Research Practices of Civil and Environmental Engineering Scholars

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Introduction

In fall 2017, the University of Colorado Boulder (CU Boulder) Libraries joined with ten other university libraries to conduct an Ithaka S+R study investigating the research practices and needs of civil and environmental engineering faculty. Ithaka S+R is a not-for-profit organization doing research and strategic guidance for colleges, universities, libraries, museums, scholarly societies and other institutions that support higher education. This study was part of their ongoing research support services program on how the practices of scholars vary by disciplines.

The report shares findings from exploratory semi-structured interviews with civil and environmental engineers from CU Boulder. Themes from the interviews include the diversity of the field, the data practices of scholars, the value of different kinds of sources, and how these scholars communicate their findings and conclusions. Finally, we provide recommendations for improving services and support for civil and environmental engineers.

The College of Engineering & Applied Sciences

The University of Colorado Boulder is a large, public, Doctoral granting research university. Student enrollment is approximately 33,000 students. CU Boulder's College of Engineering & Applied Sciences (CEAS) enrolls approximately 20% of CU Boulder's students. The college is the 32nd ranked engineering program in the nation.[1] Civil engineers work in the department of Civil, Environmental & Architectural Engineering, and environmental engineers work in the department of Civil, Environmental & Architectural Engineering and the Mechanical Engineering department. The graduate programs in civil engineering and environmental engineering are both ranked in the top 25. [2]

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[1] U.S. News & World Report, "How Does University of Colorado--Boulder Rank Among America's Best Engineering Schools?"
[2] University of Colorado Boulder Graduate School, "Rankings."

Methodology

Librarians conducted eight interviews with civil and environmental engineers at the University of Colorado Boulder. Of the eight engineers, seven were faculty members from the Department of Civil, Environmental, and Architectural Engineering and one was faculty from the Department of Mechanical Engineering. Interviews were held and recorded in the engineers' offices on campus with a semi-structured interview guide provided by Ithaka S+R. Relying on the interview guide enabled the overall tone of the interviews to be more conversational, allowing the opportunity for interviewers to ask follow-up questions and to explore topics further as needed.

Interviews were transcribed and anonymized to remove names and other identifying information. Qualitative coding of transcriptions was performed using the analysis software application *Dedoose*. The team of librarians developed consensus regarding the codes used with at least two librarians coding any single transcript. Any remaining discrepancies were resolved by the group as a whole. Coding of the transcripts allowed the librarians to view common themes, around which the findings of this report are based.

The interviews covered a range of topics that allowed scholars to both speak to their own experiences and to address the broader context for their discipline. We found that the interviews provided valuable information on the research practices of civil and environmental engineers. This insight into the work habits and information concerns of scholars is particularly useful to librarians as we continue to develop and refine our services and collections to meet their needs.

Diversity of Research Practices within Civil and Environmental Engineering

One of the themes observed in the data was the diversity of the fields of civil and environmental engineering. Scholars are collaborating with professionals from a variety of fields and types of organizations. In addition, the kind of work they are doing is varied (not what might be thought of as traditional civil or environmental engineering), and interdisciplinary. Finally, researchers are using varied research methods including modeling, experimentation, fieldwork, and social sciences methods.

Multidisciplinarity and Collaborations

Scholars described collaborations with a large variety of individuals and organizations, both within and outside of the University. Graduate students were mentioned as collaborators in every case, and they were generally the first collaborators described, indicating their importance to scholars and the close proximity that the researchers work with the students. Scholars also discussed collaborating with other university researchers, both in the organization and at other universities, and with other engineering scholars, including civil or environmental engineers, electrical engineers, mechanical engineers, chemical engineers, and computer scientists. There were also collaborations with researchers from other fields, mostly in the sciences (chemistry, biology, medical sciences), but with some social science researchers as well (sociology, geography, behavior sciences, legal studies). Scholars mentioned collaborations with other university researchers in Colorado, but also described national and international university collaborations. Outside of academia, scholars discussed partners in industry (such as the oil

