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Open Science at the University of Toronto
An Exploration of Researcher, Administrator, and Librarian Perspectives
La science ouverte à l'Université de Toronto
Une exploration des perspectives des chercheurs, du personnel et des bibliothécaires

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Résumé de l'article

Objectif : Ce projet a pour but de commencer à comprendre les pratiques de la science ouverte et les obstacles qui peuvent exister à l'Université de Toronto. Ce projet utilise des questions ouvertes pour comprendre les façons dont les personnes affiliées à l'université s'informent sur la science ouverte, y réfléchissent et interagissent avec elle. L'objectif de cette étude est de mettre en évidence la complexité et la diversité des activités et des défis dans ce domaine afin d'aider à déterminer la meilleure façon de faire avancer la science ouverte.

Méthodes : De mars à octobre 2022, 45 entrevues semi-dirigées ont été menées avec des membres du corps professoral, des étudiants diplômés, des bibliothécaires et des membres du personnel administratif déjà engagés d'une façon quelconque dans la science ouverte. Les entrevues ont été menées sur et enregistrées avec Zoom. Le fichier audio a été transcrit grâce à Otter.ai. Dans le cadre d'un engagement favorisant les pratiques de la science ouverte, un plan de gestion des données a été créé et, avec le consentement des participants, 26 transcriptions ont été téléchargées sur Dataverse. L'analyse des données s'est appuyée sur un codage structuré et un développement thématique pour étudier les réponses.

Résultats: La principale conclusion de cette étude est qu'il n'existe pas de statut unique pour la science ouverte à l'Université de Toronto. Les données qualitatives reflètent une diversité d'opinions, de pratiques et de relations à la science ouverte. Les résultats sont limités aux individus ayant des connaissances et de l'expérience en science ouverte et ne sont pas représentatifs de l'ensemble du paysage de la recherche à l'université.

Conclusion: Pour assurer la longévité de l'érudition en science ouverte, des changements systémiques pour adopter des pratiques plus ouvertes sont nécessaires. L'Université de Toronto est bien placée pour guider la transition et pour exploiter les principes ouverts pour aller de l'avant.

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Open Science at the University of Toronto: An Exploration of Researcher, Administrator, and Librarian Perspectives

La science ouverte à l'Université de Toronto : une exploration des perspectives des chercheurs, du personnel et des bibliothécaires

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Abstract / Résumé

Objective: The impetus for this project is to understand open science practices and obstacles at the University of Toronto. This project uses open-ended questions to evaluate the ways in which university-affiliated individuals learn about, think about, and interact with open science. The goal of this study is to showcase the complexity and diversity of activity and challenges in this domain to help determine how best to move open science forward.

Methods: From March to October 2022, 45 semi-structured interviews were conducted with faculty, graduate students, librarians, and administrators who were already engaging with open science in some form. Interviews were conducted and recorded using Zoom and the audio was transcribed using Otter.ai. As part of a commitment to open science practices, a data management plan was created and, with participants'

consent, 26 transcripts were uploaded to Dataverse. Data analysis used structured coding and thematic development to investigate responses.

Results: There is no singular manifestation of open science at University of Toronto. The qualitative findings reflect a diversity of opinions, practices, and relationships to open science. Results are limited to individuals who have knowledge and experience with open science and are not representative of the broader research landscape at the university.

Conclusion: For open science to have longevity, there must be systemic changes to adopt more open practices. The University of Toronto is well positioned to guide the transition and harness open principles to move into the future.

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Keywords / Mots-clés

Open Science, Open Research, Open Knowledge, Semi-structured Interviews, Qualitative Research; Science ouverte, recherche ouverte, connaissance ouverte, entrevues semi-dirigées, recherche qualitative

Introduction

Open science is a phenomenon which is rapidly changing the creation and dissemination of scientific knowledge in scholarly environments (Fecher & Friesike, 2014). One way to understand open science is that it is the opposite of “locked science,” wherein data and discoveries are trapped behind publisher paywalls (Ignat & Ayris, 2020, p. 2). Open science practices have facilitated open sharing of scientific information; they have accelerated progress in the fight against COVID-19 and saved lives (Besançon et al., 2021; Kadakia et al., 2021). This historically significant moment provides an opportunity to study the perceptions and practices of open science at the peak of its social awareness and value. Globally, governance agencies and practitioners have adopted the values and practices of open science. However, little is known about how open science manifests at the University of Toronto (UofT).

This project seeks to understand open science practices and obstacles at UofT. The objective is to map out the landscape of open science initiatives across the university's campuses, disciplines, and roles. This research considers the progress of open science at UofT, with emphasis on exploring the roles that libraries and library staff have in its adoption. The nature of this research inquiry is exploratory, rather than confirmatory: the study design is oriented to favour broad questions that yield personal responses. This project asks open-ended questions about open science at the university: who, what, where, when, and why? It seeks to understand the ways in which university-affiliated individuals who are already familiar with the concept learn about, think about, and interact with open science. Rather than seeking to present definitive arguments about the status of open science at the institution, this study showcases the complexity and diversity of activity and challenges in this domain. The responses to this research query advance knowledge regarding possible obstacles to open science at UofT and can provide actionable guidance for scholarly policies and best practices.

