and transferability criteria as a measure of trustworthiness when the data was analyzed, adapted from Guba and Lincoln (1985). More specifically, the author used strategies from credibility and transferability criteria such as triangulation, member checking, and detailed quotations to validate the findings of the research (Creswell & Miller, 2000; Korstjens & Moser, 2018). This study used method triangulation, where multiple data sources such as interviews with participants and a survey were collected to confirm credibility of the findings. The interview analysis included detailed quotations from the responses to maintain the credibility of the original participant response. Member checking included sharing transcripts with a few participants for feedback to clarify and provide additional information.

Results: Interviews

Analysis of the interview data revealed three major themes related to OS pedagogical practices and the roles librarians play in supporting OS in higher education: 1) open science pedagogy is not mandated; 2) open science initiatives vary in librarian roles; 3) open science teaching and collaboration varies. Together, these themes provide insight into the type of support librarians provide in teaching OS along with the ways in which OS is initiated and mandated at various institutions. The participants in the interviews all worked at institutions with high research activity. The participants varied across their librarian roles, with some in teaching and research roles and others in teaching and engagement roles with one participant in a role covering research data management and reproducibility. However, all the roles involved liaison activities between various disciplines in the sciences and social sciences. Examples of some of the
Open Science Pedagogy is Not Mandated

The OS teaching initiatives are not mandated at any participants’ institutions. One participant noted that the “university is reluctant to institute a top-down policy on anything, research autonomy is valued and to leave it up to the individual faculty member to set up their lab and run it how they want to” (P3). However, some participants talked about the initiatives that are centered around undergraduate research experiences that the institutions support. For instance, undergraduate research opportunity program (UROP), first year research experience (FYRE), or student undergraduate research experience (SURE) are initiatives centered around exposing students to conducting research in the early stages of undergraduate studies. Some of these programs are standalone like UROP and SURE, and others like FYRE are initiatives that faculty can adapt into their courses. One participant used these initiatives to plug their expertise on OS practices and collaborate with the faculty adapting these initiatives. While not mandated at the institutional level, however, for one participant this is a part of their job description; P5 noted that the “core component of [their] job is to espouse open science and reproducibility.”

Open Science Initiatives Vary in Librarian Roles

Interviews revealed that there are variations in the librarian roles and how they combine OS teaching as a part of their role. While OS and reproducibility work is part of a role description for one participant, most participants noted that it complements their liaison librarian responsibilities. Apart from the one interviewee, the rest of the interviewees described it as something that is a part of their own initiative and interest. However, some note that it directly relates to their role. For P3, open research is supported and includes initiatives that are funded by the library, such as an open research committee and open scholarship office. Another participant noted,

It was not my institution that pushed me into reproducibility, it was my [initiative]. The University has a data repository, but I helped reshape it and advertised a data repository that supports open science, data curation, and long-term preservation. I do not perform the tasks of the data repository, but it is something I talk about a lot. If you want to be radically transparent, we have the tools for you to make sure it’s FAIR [findability, accessibility, interoperability, and reusability] and data curators on staff that will work for you (P4).

Certain aspects of OS practices seem to be a part of other roles. “A bigger part of my job has become [supporting] systematic reviews services, that fits well into this. Evidence synthesis is thought to increase confidence in science. I see a lot of overlap between evidence synthesis and reproducibility” (P4). P1 notes, “work that I have done around this has been purely me asking can we integrate open scholarship into a particular course, if it suits the makeup of the course.” Some interviewees participate in initiatives as a part of the larger communities based on their networking and knowledge, for instance, in a journal club initiative on reproducibility called ReproducibilityTea. This...
initiative is suitable for graduate students, post doctorates, early career scholars, but generally not restricted to any particular audience.

The participants noted a lack of time as a factor in how much of their time they can devote to outreach, promotion, training, and teaching OS initiatives. For P1, OS is not an initiative practiced by the institution or the library and training staff would require time. “It is still new to a lot of the librarians […] Work still falls on me to train everyone and have it coordinated” (P1). Furthermore, liaison librarian roles encompass various responsibilities that take precedence over certain initiatives that are still born out of an employee’s own initiative.