and gas industry), and non-profit or governmental organizations including local community groups, public health organizations, the National Renewable Energy Lab, the National Academies of Science, Engineering, and Medicine, US Geological Survey, the US Environmental Protection Agency (EPA), and the World Health Organization. These collaborations also provide insight into scholar's funding sources. Collaboration is easier with colleagues at the same institution, but with tools like video conferencing and shared document applications, collaborating across distance becomes more manageable. In terms of barriers to collaboration, time was identified as one of the main obstacles. They specifically mentioned difficulty in having time to find collaborators, learning new tools for collaboration, or setting up larger collaborative projects. Also identified were the different expectations for collaborators from diverse organizations (such as federal or state government agencies) or from different disciplines (such as medical sciences) in terms of research goals and publication practices. Researchers from other organizations also had differential access to information sources like journal articles, and this was an impediment to collaborative practices.

Interdisciplinarity and Fit in Civil and Environmental Engineering

Many interviewees discussed not fitting into a traditional civil engineer or environmental engineer mold, which also highlights the interdisciplinary nature of civil and environmental engineering. One scholar spoke to environmental engineering traditionally having a stronger emphasis on water issues, and working in the area of air quality placed the scholar outside the norm in terms of research topic and research methods. In addition to interviewees feeling their topics or methodologies do not fit with traditional civil or engineering research, one interviewee discussed the disconnect between practicing civil engineers and the work done by engineering scholars:

> "Academia is so far ahead of practice that it's hard to make an impact, so that's a big challenge where sometimes people get down on themselves about academia and then they don't feel like they're making a difference."

These experiences highlight the wide landscape seen in the fields of civil and environmental engineering, across research topics and approaches, and as scholars communicate between practice and research.

Issues regarding how a scholar's work 'fits' into the field's publishing practices impacts a scholar's publishing practices. If their work does not fit into traditional civil or environmental engineering, then the work might not fit into traditional publishing venues:

> "In my field in particular conferences are actually somewhat prestigious and it seems like in civil engineering they're not and so I made a reference about "oh what if I get a conference paper in should I put it on my [annual faculty report]" and then another faculty member said "oh God no nobody cares about conferences" and I said "well this conference is a 20% acceptance rate that's actually lower than a lot of the journals that I submit to". So I feel like there is the stigma [of] I have a lot of conference publications but a lot of people in the department don't care about this."

In putting their work into the most appropriate venues, they may run into issues with tenure and promotion expectations.

Methodological Diversity

Civil and environmental engineers use a wide variety of methods, including fieldwork, lab experimentation, modeling, and social science methods like interviews and surveys. Modeling was described most often, potentially indicating its importance or popularity as a research

method. There were also several terms used to describe modeling methods, including computational mechanics, multiscale modeling, numerical methods, simulation models, and computer modeling. Each scholar may employ several different methods, for example, "most of my research is measurement based. So, we'll deploy instruments and we'll gather measurements... and then laboratory work is for calibration and instrument storage and manipulation." The scholars described using multiple methods because they were supervising a variety of graduate students, and each student's work might use a different methodology. Finally, most interviewees described literature review as one of the methods they use over the course of their research, but one scholar's methods are based on analyzing historical documents.

Data Practices and Data Management

Scholars in civil and environmental engineering utilize many types of data, from a variety of sources, which are stored in many locations. However, data management practices are not consistent in civil and environmental engineering, and this causes some anxiety for the researchers. One interviewee stated "I do have concerns that I may not be quite living up to the expectations of the funding agencies as far as data management."

Data Types, Sources, and Sharing

Scholars are collecting their own data and reusing data collected by others. They set up instruments to collect environmental monitoring data, generate data for analysis through modeling, or create data in the lab. Interviewees also described using data from others, including the EPA, public health departments, infrastructure maintenance departments, the campus facilities department, and from other researchers around the country. Requesting and using data produced by others came with a number of frustrations, including waiting long amounts of time or not hearing back. One scholar described their frustration with reusing data:

> "Well, I guess a lot of times the data isn't always clean – there's some missing values and some of the measurements are wrong, it's just stuff that people have been passing around and they might've modified it, so it's hard to tell if it's the original data set or if somebody gave you a different version."