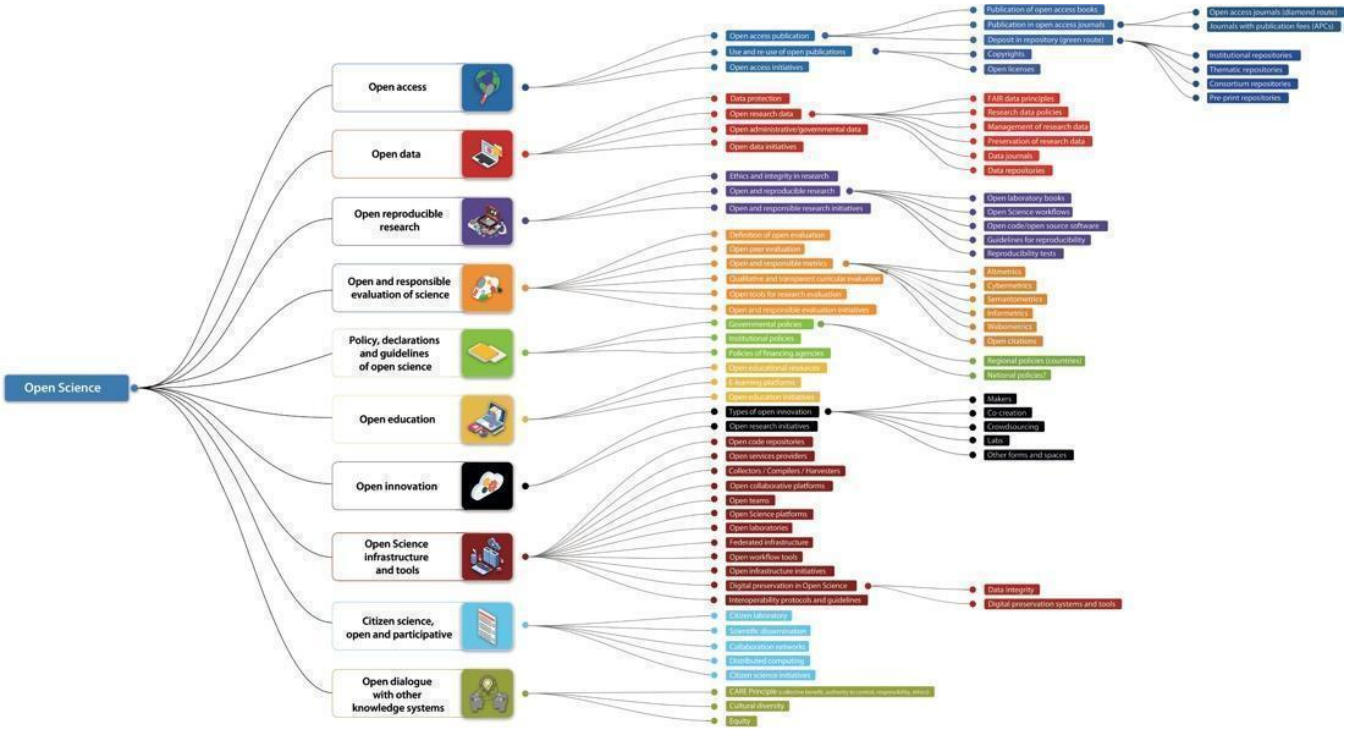
Literature Review

There is no singular definition of open science in the literature that can accurately account for the breadth and impact of opening science across disciplines, geopolitical regions, and local contexts (Chan, 2019). Indeed, the collaborative nature of the open science movement in academia and beyond has generated a vast description and a plethora of definitions. Bosman and Kramer’s (2017) blog post titled “Defining Open Science Definitions” highlights that the definitions of open science themselves can be instrumental and motivated; the authors write that “choices people and organizations make on what they see as most important and perhaps also most realistic determines how they define open science” (para. 3). Variations on definitions of open science point to the variety of values that people infuse into their engagement with the movement.

Figure 1 shows one proposed taxonomy that highlights the breadth and depth of open science.

Figure 1

Silveira et al.'s (2023) proposed taxonomy of open science



While some scholars have attempted to pinpoint a rigorous and up-to-date definition of open science (Vicente-Saez & Martinez-Fuentes, 2018), these efforts are largely futile because they are not universal and cannot sufficiently encompass the diversity of knowledge traditions around the world (Chan, 2019). Chan (2019), noting the gaps in observations in open science practices in the Global South, challenges "the tendency to define Open Science as a set of technical infrastructure, workflow, protocols, and licensing conditions that can be universally applied regardless of context, history, and human agency" (p. 17). In this spirit, this paper refrains from narrowly defining open science as a set of observable practices.

Much of the research about open science occurs in Europe, where the open science landscape has progressed rapidly due to the promotion of open access policies by the European Union (EU) (Saarti et al., 2020). In Canada, the 2020 publication of The Roadmap to Open Science articulates the federal government's commitment to open science principles and mandates that science research funded by federal government departments and agencies is published openly (Government of Canada, 2020). Despite these policy commitments, open science is still in its infancy, and it is often relegated to "Open Science bubbles" of practitioners (Armeni et al., 2021). Moreover, Canadian universities are pursuing open access mandates, yet there is a notable dearth of policy that accommodates the logistical complexities and ethical implications of openness in

the sciences. While North American institutions can look to publications describing the roles of libraries in Australia and Europe to aid in the implementation of open science, the policy landscapes are decidedly different. Open science is encouraged from the top down, from policymakers, the Tri-Agency funding bodies, and academic institutions, as well as from the bottom up, from individual innovators, citizen scientists, and researchers (Armeni et al., 2021). However, even with the enthusiastic backing of many stakeholders, there are bureaucratic, epistemic, political, and social considerations that deter the uptake of open science in practice (Armeni et al., 2021; Chan, 2019). Indeed, Canada is not an international leader in open science; there is an acknowledged deficit in Canada's approach to open science and a need to "catch up" with other international actors (Government of Canada, 2022, p. 12).

The role of academic institutions, and particularly academic libraries, in promoting openness has been baked into the literature about open science from the onset. Indeed, librarians are experts at publication support, skills training, and data management (Swiatek et al., 2020), and libraries serve as linchpins in the research ecosystem. Ogungbeni et al. (2018) conducted a qualitative literature survey regarding the place of academic libraries in scientific research. Their findings show that the relationship between academic libraries and open science has "deepened significantly and continues to grow" (p. 114). While librarians' basic skills in "locating, collecting, organizing, evaluating and disseminating information" have always been important, the added metadata-related activities involved in open science research make libraries central for managing digital content (p. 116). Moreover, Ogungbeni et al. (2018) find that libraries are heavily involved in the dissemination of open science research. Finally, in line with open access mandates and objectives, libraries have sometimes become alternative publishers through institutional repositories made available both internally and externally. Ayris and Ignat (2018) investigate the role of libraries in promoting open science by reflecting on the current practices of European research universities' libraries. Based on a review of case studies and the results of EU-funded research on research data management, they find that libraries are particularly well-suited for open access publishing, research data management, digital infrastructures, and supporting citizen science. Taken together, these two papers demonstrate that libraries are deeply integrated into the scientific research cycle, and that they can be anticipated to be involved as key players in the propagation of open science in the future.

Despite the natural partnership of researchers and academic libraries, coupled with academic libraries' investments in support of open science, the impact is still invisible (Ogungbeni et. al, 2018). Armeni et al. (2021) speculate that this is because open science is not yet accepted as normative by the wider scientific community. They suggest that open science has not reached the critical mass required to "usher in a wide-scale culture change in academia" (p. 608), citing perceived costs of change and disciplinary differences (p. 609). While it is beyond the scope of this literature review to address all the social, bureaucratic, economic, and political barriers that slow the progress of open science, it is nonetheless important to recognize that these forces are present.

Methods

Ethics clearance for this study was obtained from the UofT Human Research Ethics Board (42380).

Setting and Population

The UofT is a large research-intensive university with three campuses: St. George (downtown Toronto), Mississauga (west of Toronto), and Scarborough (east of Toronto). UofT has 40 libraries (About Us - Quick Facts, n.d.). The institutional setting of this study is UofT and its libraries; however, given the affordance of technology and the constraints imposed by the COVID-19 pandemic, the study was conducted online, and participants' physical locations were not factored into the research design.

Student enrollment for the 2021–2022 academic year was 97,066 across all campuses, including 75,582 undergraduate students and 21,484 graduate students. As of fall 2020, UofT had 15,111 active faculty (excluding 1060 session lecturers, 739 post-doctoral fellows, and 5834 teaching assistants), 9979 staff members, and 168 librarians (About Us - Quick Facts, n.d.). The participants of the study are all affiliated with UofT.

Recruitment

Faculty, graduate students, administrators, and librarians with some involvement with open science were identified by searching department websites for science, technology, engineering, math, and medicine (STEMM) areas for the terms "open science," "open research," and "open access." Researchers who self-identified with these interests in their biography or research summaries were prioritized for invitations to be interviewed. UofT news publications, project web pages, and student journals were then scanned for mentions of open science to identify more participants. Twitter was also searched, using the terms "open science," "open access," and "University of Toronto." Twitter profiles were compared against the UofT websites to confirm institutional affiliation and to gather publicly available email addresses for potential candidates. Librarians in STEMM areas involved in open science projects were identified using snowball sampling. The participants for this study were researchers (including faculty and graduate students), librarians, and administrators affiliated with UofT. A total of 95 individuals were invited to participate in the research project (69 researchers and 26 administrators and librarians). The email invitation is included as Appendix A. Just under half of the invitations were accepted: 45 participants (31 researchers and 14 administrators and librarians) were interviewed.

Data gathering

Semi-structured interviews were used to gather the data for this study. This differs from most of the research about faculty perspectives toward open science, which has been survey-based (e.g., Beaudry et al., 2019; Farran et al., 2020; Saarti et al., 2020; Swiatek et al., 2020). Interviews were chosen to prioritize flexibility and allow for a more nuanced picture of participants' knowledge and perceptions of open science. The interview guide

in Appendix B outlines the topics and questions that were used. These questions were inspired by Beaudry et al.'s (2019) Swinburne Open Science Survey.