**Open Science Teaching and Collaboration Varies**

All the participants provide various types of instruction as a part of their liaison roles, for example, one-shot instruction, workshops, embedded instruction, and teaching credit-bearing courses. As such, variations in the roles and programs supported by the library demonstrate differences in how initiatives, collaboration, and the type of instruction on OS practices is delivered. There are also variations at what point in education OS is taught. Some teach a mix of undergraduate and graduate students, and some primarily provide support to graduate students and researchers. One participant noted that they get invited to provide talks by a lot of different groups that are not within their liaison roles, due to their expertise on the subject matter. Out of the five participants, one participant showed examples of consistent teaching collaboration in an undergraduate curriculum, while others provided instruction on an as-needed basis, with an emphasis of providing support to graduate students and faculty primarily. The examples below represent various initiatives among the participants teaching open scholarship practices.

**Examples of Consistent Instructional Collaboration.** P1 provided various examples of being consistently involved in teaching OS in the research lifecycle through various initiatives at their institution. “The SURE program provides funding for undergraduate students to conduct research in the summer and I show, in one-shot sessions, how open science works across the lifecycle” (P1). Further, the interviewee noted reaching out and asking the coordinators of this program to introduce open scholarship as one of the topics. P1 also noted being embedded in a course that adapted a FYRE program and integrating open scholarship lifecycle lectures into the overall course assignment.

The most integrated example is through a course that [adapts] the first-year research experience, an opportunity for undergraduates in their first year. Each department or college that picks a FYRE program decides what that research program looks like. [For the course], what they have done is have students fill out a series of checkpoints on their way to completing a research poster that includes a survey administered to the entire university. What I did was require for all the pieces of information to be shared in public and with their peers. [For instance] when they do the methods sections, it is to their classmates. They were required to create a data dictionary and a data management plan that was all in the OSF platform. What I would do is provide an introduction, and overall
requirements [for open scholarship components], and after each checkpoint, I would come back and debrief and provide feedback. At the very end they filled out a reflection assignment on what they thought of the practices of open scholarship and what impact do [they] see open scholarship has on research more broadly. I found that this was a good way of engaging students about why it is important, the quality of work is much better because it is shared with peers. (P1)

P1 also notes challenges in the way each department differs in terms of being open to adapting OS in the FYRE initiative. “It’s very different in each college, some of them [faculty] are very closed to it. [Some] faculty who run these are much more private, they use the students to help them with their own research” (P1).

Similarly, P5 noted being regularly invited to a data science course where the professor integrates an assignment where classmates must reproduce a classmate’s homework assignment. “Hardly ever works on the first try … This is a good example of a professor integrating [reproducibility] into a course” (P5).

**Examples of One-Shot Collaboration.** Other participants did not have initiatives that they are consistently a part of when it comes to teaching OS practices to undergraduate students; however, through their roles they provided some examples of what they help teach. For instance, P2 works at a satellite campus that serves a smaller population of undergraduate students, and as such, provides various responsibilities in their role. One notable initiative P2 introduced involves integrating an Open Educational Resource (OER) project into a credit-bearing first-year library experience course. This project tasks students with creating an OER centered around their experiences as first-year students navigating the library. The emphasis of this was to introduce open access and publishing and creating a data management plan. “[The students] worked on a mock data management plan, to understand why researchers need to come up with a [data management] plan” (P2).

Similarly, all participants noted teaching the importance of creating a data management plan. In a presentation that P4 shared, that they delivered for an ethics seminar on the topic of scientific misconduct, creating a data management plan was emphasized. P4 also added that “my folks will ask me to teach about data management in Psychology, or talk about retractions, misconduct or anti racism in research.” Another example is from P3 who primarily works with third-year, fourth-year, and graduate-level students who conduct research. P3 helps support researchers “create their own research workflows and help select tools for their workflow.” For instance, “how to manage the vast amounts of research information that they generate through their research lifecycle, [for instance] pre-registrations, data, code, preprints, slides, posters for conferences” (P3). Additionally, P3 described working with faculty principal investigators and partnering with research labs at their institution to create a research workflow framework of tools, best practices, and sharing policies that can be used as a lab manual and implemented for ongoing research in the lab. “All of that is open and sharing but it has 100% to do with reproducibility, the only way to reproduce something is to have it extremely well documented” (P3). P1 and P5 explained that in one-shot and orientation sessions they teach undergraduate students about research articles and what goes into
creating an article. P5 noted “the article is the preview, but I teach what goes into creating the article […] Have had that conversation in orientation sessions.”