While reusing and sharing data seemed to be commonly practiced by civil and environmental engineers some interviewee's encountered instances where "sometimes people were a little guarded with their data." The timing of when data is shared matters, as "people in my field don't like sharing their data before it's out." Interviewees described how they did not want to share their data with others until they had had published, in addition to encountering that practice in others, indicating a routine practice in the field. Interviewees were open to sharing the data they produced, or their models with other researcher after they had published.

Data Storage

A surprising number of scholars stated their data was stored on their students' computers. One stated, "my students keep it on their computer and then at some level it gets aggregated and sent to me, but I don't actually have myself most of it at this point." Other data storage locations include their own computers or external hard drives, having files in their email accounts, cloud storage applications, and one researcher described using a large data storage facility at the university. Many interviewees described using multiple options so that they would have file backups, but several expressed a lack of organization and not knowing where all their data was.

Data Management

If interviewees were following data management practices or plans, most described having someone else, such as a colleague or student doing it. When one interviewee was asked about keeping any of their work on GitHub, or any other similar resource, they answered: "I've been asking my students to do this. We aren't using it quite well yet, but we are moving that way." Another described leaving the data management to a collaborator on a grant. Overall, data management was a challenge to scholars "I have challenges with data management in general. I promise to do things on my grants that I don't have the skills or time to actually do very well" and when another was asked if they had any plans for managing data beyond current use, preserving their data, or making them publicly accessible one scholar answered "I don't have any plans to do that, because I don't really know how" while another said they wanted to do "something other than what I'm doing." In addition, scholars spoke to the need for things like data format standardization and a shared disciplinary repository for data, similar to what DNA researchers use, so others working in similar areas could re-use the data in new ways.

Information Seeking and Use

Finding Information

The multidisciplinary tendencies of civil and environmental engineering renders many library databases insufficient for gathering relevant and comprehensive information. While these are still valued for their precision and features for enhancing a search strategy, the actual pool of searched information must be broad and incorporate materials such as grey literature and technical reports. *Google Scholar* is the preferred tool for picking up the range of materials necessary for this kind of research, although one scholar reported searching *Google* before switching to *Google Scholar* to broaden the initial search even further. Databases like *Web of Science*, *Engineering Village*, or *IEEE Explore* provide a deep dive into the academic literature, but lack the coverage for successful searching beyond that.

However, even *Google* and *Google Scholar* have significant limitations when it comes to finding information produced by governments and various non-governmental organizations. This puts scholars in the difficult situation of needing to know what exists and where it exists before searching for it. One noted,

> "Just to find it is very challenging. A lot of time. So it would be great to have better access to reports that governments put out, maybe even ones in other languages. Reports that NGOs put out, reports that say maybe UNICEF or USAID or organizations like that are putting out, because those have a lot of important literature that don't get published, but you know, as researchers we could evaluate the robustness of that or see if it's up to peer review quality and can utilize that data in the work that we're doing too, but oftentimes that gets lost and I feel that that's a big challenge."

Some scholars voiced frustrations with the abilities of graduate students in their labs to conduct adequate searches for information. Lack of familiarity with database features and proper search string composition was an understandable concern and one with which librarians are familiar. Even Google Scholar with its broader search capabilities is subject to students' shortcomings when navigating the information landscape. "If they cannot find [it] on a Google search on the first page they think it does not exist," one scholar explained. Nevertheless, a lack of awareness of the library's ability to assist with comprehensive searches was also evident. Few scholars provided search training for students in their labs with most of it occurring on an ad hoc basis.

Sources Used

Every scholar interviewed indicated regular use of peer-reviewed academic literature, but also mentioned routinely seeking out other types of scientific publications. Grey literature of all types and from a wide variety of sources is both heavily used and highly valued. The actual use can be plainly informative or have a more practical approach if scholars need to assess the quality of the research contained therein or use the document's references to find literature from other organizations.

Conferences were viewed very differently depending on a given scholar's niche within the field. "People are still somewhat siloed in their conferences," remarked one scholar for whom conferences did not regularly come into play, but recognized their varied reception and use throughout the discipline. For some, conferences are a way of keeping up with research and discovering who the major players are. Others saw conference presentations as tantamount to a publication in an academic journal, but struggled with poor indexing and outdated dissemination practices that prevented access if they were not at the conference themselves.