From March to October 2022, 45 semi-structured interviews were conducted with faculty members, graduate students, librarians, and administrators. Before each interview was conducted, a signed consent form was required. The length of the interviews varied with an average of 29 minutes. All interviews were hosted and recorded via Zoom. Madelin Burt-D'Agnillo conducted all the interviews. Due to the nature of semi-structured interviews, there were slight variations in the interviews; unique follow-up questions were asked based on participants' answers.

Transcription and De-identification

Interviews were recorded using Zoom and the audio was transcribed using Otter.ai. Anonymization occurred in step with, and following, the transcription of the interviews. Participants were randomly assigned an identification number or letter. Librarians and administrators were assigned letters, while researchers were assigned numbers.

Questions 1, 2 and 10 were removed from the transcripts to reduce the risk of including identifying information. The answers to these questions were administrative rather than informative.

Open Science Practices

The project was informed by a commitment to open science practices. In the context of this study, this commitment translated to ensuring a data management plan was created and followed (see Appendix D). When the anonymization was completed, as a final step before depositing the anonymized transcripts into a data repository, participants were sent their transcript and asked to confirm their satisfaction with the transcript or request further anonymization. All approved transcripts (n=26) were uploaded into Dataverse.

Data Analysis

Data analysis followed a qualitative paradigm with structured coding and thematic development. Coding practices were inspired by ITHAKA S+R's "Coding Refresher" training (Cooper, 2019), with additional guidance from the Template Analysis method (Brooks & King, 2014). The coding process began with each author independently reading three randomly selected transcripts. Each person developed open codes based on their familiarization notes. The authors then met to review the individual codes and collectively chose nine initial, high-level codes. NVivo was used for data analysis. Madelin Burt-D'Agnillo re-coded the three transcripts using the shared codes in the NVivo software. Scope notes were developed to accompany the codes. Most codes were designed deductively and reflected the semi-structured interview questions.

The authors coded the transcripts actively together over the course of several meetings. Each transcript was read, codes were discussed, and authors' consensus determined the codes to be used. During this initial coding phase, several additional codes were added to the codebook. This was a recursive process in which the authors returned to

the transcripts several times to apply new codes. Once the entire data corpus was coded, the authors worked collaboratively to develop topic summaries based on the most common codes. Several similar codes were combined and others were dismissed as irrelevant or unrepresentative. The authors then drafted the key findings from the data analysis process. Each finding required a distinct rhetorical strategy, although with a common emphasis on descriptive language and centering the participants' words.

Results

Participant Demographics and Research Areas

Questions 1 and 2 (see Appendix B) gathered demographic and research/role-related information on participants. Due to faculty appointment crossovers, it was challenging to identify the most prevalent fields for the researchers and faculty. The faculty with the highest participation was the Faculty of Medicine, followed by the Faculty of Applied Science and Engineering, and then the Faculty of Arts and Science. Given the ethical imperative to maintain participants' anonymity, the authors have decided not to list participants' research foci or their areas of expertise. Table 1 highlights the years of experience of the participants.

Table 1

Years of experience of participants

Years of experience	**Researchers (n=31)***	**Other (n=14)@**
>20 years' experience	11	1
10-20 years' experience	11	8
<10 years' experience	9	5

*faculty and graduate students @librarians and administrators

Interview Responses

The remainder of the questions asked of the participants (except for question 10 which was used to identify potential additional interviewees) focused on open science practices. The results that follow are grouped into categories based on the types of responses received. Table 2 shows the groupings of questions by category.

Table 2

Participant responses summary categories

Questions	Category
3. How do you define Open Science?	Definitions of Open Science
4. What is your experience with Open Science practices? How do you interact with them? 5. Where do you learn about Open Science practices?	Learning about Open Science
6. Are there any barriers that prevent you from adopting Open Science practices in your work? Do you experience any of the barriers on this list? (included in Appendix C). What could help you overcome these barriers? 7. Are there barriers that prevent researchers (including students), faculty, librarians, and administrators with whom you work from adopting Open Science practices in their research? List included as Appendix C. What could help them overcome these barriers?	Barriers and Solutions to Practicing Open Science
8. Have you received research support relating to Open Science practices from the University of Toronto Library system? If so, what type of support did you request/receive and at what stage of the research cycle	UofT Supports
9. In your opinion, how important are Open Science initiatives at the University of Toronto?	Importance of Open Science at UofT

Definitions of Open Science

Defining open science is an imprecise art as it is evolving and contextual. It proved impossible to pin down one shared definition that encompassed the wide variety of qualities and criteria that participants offered in their responses. Instead, the findings

are presented as four thematic categories: metaphors for describing open science, values embedded in open science, access to content, and sharing of materials.

Metaphors for Describing Open Science

Participants provided multiple metaphors for open science. The most popular pictorial metaphor was that of an umbrella under which various practices sit. Other descriptive imagery included a basket, a scientific enterprise, an ecosystem of creating and producing knowledge, and a transparency device. Another type of metaphor used was one to demonstrate the active qualities of open science: a movement, a behaviour, a process, and a practice. Participants commonly described open science as tiered, layered, or containing various facets.

Participants also conceptualized open science as a disruption to routine, traditional science: “The promise of open science is there to make science messy again” (Participant O). Participant 50 flagged the effect of open science on traditional thought patterns around the product of research: “for a long time, we thought that the product that we were producing was the research paper. And I think these days, the open science movement recognizes that that's just an advertisement.”

Values Embedded in Open Science

Participants also defined open science in relationship to a set of values. The pursuit of open science was often regarded by participants as moral or righteous. One key value echoed repeatedly throughout the interviews was transparency. Participants widely interpreted “open” science to mean “transparent” science: “For me, open science is really this process of being fully transparent so that people can leverage your research in a much more efficient way so that the whole field can move forward much more quickly” (Participant 21).

Many of the responses focused on how the value of transparency reverberates throughout the scientific workflow, including in methodological decisions, choices around which projects to pursue and which projects to fund, preprints and preregistration, and protocols. It was repeatedly highlighted that transparency and open science are a direct reaction to the failure or (at the very least) the tendency of traditional science to fall short of this level of transparency.

Access to Content

Open science was frequently equated with accessibility. Broadly, “access is available to scientific findings” (Participant 33) with “no barriers in cost, or accessibility in terms of technology” (Participant I). More specifically, participants highlighted the importance of access to “physical materials and data that [are] used as input as well as code that's used to actually generate the results” (Participant 19), to “research findings [open government, open data, and citizen science] that includes data and publications and workflows and code and decision making” (Participant M), and to “ open publishing… so that the results of studies and research are accessible broadly” (Participant S). The last point was not universally embraced as part of the “accessibility” imperative of open

science. Many participants pointed out that open science is more than open access, and others acknowledged that open access does not factor into their definition of open science at all.

Accessibility also showed up in answer to the question “for whom is science open?” Participant 33 shared a fulsome response:

> Open science, to me, means that access is available to scientific findings to everyone, not just scientists, not just professors and not just graduate students. It means that if my grandmother wanted to look up something, she would be able to […] In my view, science is for everybody. It's not for an elite group of people. […] So, I believe science should be available everywhere, anywhere, doesn't matter which country, what institution you belong to, and whether or not you're actively doing scientific research.

When defining open science using accessibility as a guiding principle, participants focused on both what materials are available and for whom these materials are available.

Sharing of Materials

Open science is not simply about access to scientific materials, but also about contributing to the availability of these materials through one’s own research. The following quotes demonstrate the range of types of materials that participants share: “anything from raw data to a failed experiment, to analyses and results, sharing everything openly with no restrictions” (Participant 17); “Our discoveries and our findings and our results, regardless of whether they are positive or negative” (Participant 18); “And then open materials being that you are sharing your stimuli. And all the procedures needed to replicate your experiment. Whether that is pictures, videos, audio files, ideally, code, I think it should become standard practice to share programs and code” (Participant 24).