**Perception of Teaching Open Science Practices at Different Academic Levels.** P3 expressed some apprehension about teaching OS practices to undergraduate students because [open science in the research lifecycle] “is a huge overwhelming thing, and it makes more sense to introduce the open science lifecycle and practices at the graduate level as their life revolves around research. For undergraduate students it is good to introduce them to open science and reproducibility but maybe not best to start training them.” Similarly, P5 noted that they would not teach data management plans to undergraduates, only to graduate students because they deal with grants. P5 noted that they reframe research as “project management” to undergraduates as not everyone wants to go to graduate school. In contrast, P1 taught the importance of research in a practical context to the students who do not see themselves continuing in research. For instance, the implications of using research in a practical role as a health care practitioner and how transparency matters in that context.

**Understanding Tools in Open Science.** There are various tools used in OS practices, for instance R, Python, Open Science Framework (OSF), and so on. When asked whether they needed more training to understand these tools, the participants noted that they did not feel like they needed to know the tools in depth. The interviewees noted the importance of understanding why they are used, to being able to point students to a specific tool. P4 mentioned that it is important to “understand why they are used and a little bit how they are used, and tool selection factors in, why someone would use R versus SPSS.” Similarly, P3 emphasizes other library units such as “data and statistical service, visualization lab, research computing” as resources that they point students and researchers to. Both P3 and P4 noted that they would work with vendors to demonstrate a particular software. “If you have labs and undergraduates working in labs [vendor demonstration] would potentially help” P4. Additionally, P5 addressed the importance of having the knowledge of proprietary vs. open-source software in computational reproducibility, as proprietary software is not always transferable across different operating systems. All the participants used the OSF to show how it can be used across the research lifecycle.

**Results: Survey Questionnaire**

Building upon the insights learned from the interview results, the survey data analysis revealed various themes related to librarian support in teaching OS practices in higher education. The results revealed that most of the participants work at institutions of very high research activity with some working for liberal arts and teaching-focused institutions, and one, labeled as other, at a single program unspecified institution, as shown in Figure 1. The survey respondents varied across their librarian roles, such as liaison librarian and subject specialist roles with some in teaching and research roles and others in teaching and engagement roles. A few participants noted working in collection management, data management, and administrative roles. Those working in liaison librarian and subject specialist roles noted supporting disciplines in the sciences and social sciences. Examples of some of the programs that the participants support are Biology, Biomedical Sciences, Computer Science, Economics, Education and Leadership,
Among 26 survey participants that answered the question whether OS initiatives are mandated at their institution, most (77%) noted that initiatives for teaching OS practices in the curriculum are not mandated by their institution, while 19% were unsure and one participant noted that it is instituted at their institution. When asked whether the library has a mission statement to support OS practices, 35% of the participants answered yes, and 58% answered no, with two participants not being sure. In a follow-up question, 69% of the participants answered that teaching OS practices is their own initiative. Additionally, the questionnaire asked participants to identify the type of support their library provides that relates to OS instructional practices; this question allowed respondents to select multiple answers. The most popular choices were “scholarly communications” (73%), “using digital repositories for data” (73%), “creating data management plans” (69%), “open publishing” (62%), “open scholarship” (50%), and “open science policies” (35%). When asked if this initiative aligns with their job description, 65% of the 20 participants that answered the question answered yes.

Among 20 participants, most noted that they actively provide teaching support on OS practices (90%) and collaborate with various units within the library to promote OS instruction (65%). When asked how they publicize their OS instructional support, the most popular responses included “personal faculty contact,” “notices on library web,” and “notices or letters to faculty.” The responses varied when asked if librarians participate with various units across campus to deliver OS instruction. This was an open-ended question that was coded into categories based on the responses. Common
responses included collaborating with the Office of Research and specific departments or divisions, for instance, centers for teaching and learning, division of computation and data science and geophysics programs, graduate studies, international studies undergraduate research cohort, and curriculum and instruction. There were variations in survey responses when asked whether participants found if this initiative is extra work on top of their current roles, (participants could skip this question if this was part of their role. Among 14 participants, most responses ranged between “neither agree or disagree” (36%) and “somewhat agree” (36%).