While current information is valued for innovation and helping scholars stay up to date on research trends, older information is also sought because of the insight it can provide into past engineering practices, especially as scholars find themselves dealing with structures and materials developed decades before. The library is viewed as particularly useful to scholars needing access to this kind of information.

Preprints are used by scholars whose fields are developing extremely quickly as a way to discover and disseminate research with which traditional modes of scholarly communication, like peer-reviewed academic journals, are not able to keep pace. Waiting a year for an accepted journal article to be published and available is not efficient or effective for these scholars or the research community they wish to reach. Still, some researchers expressed wariness over sharing their research before it is officially published. Preprints also posed a problem with multiple versions of the same information being available.

Information Management

Managing information through software such as *EndNote* or *Zotero* is frequently delegated to graduate students. Several scholars were quick to point out that their students knew far more about these systems than they did. Some scholars use citation management software themselves, but struggle with finding time to create efficient workflows for saving and indexing documents. Others rely on a folder on their own computer for saving PDFs related to a particular project, although storage space becomes an issue for long-term retention. Files might only be saved for the duration of a project in these cases and if the citation is needed at a later date, the scholar can turn to the references in their own paper. Somewhat surprisingly, better search capabilities were a factor for deciding to save something at all, but this is related to the time required to learn new software that could be viewed as peripheral to the actual research, "There's more and more stuff that's just available with a search. It's harder to justify keeping it yourself...if I had more time I can imagine I would have a better system."

Research Communication Practices

Open Access Considerations

The nuances of a changing publication landscape can be a messy subject for scholars to untangle with regard to open access. Most scholars interviewed reacted favorably to the *idea* of open access, understanding the value of making their research freely available to a wide audience. Nevertheless, cost is an overwhelmingly prohibitive factor given that some open access journals require thousands of dollars to make an article open access. One scholar put it well, "I like that it's accessible to everybody and that they don't have to pay for it, but I'm torn because it means I pay for it." Grant money, particularly for federally funded research, can help with this cost, but publication funds are not a standard practice in the field.

For those scholars able to publish in open access journals the experience seems to have been positive and one they would seek out again. "Once I published in a journal that was open access, and it's been by far my most cited paper. I would love to have the money to pay for the open access option for my journals." Others have had some luck with participating in open access through preprints or even making research available on their own websites. Reviewing for open access journals is also an option with credits towards publication costs sometimes given to reviewers as compensation for their time.

If cost presents the greatest restriction for publishing in an open access journal, legal ramifications are its counterpart in making research available through an institutional repository. Scholars are familiar with the University of Colorado's open access policy[3] and with the increased ability to share their research the repository allows, but they are also mindful of the copyright agreement they sign each time they publish an article. "I haven't done it because I was worried about it being illegal," and "I'd be happy to do it, I'm just ignorant on what I'm allowed to do," were statements typical of the sentiments expressed during the interviews when scholars addressed questions about repositories.

There is also some suggestion that the idea of what an online institutional repository is and what function it serves remains a bit unclear, especially to newer faculty who may not yet be familiar with this type of library service. One scholar seemed to think this was a type of subscription database. Others viewed institutional repositories as akin to *ResearchGate* or *Academia.edu*. No scholars reported using CU's institutional repository as a means of sharing their research.

Workplace Considerations

Most scholars have a few journals in which they preferred to publish. These often align very closely with the specific focus area of the scholar's research. Scholars have a strong sense of the journal's audiences, acceptance rates, and turn-around times for publication. One scholar with a non-traditional background mentioned wanting to publish in civil engineering journals, which they had not done previously, but still feeling like an outsider in terms of knowing exactly where to publish.

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[3] University of Colorado Boulder, "Open Access Policy," https://www.colorado.edu/policies/campus-open-access-policy, accessed September 21, 2018.

Metrics also factor heavily into publishing decisions, particularly for pre-tenure faculty and those seeking promotion. Acceptance rates were frequently mentioned as an indicator of prestige, as well as impact factor, which serves both as a means of distinguishing what "good" journals are and the potential for recognition in the form of citations. A pre-tenure faculty member lamented, "I want my citations to go up because there's people telling me 'you know your H index has to be at least 10 to get tenure' or something like that and mine's only at seven so I'm like really insecure about it."