Learning about Open Science

There are three types of responses observed for this category: the ‘when’ of learning about open science, passive learning versus a more active pursuit of information, and different media for engagement with the topic. Together these findings reveal a diverse educational landscape for learning about and interacting with open science.

The When

When answering a question about where they learn about open science, participants often shared *when* they first learned about it. A common response from participants was that they first learned about open science during graduate school. Participant 59 marked their first “exposure” to open science to their time in grad school over 25 years ago, where they explored open science through an open-source software. On the other hand, some participants struggled to remember when and where they learned about

open science, “Where do I learn about open science practices? It's been so long; I feel like I've always known about them” (Participant A).

Passive versus Active

Another key finding on where people are learning about open science was that participants often learn about it passively, without deliberately (actively) seeking instruction or information. Some described their learning as by osmosis and self-directed navigation. Rather than referencing formal courses or workshops, these descriptions centered on non-formal mechanisms: “it's just a lot of scanning and a lot of asking the key leading colleagues, hey, what's going on? Are you going to any conferences? What have you published?” (Participant O).

Participants are often grappling, alongside their disciplinary colleagues, with why and how to engage with open science:

> [T]here's still a lot of discussion within my own field about: Do I even want to share? Why will I share? What is the incentive structure? But then even once you're to that point, how do you share? What's the format? Is it a general format for all of our subfields? (Participant 51)

Media

There are dozens of sources from which participants learn about open science. The media sources are organized into five types: documentary, events, people, social networks, and organizations.

The first media category is documentary (both textual and audio-based) whereby participants are directly interacting with a public source; the information is not mediated by a human or an event. Some sources include articles, books, blogs, podcasts, magazines, news media, and “surfing the web”. The second type is events, either synchronous or asynchronous. Participants learned about open science by attending an event or series of events, physically, digitally, live, or recorded. These include conferences, workshops, and webinars.

People is the third media type. This group includes specific individuals or general groups of people who have some advanced knowledge about open science, such as colleagues, experts, supervisors, professors, or communities of practice. Social networking, specifically Twitter, is the fourth type of media mentioned. Several participants named Twitter as a space from which they learn about open science. This category is being viewed as distinct from people to highlight the ways in which Twitter facilitates engagement with open science. Participant 47 described their tumultuous relationship with Twitter, while also flagging its importance as a venue for learning about open science:

> I used to say I love-hate relationship. Now it’s a hate-hate relationship with social media and Twitter specifically. I just think it’s a very toxic place at this point. But

> that's where I learned. I mean, it also was a positive place where I learned a lot about the conversations.

The final media category is organizations, which accounts for institutional structures that facilitate learning about open science. Some examples include government initiatives, funding agencies, libraries, consortia, labs, and professional networks. There is no one single route that participants take to learn about open science. One insight is that researchers often have a passive orientation to learning about open science; they do not actively seek out new information about it, but rather, they absorb knowledge about it through non-formal mechanisms. Moreover, learning about how to use open science practices may require different inputs than learning about why to do so.

Barriers and Solutions to Practicing Open Science

This section combines the results from participants' responses to question 6 and 7 of the semi-structured interview guide, which references a list of 19 statements about open science from Swinburne University of Technology's study (Beaudry et al., 2019, p. 27) included as Appendix C. Seventeen of the statements are organized into four thematic groups: Funding and Funders, Culture and Attitude, Infrastructure and Supports, Interest, Expertise and Time (listed in Table 3). The final two statements, "there are no perceived barriers" and "other", are discussed at the end of this section. As part of their responses, participants were asked to propose solutions to the barriers identified. These solutions range from simple and local to more complex and abstract. This section includes existing practices and proposals for new ways of operating, at individual, faculty, discipline, and university levels.

Table 3

Thematic groups and their associated statements (Beaudry et al., 2019)

Funding and Funders	**Culture and Attitude**	**Infrastructure and Supports**	**Interest, Expertise and Time**
1. Lack of funding for open access publishing	2. Lack of credit in my institution for engaging in open science	5. Lack of information about open science practices	10. Lack of time to engage in open science practices
4. Lack of mandates from funders, institutions, or other regulators	3. Lack of recognition in my field about the value of open science practices	6. Lack of professional staff that provide support for open science practices	11. Lack of time to learn open science practices
7. Lack of research funding to support open	13. Researchers are discouraged from engaging in open science	8. Lack of training required to implement	12. Lack of expertise to engage in open science practices

science practices	practices by their colleagues	open science practices	(e.g., assignment of metadata)
	14. Students are discouraged from engaging in open science practices by thesis supervisors	9. Lack of supporting infrastructure (e.g., open data platforms)	16. Researchers don't want to be told how to do their research
	15. The open science community is intimidating		17. Lack of interest from researchers

Funding and Funders

The first thematic group, Funding and Funders, represents funding for open science and open access publishing, and mandates from funders, institutions, and other regulators. Statement 1, Lack of funding for open access publishing, received the most commentary of any statement in the list, perhaps because it is the first statement or because it is a topic that resonates significantly. A barrier to open science is the (disproportionately high) cost involved in publishing open access. Several participants mentioned that the cost of open access publications exceeds their funding, and that article processing charges (APC) waivers are not sufficient to offset these costs. On the other hand, there were participants for whom lack of funding for open access publishing is not a barrier. These participants often indicated that they have access to funding and so they can afford it, even if they are frustrated or turned off by the high cost.

Some participants choose not to pay for open access publishing and instead find other ways to make their work available. Participant 2 shared why this barrier is not an issue for them:

> I kind of prefer journals that have open access naturally, like after six months or a year […] [O]ne of the things I feel I can get around this is that most journals these days allow you to put your stuff in BioRxiv […] So I haven't personally experienced that to be a major challenge.

An obvious solution to the challenge of the high cost of open access publishing is for funders and institutions to offer more consistent and abundant funding streams. Participant 35 articulated some possible mechanisms for this funding:

> More funding, more funding…If the University of Toronto had agreements with every journal we publish to publish open access [then] I don’t need the money. If someone else is paying for it. I don’t need the money to go through me. I would take advantage of that.

Participants also emphasized the importance of funding for students to attend open science conferences and annual open research funding allocations for early career researchers.

There were several ideas shared about improving the accessibility of funding. Participant 55 said they would like to see adjustments that make funding "easily available that wouldn't require a very taxing grant application." Participant 38 offered a unique idea for making funding applications more equitable:

> Funding by lottery is a way to go. Not acceptance by lottery, that would be just foolish, it should be some expert evaluation of the fruits. But when we're deciding what to be researching, what not to be researched, and what sort of project should go forward or not, do it [by] lottery.

The lack of mandates from funders, institutions, or other regulators (Statement 4) did not produce a strong dichotomy in responses. Some participants said that mandates make a "big difference" (Participant 15) and external motivation would encourage more uptake, whereas others cautioned against mandates because "people kind of revolt against some of these things" (Participant 2). Those who supported mandates shared that they are infrequently enforced and therefore toothless.

One proposed solution to the barrier of open science is therefore to implement—and enforce—mandates around open science.

> So, they can make it [that] anything that uses federal funding has to have…basic safeguards in place like power analyses that are actually conducted, replications of your work like you to show evidence [that] you've replicated your work...maybe some evidence that you've taken training. I mean, these are not tough things to do. (Participant 47)

A lack of research funding to support open science practices (Statement 7) strongly resonated with participants. Participants pointed to the need for funding to share data openly, such as the general costs of maintaining open infrastructure.