Open Science Teaching

The participants provide various types of instruction as a part of their roles, for example, one-shot instruction, workshops, embedded instruction, and teaching credit-bearing courses. The question about the mode of delivery for teaching OS practices allowed respondents to select multiple answers, most chose all the options for “in-person,” “online,” “hybrid,” and “asynchronous module instruction.” When asked what type of lessons they provide on OS practices, most popular choices included publishing in open access, reproducibility and replicability, publishing data, open science tools, teaching transparency in research, and writing data management plans, as shown in Figure 2. In the open answer option of the survey question, one participant noted “we do not have full, stand-alone workshops on each as a single topic; rather, we embed various topics above into several data-related sessions we give and incorporate topics in one-shot or other workshops as applicable.” Another noted “I usually include the open science things as part of normal workshops on doing literature reviews and such.”

Figure 2. Examples of lessons on Open Science practices taught by librarians (Participants could select multiple responses)
When asked at what point of education the participants taught OS practices, among 20 participants, the most common responses were undergraduate (65%), graduate (85%), with postgraduate at 40 percent and other (responses included teaching faculty and staff) being 25 percent, as shown in Figure 3. Additionally, when asked at what point of education (undergraduate- or graduate-level) would teaching OS practice be beneficial, most survey respondents answered “both.” One survey respondent noted in the open answer that “the concept should be introduced in K to 12 education” and another answered “both and also continuing opportunities for employees who work in/run labs, etc.”

![Figure 3. The level of education at which librarians teach Open Science practices (Participants could select multiple responses)](image)

The participants were then asked open-ended, text-based questions, to describe the type of lessons they provide regarding OS practices in undergraduate- and graduate-level courses. The responses included similarities and differences in OS lessons between undergraduate and graduate courses. There were 9 responses that included teaching examples in undergraduate courses and 14 responses of teaching examples in graduate courses. Between undergraduate and graduate teaching support, teaching data management (data literacy, lifecycle of data management, final data dissemination) were popular responses. Teaching tools and workflows, such as using the Open Science Framework (OSF) platform, to manage project work was another common response. Open access publishing was mainly included in graduate teaching, which makes sense as graduates work independently and with faculty to publish studies. The responses labeled as “other” for each of the questions included unique responses that did not conform to a theme; some examples from that category included teaching the meaning of open. A few responses noted that receptiveness from faculty varies, which was not related to the survey question. When questioned regarding the usefulness of instructing OS practices in the classroom, the majority of the survey participants expressed it is very useful (68%), a few expressed that it is extremely useful (21%), a minority of respondents acknowledged its slight usefulness (11%).
Professional Development

More than half of the participants received professional development on OS practices and teaching (60%), while 40% did not. When asked whether they use a specific professional development platform, most answered that they do not. The ones who do provided examples: “It’s hard to find trustworthy information online these days. I try to research on scholarly articles and books and make my own lesson plan”; “listservs, nsf/nih, oer commons”; “carpentries, conference sessions from relevant meetings, working group on nih dmsp guidance, open science knowledge base.” Most of the survey respondents except for one answered that they needed more training in understanding tools used among various disciplines in their research.

Discussion

The findings in this study provide a deeper insight into librarian support and opportunities to embed OS instruction in the classroom. Most of the respondents from both samples work at institutions of higher research activity and provide liaison support to various disciplines. The sample from both study populations portrayed a varied approach to teaching OS in education, highlighting that this is dependent on the institution, library services, faculty collaboration, and faculty willingness to teach OS practices. This, in general, is not new to librarian work. Often instructional collaboration depends on faculty knowledge of a librarian’s expertise and the faculty willingness to collaborate. It should be noted that since this movement is still nascent, faculty may feel overwhelmed in understanding best approaches to incorporate OS practices into research and teaching (Strand & Brown, 2019), which impacts how the library can provide teaching support. Additionally, as noted in some studies that focused on researchers adopting OS practices, the current academic landscape still values publishing and grant funding and lacks incentives to practice OS (Bruton et al., 2020; Zečević et al., 2020). Nonetheless, these findings reveal several opportunities. Librarians could work to collaborate with various research entities that are unique to their campus, for instance, collaborating with undergraduate research experience programs, working with the graduate studies office, establishing relationships with faculty, and spreading the word across campus about their knowledge on instructing OS practices. The survey revealed that for some participants, OS is part of the mission at their library. However, most noted that the library does have units that provide OS support, such as scholarly communications. This further highlights the opportunity for those working in liaison and research and teaching roles to collaborate with library units to promote and develop instruction about OS practices in research and share their guidance with those who are still unsure what it means to teach components of OS practices.