Tenure and promotion make publication considerations a tricky puzzle to solve and scholars must balance impactful publishing with frequent publishing. One scholar mentioned these pressures made them less selective on some decisions, "Now that I'm thinking about tenure as the end goal, I am changing my opinion of how often I'm publishing and where I'm publishing. Much more open-minded now, is the right word." The pressures of academia could also very well be an impediment to open access when it comes to choosing where to publish, "At the national labs, where they may not have the same pressures that we do here, to publish, or to be ahead, or to be competitive in that sense, get the next grant, or whatever. There's more willingness to just be open."

Post-tenure faculty have the luxury of making the audiences of their publications, even non-academic ones, the primary factor in these decisions. "If we're really trying to reach other climate researchers, we might publish in Climate Change. If we're trying to reach people who are talking about what's the economic impact on things, we might publish in Development Economics." Outside of academia, government organizations at the state and federal levels were frequently mentioned as desirable audiences. There is an earnest and deeply professional desire among civil and environmental engineering scholars to reach practicing engineers who are actually "doing" the work and to see one's own work have an impact that resonates outside of bibliometrics.

Recommendations

Data Management Support

Recommendations regarding data practices are to provide educational opportunities for data management practices, and to address benefits and options for scholars in civil and environmental engineering. Taking time to learn about data management and related services will help scholars reduce the stress they feel with regard to their own practices. Experts are available at the University of Colorado Boulder Libraries to assist scholars in learning about and using these services. Because time was identified as a limiting factor, offering tools and services that can help them competently practice data management in an efficient manner is important. Offering guidance and best practices about data storage options would help research teams keep their data in safe locations that are accessible to the entire team, and provide a solution for long-term storage. Scholars also mentioned the need for repositories and metadata provision to help preserve and make accessible data sets.

Publication and Promotion of Research

Scholars made several requests related to publishing practice. While they are overall aware of many different publishing venues and which are the best fit for their work, questions remain with regard to open access and predatory publishing. To address this need for greater clarity on

publishing options and pitfalls, the Libraries could better market to civil and environmental engineers their information sessions, consultation services, and written materials that address these publishing issues. The Libraries currently have personnel well versed in publication through open access journals and institutional repositories who help on a case-by-case basis with author agreements, publication funds, and journal evaluation, services of which many scholars are unaware. This expert assistance could also help to calm scholars' fears they are doing something "illegal" when making publications available through the institutional repository, or that they are publishing in a less reputable journal. Additionally, scholars requested more support for publicity for themselves, their students, and the work they are doing with their teams so they can more effectively promote their work. The Libraries frequently feature research from other departments in events and exhibits and should seek opportunities for this kind of collaboration with civil and environmental engineering faculty.

Education for Graduate Students

While civil and environmental engineering scholars were overall extremely competent at finding information related to their areas of research, the disconnect between their abilities and those of the graduate student workers in their labs suggests a potential for librarian assistance. Additional graduate student skill gaps mentioned were in writing, properly citing sources, and statistical analysis. Librarians offer graduate students assistance with literature review, citation management, and data management, and more effective promotion of those services to graduate students is important. Librarians can be called on to help as questions arise, or can offer semi-embedded assistance, where they would be more formally integrated with developing the lab's workflows related to information seeking and management. A new possible service model is for librarians to partner with writing center and statistical analysis center campus services to provide a graduate student research orientation. This would provide graduate students with the opportunity to learn about a number of services available on campus, and develop skills to help them throughout the research cycle.

Conclusion

This study has offered valuable insight on the information needs, research practices, and concerns of civil and environmental engineers at the University of Colorado Boulder. While the study takes into account the broader landscape of the civil and environmental engineering field, viewing the findings through the lens of librarianship offers actionable directions for greater support and better services for these scholars. University Libraries at the University of Colorado Boulder have positioned themselves to offer support not just through traditional liaison librarianship, but also through services centered on data management, open publication and dissemination of research, and dedication to student success. Knowing the particular ways in which these services may be adapted for civil and environmental engineering provides a foundation for robust and nuanced services that speak directly to the scholars who need them.