Participants see a role for funding bodies and institutions to prioritize and support open science. There is a desire for funding agencies to "follow the example of some European funding agencies and be just very explicit" about their commitment to open science, as well as to "defund big publishing" (Participant 22). The messaging behind open science from these agencies and institutions influences the perception of open science for researchers:

> I think messaging is really important. So, the funding agencies obviously have a stake in directing things, but then how that's amplified within our own institution […] has potentially an important role to play in being informative and signaling to researchers that this is valued. (Participant S)

Taken together, these statements show that (lack of) funding and (unenforceable) mandates can be barriers to practicing open science. As a possible solution,

participants would like to see “more investment in [open science] at the institutional level” (Participant F). They are broadly putting responsibility on administrators to coordinate efforts for open science initiatives.

Culture and Attitudes

In contrast to the more tangible variables in the Funders and Funding thematic group, Culture and Attitudes involves a more subjective experience of open science that is specific to each participants’ area of research and peer community. This thematic grouping speaks to the social realities of open science, including issues of credit, recognition, discouragement, and intimidation. Three of the five statements (3, 13, and 15) generated more disagreement than agreement.

Lack of credit in my institution for engaging in open science (Statement 2) is a statement with which many participants identified. Participants shared that they do not receive credit or rewards for practicing open science; this was not only attributed to the UofT but was perceived as an almost “universal truth across global academia” (Participant 15). Participant 62 shared that they only receive credit for part of their open science work, excluding sharing data and code: “All that [the institution] really care[s] about is a peer reviewed publication. And then the publication itself gets cited. They don't care a lot like how you got to that result...They reward the publication but not accompanying products with it.”

Likewise, Participant M shared that librarians who are not utilizing traditional publishing models might not receive credit for their contributions to open science:

> [A] lot of my colleagues are contributing in ways that are like developing tools to support open science and publishing and GitHub. But those don't necessarily make it to their CVs. And it's really just considered like part of their regular work.

A minority of participants disagreed with this statement and shared that they do not think a lack of credit is an issue, either because credit is not an incentive to their practice of open science or because they do not experience a lack of it.

Lack of recognition in my field about the value of open science practices (Statement 3) received equal sentiments of resonance as not. On the resonance side, Participant 50 shared that they have “very much felt” the lack of recognition in their field, especially when it comes to writing code. Participant 21 disagreed and shared that open science has translated to more recognition for them:

> Number three doesn't apply to me, it's actually the opposite. If you're open, you will have much better collaborators, you will have a much better reputation, people will know your work, your work will have greater impact. So, for me, because I'm following the open science practices, I'm actually getting more recognition.

More respondents disagreed with Statement 13, Active discouragement of researchers from engaging in open science practices by their colleagues, than agreed with it. Of

those who agreed with the statement, Participant 11 cited a long history of peer pressure from colleagues: “[T]here is a long tradition, since Galileo, that we should hide our research until we're ready to publish it and be the first to publish it…There is a culture of secrecy and that's very hard to fight.” Those who disagreed felt that in their field or network of colleagues, “there is an encouragement to share” (Participant 38).

Statement 14, students are discouraged from engaging in open science practices by thesis supervisors, is closely related to Statement 13. More participants think that students are discouraged by their supervisors than those who do not. Participant 47 spoke about the difficult position that some students can find themselves in:

> I think there are major impediments for students, and there's a big power differential there. So, if you're a student, you're kind of left in a really tough position: [do] you want to do the right thing […] at least what you think is the right thing? Or do you want to do the thing that will maybe please your advisor and then get your good letter? And then maybe, hopefully, get you a good job?

The open science community is intimidating (Statement 15) generated slightly more disagreement than agreement. Participant 62 noted that, “I refer to it as bro-pen science…because it's predominantly a bunch of dudes out there.” Those who agreed with the statement that the community is intimidating cited social media, namely Twitter, where researchers can be criticized harshly or subjected to public scrutiny because of their work or identity: “[Another] big set of concerns that I hear about is people find the open science community to be off putting, there's a lot of assumed knowledge. Sometimes the atmosphere on Twitter can be not that nice.” (Participant 54)

These unhelpful incidents of public shaming were not condoned by participants. Participant 21 said that there are “extremists everywhere,” including scientists who will “trash everything that’s not completely reproducible.” Even still, they continued, “I feel very intimidated by people who say, I don’t want to share anything. Okay, what’s the deal? Why don’t you want to share? Are you afraid that people [will] scrutinize your work?”

These excerpts show that issues related to Culture and Attitudes may be barriers to open science. However, this group has less coherence compared to the other thematic groups. This finding suggests that Culture and Attitudes are not the most significant barriers to open science. Additionally, the barriers related to Culture and Attitudes require more broad-based culture change.

Participants suggested common practices to stop. Participant 51 suggested that “we should just stop citing people who don’t provide data in code, writ large as a community… I don’t believe your results. If I can’t reproduce what you’ve done”. Participant 15 proposed that “banning data availability statements that say, “[data] available upon reasonable request" would be an amazing blanket rule in general. It just seems like a really crappy excuse to just not do anything.”

Participants also offered new practices that could contribute meaningfully to the culture of open science. Several participants wish to see more opportunities to involve undergraduate and graduate students in open science. To deal with issues of intimidation via unhelpful online public shaming, Participant 62 recommended that public organizations like the Open Science Framework (OSF) have a code of conduct for people who are affiliated with OSF. Participant Q also offered some ideas about how to remedy feelings of intimidation in open science culture:

> I feel like a lot of the intimidation has to do with feeling fraudulent or if one's coming from the humanities, then I think a lot of people from humanities don't like using the word science or data doesn't really resonate with the kind of outputs that they create. So, I would want to find ways to translate that. And to say, yes, like, you actually belong here. […] And maybe, you know, we would create spaces where we just use different kinds of language. Instead of saying open science, maybe we call it open research, that sort of thing.

Participants broadly philosophized on what is necessary to build legitimacy and recognition for open science. A few salient statements that capture this topic well focus on how to solve the problem of time: "It's a matter of...culture. It's a culture change that we need. And it's going to take a lot of time. And a lot of convincing" (Participant 11); "I think we've got 25 years or so to change people's minds. And that's about the time it takes a full generation of scientists to kind of churn through the system" (Participant O).

Infrastructure and Supports

Infrastructure and Supports, the third thematic group, relates to pragmatic conditions for open science by combining barriers that are institutional or informational, including lack of staff and training. Responses to this thematic group show an overall perceived lack of information, professional staff, training, and infrastructure. These statements resonated with most of the respondents.

A lack of information about open science practices (Statement 5) was a statement that over half the respondents felt was indeed a barrier, with lack of knowledge highlighted as one of the reasons for this—both personal knowledge as well as that of colleagues in the same field. Not everyone felt that a lack of information was a barrier. Participant 21 shared, "I don't think that's an issue nowadays. If you're really interested in open science, there are so many good reviews, so many guidelines, so many standards that you could follow that I don't think it's the lack of information." Participant 13 said that they are "on the fence" about this statement, citing the amount of information, not the lack of it, as a barrier. In this case, the abundance of information makes it challenging to parse out what is necessary and valuable.

A lack of professional staff to provide support for open science practices (Statement 6) received more agreement than disagreement. Some examples of areas where staff were lacking are: "explicit knowledge and expertise about open science practices in qualitative inquiry" (Participant 13); "expertise in transparency and reproducibility of data sets" (Participant 21); and "intimate knowledge of some of the technology tools that can

be used to support those open science practices" (Participant R). Participants who agreed with this statement were often emphatic about it. Fewer participants said this was not a barrier for them. Participant 19 said: "Uploading your papers to BioRxiv is very easy. Uploading your code to GitHub [too]. So, I think there isn't any technological barriers we need to overcome."