Results show that the participants from both samples provided instruction to undergraduate and graduate students. The participants shared examples of their involvement in OS instruction, highlighting variations in implementation across institutions. While the instruction reached undergraduate students, the interview sample revealed that the focus is still on providing this support to graduate students and those already conducting research. This differed from the survey findings, where responses indicated teaching OS in both undergraduate and graduate classrooms. Data management emerged as a common topic of importance, while other topics taught
included transparency in research, questionable research practices (QRPs), pre-registration, reproducible research, OS tools and workflows, and publishing in open access. It makes sense that data management emerged as a popular instruction topic due to many funders requiring researchers to create data management plans for their research, aligning with previous studies indicating that this is a common OS instruction topic (Hanna et al., 2021).

Additionally, the results highlighted the perception of when OS should be introduced in higher education. In interviews, some participants expressed reluctance to teach certain aspects of OS, such as creating data management plans, at the early undergraduate level. However, this could be due to the participants mainly supporting students at the graduate level. In contrast, survey results showed that the respondents thought OS should be taught in undergraduate and graduate curriculum. It is important to highlight that the participants in both samples were not asked if they thought certain lesson content would be applicable to teach at a particular stage in education, which would provide a better understanding for their answers. The variations in responses on the perception of when OS should be taught highlights an important takeaway. For instance, aspects of OS practices could be taught at various stages of education, such as introducing research ethics and QRPs in the early stages of undergraduate curriculum and progressing to data management, research tools, and workflows in higher level, research-focused courses. A similar approach could be applied in the graduate curriculum.

Most of the participants work at institutions of very high research activity with some participants working at institutions seeking R2 (high research activity) status. While it makes sense that teaching OS would be more prominent at higher research activity institutions, the findings provide a valuable opportunity for librarians and educators at teaching-focused institutions to introduce students to research within the classroom, even in situations where funding for research activities is limited. The topics shown in the literature review and participant examples could be adapted in courses, for instance, integrating OS practices into courses that cover research practices, especially at institutions where the focus is teaching and not research output. As a result, this has the potential to expose more students to OS research practices and as Frankowski (2023) mentions, contributes to diversity and inclusivity in access to student research experiences.

Participants in the survey indicated that they need more professional development in OS practices. When it comes to understanding tools used for OS practices (R, Python, Open Science Framework) the samples contrasted, with those interviewed noting that they did not need to know the tools in depth, but to understand the tool being used and be able to point it to students and faculty. The survey respondents noted that they need more training in understanding various tools. Since it was a close-ended question, the context behind what they need to know could not be clarified. Overall, the results show that there is not one single way to get professional development on teaching OS practices, reflecting the evolving adoption of OS in teaching and learning. Opportunities for learning may arise from different sources such as The Carpentries, encompassing lessons from programs like Data Carpentries and Library Carpentries.
Further, participants seem to seek professional development opportunities on their own.

There were variations in the open-ended comments of the survey that vary between positive and negative perspectives. Some participants noted that the more exposure students have the better and that it is good to get them thinking about OS practices as undergraduates. One specified that they “do think it is useful to teach open science practices in the classroom as long as there is buy in from the instructor.” Some responses referred to the teaching of OS faculty and librarian collaboration as an ongoing struggle where librarians often face faculty disinterest until required to engage in OS by research and teaching demands, with inconsistent uptake. One respondent noted that:

Librarians are pushed and pulled in too many directions where time is hard to find. Implementing "open science" programs and ideas is an opportunity that never makes it to the top of the list in most undergraduate, graduate, and interdisciplinary programs. Too often, only librarians and research office staff are interested, and that at only saving funds that are hard to find e.g., textbooks, APCs.