There is a strong desire for more practical, self-service guidance and resources to support open science practices. Participant 31 stated, "we don't need an administrator, we need the resources to do these things. And so, I would not like to see a Vice Dean for open science, I'd like to see resources and support for open science." To this point, Participant J would also like to see a tool to support researchers with the self-archiving process:

> So, if they kind of go through and answer various questions like a choose your own adventure sort of thing, that would then point them to the correct course of action around making their research open access, whether that's self-archiving the manuscript after an embargo period, or whether that's paying the APC charge, and how they're going to go about doing that.

Statement 8, a lack of training required to implement open science practices, had strong agreement from participants. Participant 18 spoke about the value of training in their own experience and hypothesized that without it their practice of open science would be more limited, "Training is a big one. Because, again, I saw how it actually made it smoother for me to start adopting the practice. And so, if I didn't have that, maybe I would be hesitant, and I wouldn't feel confident to start."

One barrier that was identified is the limited scope of trainings, especially those that are offered by the libraries. "[I]t's not for the lack of trying that the library offers training. But the library can't reach everybody. We've got 100,000 people among three campuses… and not everybody wants to come to the library" (Participant Q). This finding brings to light the reality that several trainings and venues for training exist, but that the barriers of time and capacity may be a limiting factor to accessing this training.

Training and education about open science emerged as a key proposed solution. Participants offered several media through which this training could occur, such as seminars and workshops. Participant 24 spoke about the need for skills training for students of all levels at the university, "as part of the PhD program, or master's program […] or even like, ideally undergrad program, there should be a full course on, like data management for science."

Participant 50 called for the creation of on-ramps to help people get started with open science practices:

> And what we now need is to think about really creating on-ramps. So that people can sort of get on board with open science practices, especially reproducibility as easily as possible and not feeling that it's an intimidating aspect. So, some small things are integrating it just into teaching. So, it's just a normal part of your

> practice that you write the code and then you put it up online. Another aspect is sharing code just with one or two people and then gradually increasing that to the public.

The final statement in this section, a lack of supporting infrastructure (Statement 9), prompted similar levels of agreement as disagreement. For some fields infrastructure is a "solved problem" (Participant 19), whereas in other fields, there are not yet solutions for sharing open data. One problem is the sustainability of open data, "The big problem is storage. Where to put it, how to maintain the fact that it's findable and accessible…Every two months…the amount of storage just continuously goes up." (Participant 51)

Predictably, participants conceived of infrastructure in various ways. For example, Participant 62 felt that at UofT, "we are lucky to have good overall infrastructure. I would include not just open data platforms, but just good Wi-Fi is incredibly important when you're trying to share data, download data and just find it." There are many ways in which infrastructure is specific to the research field, institution, and practice. Sufficient infrastructure is a prerequisite for open science. Participant 19 articulated the importance of having this infrastructure in all disciplines:

> For a while, in my field 15 years ago, it wasn't really possible to share your data because there wasn't a website or repository to share your data and any place that could digest large amounts of data. Obviously, you can't mandate people to share the data if there is no place for it.

Interest, Expertise and Time

The final thematic group focuses on an individuals' time, expertise, and interest in open science practices—or their perception of these qualities in other people. These potential barriers are mostly related to an individual researcher's personal capacity and competencies, although some systemic barriers may exist across disciplines and roles. The responses from the interviews show a subtle trend toward agreement with the statements, except for Statement 16 (researchers don't want to be told how to do their research), which generated more disagreement than agreement.

The first two statements, lack of time to engage (Statement 10) and lack of time to learn (Statement 11), were often linked together in respondents' answers. Interestingly, participants disagree about whether open science is a time-consuming activity; for Participant 13, there is an "absolutely huge lack of time, big, big lack of time," whereas for Participant 19, open science practices integrate more seamlessly into their workflows and therefore it "doesn't take a lot of time." Participant 50 pondered how much time researchers can spend on open science practices: "academics spend 70% of their time teaching, and then 50% of the time doing research, and then 30% of the time doing admin, and 20% of the time, they're overseeing their students. I don't know, there's no place [to] give them more time."

Lack of time was also associated with other incentive structures in the academic system. “People are on crazy deadlines all the time in such a high-pressure job that […] it means that tasks that are considered lower value are going to be cut. For a lot of people that is open science.” (Participant 15)

Some participants had quite rigid thoughts on the question of time and open science, stating that “lack of time” is not a valid excuse for not practicing open science. Participant 21 felt that “lack of time is a question of priority. For me, it's number one […] I live it. It's very pervasive in everything I do. So, I don't really allocate time for open science…this is part of my scientific process.”

Lack of time to learn open science practices (Statement 11), like lack of time to engage, was deemed a barrier for many participants. Participant M, a librarian, highlighted the lack of time to learn about open science practices across a range of disciplines. Perhaps this is less of a challenge for faculty members, who may focus on learning about open science as it relates to their own discipline.

Statement 12, lack of expertise to engage in open science practice, is flagged as a barrier more often than not. The experience of “lacking expertise” was familiar for Participant I: “I don't know if this is typical librarian, but I feel I always lack expertise. I feel like I should be learning more and then maybe learning more by doing; so, taking part in other open science initiatives across campus to learn a little bit more.” Fewer participants said that expertise was not a barrier to their open science practice, as in the case of Participant 38: “In our field, open science is itself so open and so all over the place that I'm not sure if you really need that much expertise to do that. But maybe more fundamental fields, they do need that.”

Researchers do not want to be told how to do their research (Statement 16) is the only statement in this thematic group that has more disagreement than agreement. This statement is provocative and a variety of interpretations surfaced on the subject. Several librarians shared personal anecdotes about this experience in their work. Participant A, for example, acknowledged that this sometimes comes up during instructional presentations: “whenever [there is] any sort of mandate or any sort of commitment, there tends to be pushback, even if researchers themselves would voluntarily commit to certain things, they just don't like to be committed to those things.” Participants also responded to this prompt by noting that this is “more of a personality issue” (Participant O) when there are “egos at play” (Participant Q), rather than an actual barrier to the pursuit of open science. Likewise, even when participants agreed that they did not want to be told how to do their research, they did not perceive this as a reason not to practice open science. Participant 38 summarized it as follows: “researchers don't want to be told how to do the research. Generally, this is the case, but I don't think it's an impediment for open science. I mean, not many people like to be told what to do.”

Lack of interest from researchers (Statement 17) is another example with almost equal agreement and disagreement from the participants. Several participants pointed to specific conditions that might make open science practice unappealing to researchers;

others just stated plainly that “some people don’t care” (Participant 21) and “some people are legitimately not interested” (Participant 51). There were also participants for whom “lack of interest” did not resonate: “I think researchers are interested because it makes their research much more visible” (Participant 58).

As a whole, this thematic group focused most acutely on an individual researcher’s attunement to open science; thus, it is challenging to draw overarching conclusions. A resounding solution to the final thematic group comes in the form of incentives and disincentives. Participant 10 explained: “So, I feel like incentive is a huge thing […] [I]f an institution actively rewards open science practices, I can see that being a major move in the right direction.” Examples of possible incentives that participants envisioned are scholarships or grants that are only available because of researchers’ implementation of open science principles, as well as promoting research that applies open science principles in the university’s public media.

Other participants hypothesized that acknowledging open science as part of one’s annual activity reports (Participant A) or CV (Participant 55) would be advantageous. Participant 31 suggested that open science should be considered a service contribution in lieu of other commitments. Some participants offered that engagement with open science practices could become part of the evaluation, tenure and promotion criteria (Participant 22).

While there are barriers to open science, there are also many thoughtful suggestions for how to approach these barriers productively. Participants want to see solutions to open science that make it easier to practice, and they want to see more incentives that are as painless as possible to access. They see a role for several actors to contribute to these solutions: government, funding agencies, institutions, and individual researchers, librarians, and administrators. At the end of the day, these suggestions came from a place of practicality; as Participant 31 succinctly stated, “[w]e need some kind of harmonization between the idea of open science as a priority and how you actually go about implementing [it].”

“I do not perceive any barriers”

A minority of the participants chose Statement 18, I do not perceive any barriers. Participant 25 identified that some of the statements on the list could impact other researchers but that they personally have been well-supported by their supervisor:

> So, if I'm answering as a PhD candidate, I would say that I do not perceive any barriers. My supervisor has always been super supportive. As I've mentioned, publishing open access sometimes comes with additional costs. And he's always been happy to provide funding for those and he's always encouraged me to follow my quote unquote "open science dream."

Participant 14 challenged the premise that any of the statements were barriers, suggesting instead that the statements are all things that researchers encounter but that they should not be considered barriers.

> None of them are. All of them are excuses. None of them are barriers unless you want them to be barriers. […] So, none of this is stopping you. These are all reasons that you can put up as because you're a wimp, and you don't want to do it.

When they were initially asked the question, Participant 10 responded that "there are no barriers." But then when they reviewed the list, they noticed that there might be barriers that exist for other disciplines: "I think my initial reaction when you asked me that question is almost closer to 18, that I don't see any barriers. But just from reading this list, I'm aware that obviously, I don't know everything about open science."

Participants did not universally acknowledge all 19 statements as barriers, although overall the statements received more agreement than disagreement. This reinforces the belief that these statements are indeed barriers for some individuals.

Other Barriers

Participants provided several insightful additions to the list of statements. These additional statements represent individual as well as collective struggles that prevent researchers from practicing open science. Seven areas were noted during analysis as potential barriers. These have been organized alphabetically.

Collaborations & Collaborators

A barrier to open science may appear in the form of collaborations with individuals who work on the research and who are not comfortable or willing to practice open science. While a researcher may be fully committed to practicing open science, their collaborators may be unwilling to engage in the same ways. This barrier was identified by several participants, many of whom work in multi-lab collaborations and with "people [who] are doing great science" and "people who are doing very niche stuff" (Participant 15) but who do not practice open science. Participant 49 explained that generally the individuals with whom they work are not philosophically opposed to open access publications, it just is often not their highest priority. In these cases, Participant 49 may take on additional roles in the project, such as the assignment of metadata, instead of a corresponding author who may not see the value in that piece of the project.

Competitive Culture of Academia

Participants named the culture and structure of academia as a barrier to pursuing open science. This barrier has some relationship to the second thematic group discussed above, which deals with issues of credit, recognition, discouragement, and intimidation, but differs in that it draws attention to the competitive culture of academia. Several participants spoke about the pressures of academic life: to produce novel research (which funding agencies and prestigious journals prioritize), to publish in high impact journals (which do not have open science practices), and to navigate better or faster research outputs.

Another way that the culture of academia shows up is in the interpersonal relationships: participants named power dynamics between professors and their trainees, as well as gatekeepers in the field who are not promoting open science. In one case, Participant 35 noted that the inverse of Statement 14 (students are discouraged from engaging in open science practices by thesis supervisors) can also be a barrier:

> [S]tudents don't want to engage in open science, contrary to the desire of their supervisors […] The students are really afraid of being scooped. And it's hard to convince them that even if you're the second to show something, that paper is still going to be broadly cited. And it's very often [common] for important findings to see two [or] three papers cited together. Right, but I think [that] some trainees want to protect their work or feel like they protect their work better if they don't show [it] too broadly.

In this example, the high-pressure environment of academia deterred a student from pursuing open science, despite their supervisor's encouragement to share their findings openly. Taken together, there are competitive realities of academia which act as barriers for open science.

Different Approaches to Research and Research Data

Open science may be complicated by differences in disciplinary or methodological orientation to research data. For instance, qualitative researchers in this study often named the complexity of conducting open science within their work. Some open science practices, such as preregistration and open data, have different implications for qualitative researchers. Participant 13 spoke about the messiness of open data in the form of transcripts when working with sensitive data and highly identifiable research populations:

> So, one of the issues that we've wrestled with in our work is that by asking for that consent to have the data stored, and made open at the beginning of the study, there's one concern that people might not share the same things if they know that that's sort of a condition of their participation in the study. […] Yeah, so and then there's other issues around the de-identification of data and how that kind of decontextualizes and maybe strips away too much information where we then don't understand enough to engage in a robust secondary analysis.

Another consideration is that researchers' methodological orientation may produce a strong sense of ownership over the data and they may be unwilling to share it openly. Thus, the data generated in a project as well as a researcher's relationship to it may pose barriers to being shared openly.

Industry and Employer Considerations

Another barrier that prevents researchers from engaging with open science is their (actual or potential) relationship with industry partners. Participants stated that industry partners are less likely to support open science; instead, there may be a push toward intellectual property and generating revenue based on scientific discoveries. Participant

48, a self-described “information anarchist,” spoke about the impossibility of finding consulting work in their field because of the incompatibility of open science and intellectual property. Participant 2 also spoke about the challenge of working with company partners, many of which are concerned with getting a “return on investment” for their funding. This researcher shared that the industry consideration is front of mind for their students as well.

Participant 21 spoke about the pressure to generate revenue from academic institutions:

> Institutions, they’re a bit ambivalent right now. Because they want you to be open. They know it’s good for science, but...they don’t want to take any risk. But it’s funny. Now, they also want you to commercialize stuff, they want you to generate revenue based on your discovery. So, on one hand, they tell you, "be open and transparent". And I’ll get on the other side, they tell you, “You know what, if there is potential for revenue, maybe you should protect your IP.”

Therefore, just as there are barriers that may occur because of collaborations between researchers with different approaches to science, there are barriers attributed to researchers, industry partners, and employers.

Inequities Between Countries and Institutions

There are systemic, structural barriers which make open science inequitable. Participants who raised this barrier were often referencing others’ experiences, rather than speaking from their own personal experience.

Participant 51 spoke about the inequities that result in different institutions’ funding budgets:

> [T]here’s an issue in science around equity, and there are a lot of different cuts to equity and none of them should be minimized…If you consider an institution like the University of Toronto: I buy a million-dollar [tool]. That’s what you do at a place like UofT, there is money, right? What if I’m not at a tier one university? What are my opportunities to interact with the scientific method? I could be brilliant. Lots of brilliant people end up at different schools for a lot of different reasons.

Participant 62 extended this to address the ways in which open science can perpetuate systemic barriers between countries:

> North America and Europe, where we just do our science in one way. And then people from South America, Africa, and Asia are just supposed to somehow fit their way in. And like we go down to where they do research, we do our parachute science, we come back, we don’t actually form lasting collaborations. So, efforts, some of them are more reluctant to even share their data, because people just use their data rather than actually forging the collaborations that they would rather have and they need.

The scale of these barriers is beyond the scope of any one academic institution, but they expose the dynamics of open science and the geopolitical and economic factors which influence its uptake.

Reputational Issues

While open science has a strong, positive reputation within the community of researchers involved in this project, reputational issues are still present. Concerns about the quality of an open access journal, open textbook, or open-source product were named by several participants. Participant 25 summarized by saying that some low-quality open access journals may give "open access in general a bit of a bad rap." Likewise, Participant 27 pondered that open access textbooks may have a stigma associated with them: "[M]aybe there [are] arguments [that] this is not the most recent, most peer reviewed way of creating resources for students." As these two participants have identified, a barrier to open science may be the perception that open access publications or textbooks involves a "trade-off" between openness and prestige.

Risk

The final other barrier identified by participants is the risks that are involved with open science. These risks include the risk of using an open-source software in place of a proprietary, commercial one. Participant 59 identifies that there are both reputational pros and operational cons to adopting open-source software.