Nevertheless, government policies in Europe (European Commission, n.d.) and North America are changing how research is shared. The new government policy in the United States has created an opportunity for the adoption and integration of OS practices. The new policy that was introduced by the White House Office of Science and Technology Policy (OSTP) for researchers using federal funding to make their research immediately available to the public (The White House, 2022) will increase the need to teach components of OS practices in the research lifecycle to students and researchers. As such, the findings in this study show that by collaborating with campus entities and faculty and using existing resources, librarians can play an important role in promoting and developing OS instruction, ultimately facilitating a culture of openness and transparency in research.

Limitations

This exploratory study intended to gain an initial understanding on how librarians contribute to teaching OS practices at higher education institutions. Given that the topic is emerging, the small sample size may not be representative of the general population of librarians who teach about OS working at higher education institutions that practice teaching. While it would be optimal for the data of this study to be available, the IRB approval did not include consent for granting access to the data beyond the author. The lack of planning for data sharing was primarily to ensure data confidentiality and participant protection where planning for data sharing became secondary. Additionally, the survey questions aimed to gather information about library services supporting and advocating for OS instructional practices, and the question addressing if those initiatives align with the respondents’ job description was meant to garner further insight into the type of services related to OS that are supported by the library. However, several respondents noted that they needed further clarification. The
question should have specifically focused on the available library services that potentially align with teaching OS practices.

**Conclusion**

The purpose of this study was to gain a better understanding of librarian pedagogical support in OS practices in higher education. This study presented a number of findings that emphasize the role of libraries in providing training and support for OS practices, the importance of librarian-faculty and campus collaboration, and the need for progressive integration of OS practices in education. While there were variations in librarian roles and the type of content taught related to OS practices, both samples highlighted the importance of librarians’ emphasis on teaching data management plans, transparency in research, QRPs, open publishing, and research workflows and tools. The study highlights some opportunities and challenges in incorporating OS instruction in the classroom, while also recognizing the evolving landscape and policy changes that will drive the adoption of OS practices in research and teaching.

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**References**


**Appendix I**

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<td>What type of higher educational institution do you work in?</td>
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<td>What is your role at the university? What programs do you support in your role?</td>
</tr>
<tr>
<td>Do you teach?</td>
</tr>
<tr>
<td>Is open scholarship or initiatives around open science and reproducibility/replicability included as a part of the core component of the curriculum at your university?</td>
</tr>
<tr>
<td>If not, does the library work to actively support and advocate for it?</td>
</tr>
<tr>
<td>If so, what aspects of open scholarship (open methodology, open educational resources, open access, teaching about reproducibility, teaching about questionable research practices, etc.)?</td>
</tr>
<tr>
<td>Describe your experience with providing curricular support on open scholarship for undergraduate level courses?</td>
</tr>
<tr>
<td>Do you collaborate with faculty to create lesson plans that teach open science?</td>
</tr>
<tr>
<td>What disciplines have already been implementing open science and reproducibility in their teaching? What disciplines are prevalent in that type of support?</td>
</tr>
</tbody>
</table>
At what point in undergraduate education do you see these practices being taught? (first year, second year, etc.)

How did you get to be included in these initiatives? Is it through outreach, building relationships?

Are there any open pedagogical examples that you are willing to share?

Do you find that you need more training in understanding the tools used in various disciplines for their research?

Additional comments.

Survey Questions

What type of higher education institution do you work in?

- [ ] Very High Research Activity (Research 1)
- [ ] High Research Activity (Research 2)
- [ ] Bachelor Granting
- [ ] Master's Granting
- [ ] Liberal Arts
- [ ] Teaching Focused
- [ ] Other (Please Specify): __________________________________________________

Does your library focus on a specific discipline? Please include the discipline or subject area.

- [ ] Health Sciences
- [ ] Engineering
- [ ] Business
- [ ] Music
- [ ] Humanities
- [ ] Math
- [ ] Business
- [ ] No specific discipline
- [ ] Other __________________________________________________

What is the role in your job (e.g., reference and instruction librarian, subject specialist, collection development, outreach librarian, digital services librarian, etc.)
What disciplines / programs do you support in your role?

Which of the following would you include in your definition of “open science practices”? (Check all that apply)

- Open access to publications
- Open access to research data
- Open source software
- Open educational resources
- Open peer review
- Open pedagogical practices
- Open education
- Citizen science
- Open practices in the research lifecycle
- Other (please specify) __________________________________________________

Do you teach? (one shot instruction, workshops, embedded instruction, credit bearing courses, modules, etc.)

- One Shot Instruction
- Workshops
- Embedded Instruction
- Credit Bearing Courses
- Other (please specify) __________________________________________________

Does the university have a mandate for the integration of teaching open science practices in the curriculum?

- Yes
- No
- Not sure

Does the library have a mission statement to support open science practices, including teaching open science practices?

- Yes
- No
Not sure

If the answer is no or not sure in the previous question, do you pursue teaching open science practices on your own initiative?

- Yes
- No
- Not Applicable

Which of the following does the library do to actively support and advocate for open science instructional practices?

- Scholarly communications
- Open scholarship
- Open publishing
- Creating data management plans
- Using digital repositories for data
- Open science policies
- Open peer review
- The library does not have an initiative
- Other (please specify) __________________________________________________

Does this initiative align with your job description?

- Yes
- No
- Other (please specify) __________________________________________________
- Not Applicable

Do you actively provide teaching support on the topic of open science practices?

- Yes
- No

Do you collaborate with various units within the library to develop and promote open science instruction?

- Yes (please specify the units) __________________________________________________
- No

Do you collaborate with specific units or departments on campus that focus on embedding teaching open science practices into the curriculum? Please specify.

________________________________________________________________
Did you continuously reach out to faculty to collaborate in these initiatives?

- Yes
- No

How do you publicize instructional programs that relate to teaching open science practices in your library? (Check all that apply)

- Personal faculty contact
- Notices or letters to faculty
- Notices in campus newspaper
- Notices on library web
- Posters
- Email discussion lists
- Departmental meetings
- Social media
- Other, please specify: ________________________________________________

What type of lessons do you provide? (Check all that apply)

- Transparency in research
- Reproducibility crisis
- Reproducibility and replicability
- Questionable Research Practices
- Pre-registration of research
- Creating research workflows in OSF, etc.
- Writing data management plans
- Writing data analysis plans
- Publishing in open access
- Publishing data
- Open science tools
- Citizen science
- Other, please specify: ________________________________________________

Do you collaborate with faculty to create lesson plans that teach open science?

- No
At what point of education do you teach open science practices?

☐ Undergraduate
☐ Graduate
☐ Post-Doctorate
☐ Other, please specify: ________________________________

At what point of education do you think teaching open science practices is useful?

☐ Undergraduate
☐ Graduate
☐ Both
☐ Other, please specify: ________________________________

Describe your experience with providing curricular support on open science for undergraduate level courses? (e.g., creating modules that address open scholarship that are embedded in the classroom or lab, guiding students on using platforms to register their research, finding OER lesson plans that faculty can replicate in their own teaching, providing guidance on statistical tools, etc.)

________________________________________________________________

Describe your experience with providing curricular support on open science for graduate level courses? (e.g., creating modules that address open scholarship that are embedded in the classroom or lab, guiding students on using platforms to register their research, finding OER lesson plans that faculty can replicate in their own teaching, providing guidance on statistical tools, etc.)

________________________________________________________________

What format do you use to deliver the instruction? Choose all that apply.

☐ In person
☐ Online
☐ Hybrid
☐ Asynchronous Modules
☐ Other, please specify: ________________________________

Do you use any professional development platforms to find examples of lessons or lesson plans on teaching open science?

☐ Yes, please specify ________________________________

☐ No

Have you received professional development on open science practices and teaching?
Do you find that you need more training in understanding the tools used among various disciplines in their research?

- Yes
- No

If this is your own initiative, do you find that it is extra work on top of your current role? If this is a part of your current role description, please skip this question.

- Strongly disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Strongly agree

Do you think that it is useful teaching open science practices in the classroom?

- Not at all useful
- Slightly useful
- Moderately useful
- Very useful
- Extremely useful

Please provide any other comments