> [F]or an organization, for an institution: What risks do they run in adopting open science into their day-to-day operation? […] That's adopting an open source, open science, open source, open approach to stuff, [it] reduces costs, but there's an inherent risk to an operation by doing that, because sustainability maintenance, all that sort of stuff, right? So, there's an institutional reputational risk. So, I think that's one, probably a bit of a reluctance operationally to bring some of the open science or open-source approaches into general practice.

One of the main barriers that can prevent open research is a researcher's commitment to privacy and confidentiality. This is inherent in all types of research but is especially relevant when dealing with personally identifiable information. Participant 21 spoke about the challenge of institutions which do not want to take risks and highlights the pros and cons of data sharing, as well as the risks of closed versus open science.

> It's much harder to quantify the risk of not sharing the data. Imagine that nobody shares data anymore. The science will be so slow, we won't be able to make any progress any breakthroughs. We're going to publish papers, nobody can check. So, it's going to be false leads everywhere. Right? How do you quantify that? How do you quantify the lack, the bad consequences, the adverse side effects of not sharing? Nobody can really do that easily.

These additional barriers suggested by participants further highlight the obstacles and opportunities within the open science community.

UofT Supports

This section summarizes the responses to question 8 of the semi-structured interview guide. This is one of the questions that was modified depending on the role of the participants (Appendix B). Responses are first listed by types of supports named and then evaluations of these resources are presented.

Library Services and Librarians' Offerings

The UofT librarians offer support throughout the research lifecycle. Participant M succinctly outlined some of these moments highlighting several possible areas of support from the libraries, both direct and indirect:

> [Start of project] So, if you're starting a project and you require data for your research, you can start with some of our repositories - to search and discover and explore and download to do your analysis and your research.
>
> [Mid-project] [H]elping researchers to create data management plans, helping researchers to select and find data that's most appropriate, all the way through to thinking about digital preservation and how best to structure and organize and, and preserve your research data for the long term.
>
> [Conclusion of project] We have a data repository for research data where you can deposit your research data and share it with your collaborators or your research team, and it supports versioning of datasets and files. It supports collaboration, you can add individuals to view or download your data …we offer a DOI to mint with your dataset that you can share in your publication or cite your data from your website and things like that.

The first area of support for open science from the library is what might be considered "direct support," whereby a researcher or student consults with a librarian for guidance on a topic related to their open science practice. This support may be one-off or more enduring, as in Participant 27's comment: "[it's a] never ending collaboration until they tell me they're sick of me." Participant E, a librarian, spoke about their role consulting on digital projects and specifically how it applies to open science: "[I]f we want that data to persist, we have to think about ensuring it's in a format that is portable, and durable…[T]o me, those are at the core kind of open science issues, data sharing issues." Other examples of topics about which participants seek consultation with librarians include archiving and licensing queries, copyright and permission queries, and support with Open Journal Systems.

A second type of assistance for open science is more "behind the scenes" support, whereby librarians and libraries are contributing to the background needs of open science practices. One example can be found in publishing and specifically "transformative agreements" with publishers. Participant F shared that they view their role as being a "middle" person between researchers and publishers:

> The role now seems to become sort of validating a researcher's institutional affiliation, helping that researcher prove to the publisher that they do, in fact, work at a university so that they're eligible for the privileges that we've negotiated for them. And then taking these agreements and then assessing them and seeing which ones are popular, or not, or seeing which ones are working or not, and then on behalf of our researchers negotiating them again, renewing them or not, or getting more.

Despite the indirect—and potentially obscured—support offered by librarians, researchers and students still recognize it exists through open access discounts, sponsorship for an open scholarly monograph program, and skills training.

Many participants highly value librarians' expertise in the open science domain and that the assistance is available through a neutral campus entity, "Because the library is a central place, there is no factional warfare between departments and the library." (Participant 50)

However, not all librarian support is well received or appropriate to the audience.

> Yeah, maybe last year or the year before there was this university or university library mandated training for how to do open science and it was useless. Yeah, it was short. It was done by people who have never done research. And it was all just very obviously paying lip service. (Participant 48)

Some researchers and students have little awareness or interest in engaging with open science practices from the libraries. Several participants confirmed this in their personal experience or their impression of others' experience.

Some participants heavily engage with UofT support resources for open science, and others have no engagement—or awareness of such resources—at all. This spectrum of engagement may be indicative of different support needs of participants, and it may point to directions in which the UofT system can expand its reach.

Importance of Open Science at the University of Toronto

Given the subjective nature of interview question 9, "In your opinion, how important are open science initiatives at the University of Toronto?," it is not surprising that participants interpreted it in multiple ways. Responses addressed the questions as how important is open science to the university compared to other institutions, as well as how important is open science compared to other priorities within the institution. Despite the various interpretations of the question, there are some patterns of meaning that can be gleaned from the responses.

There is a nearly universal acknowledgement that open science is important and that institutional actions ought to reflect that. Several participants mentioned that the UofT has the potential to lead or set precedents regarding open science because of its size, scope, and global presence:

> COVID is a great example. Where all of these different research labs we're working openly with labs across the world, in different groups to be able to come up with therapies, or research before it was published in peer reviewed journals and share that data openly so that we can really come together to fight this pandemic. (Participant 17)

> And so UofT being like the Juggernaut it is, or the having the oomph that is like, you know, if it can get behind promoting this shift in thinking about sharing, basically, it's actually encouraging people to share, right, then I think it is really important because it's a big culture shift. And I think it's really important to have like a really large research institution, like UofT get behind it, because I suspect that some of the most challenging barriers would be found at UofT…I would say, in fact, like, smaller institutions are more nimble. (Participant Q)

The hypothetical or idealistic vision of open science at the university clashed in some cases with opinions of how things actually are. Several participants took the position that open science is not valued at the institution, either declaring that the administration does not care about open science, that they are unaware of any initiatives in this domain, or that open science at the university is only "important" for its reputation: "My cynical take is that open science initiatives are only important at UofT such that they serve the interests of a certain perspective on what UofT is" (Participant F).

There were also individuals who responded that the UofT highly values open science initiatives, as evidenced by various initiatives at the institution. Participant 33 points out UofT's institutional repository as an example—"UofT likes open science. And we're encouraged to put everything in an open UofT repository after publication"—while Participant M focuses on institutional strategy: "And I do see a commitment to improving open science initiatives. And the university is taking this Tri Agency Research Data Management and Digital Research institutional strategy very, very seriously." Most participants expressed a lack of clarity from the UofT on the institutional evaluation of open science practices. There was a tentative acknowledgement that UofT values open science, but the degree to which it does was uncertain.

This final topic summary does not demonstrate a resounding or affirmative answer to the question of the importance of open science at the UofT. From the vantage point of the participants in this study, open science initiatives at the UofT are absent but necessary or present but insufficient and there is no overall agreement or sense of whether the UofT places value in these practices.

Discussion

The use of semi-structured for this study is a departure from previous studies of open science at academic institutions (e.g., Beaudry et al., 2019; Farran et al., 2020; Saarti et al., 2020; Swiatek et al., 2020). There are strengths and challenges to this method. A significant advantage is that it facilitated generative conversations, which yielded a rich data corpus; it enabled each interview to go slightly "off script" and allowed the interviewer and participant to build trust and rapport. The choice of method also generated logistical challenges in the recruitment and data gathering process, as well as during data analysis and data sharing. It was a challenge to capture the unique perspectives of so many participants, and therefore some excellent ideas were cut from the results. Another challenge relates to the anonymization process, which was time-consuming and imperfect. Maintaining participant's confidentiality while also striving to create an open data set of interview transcripts proved to be difficult. There are significant challenges associated with qualitative open data, both ethically and because it is highly resource-intensive (Tamminen et al., 2021). Participants were informed of the intention to anonymize and share their transcripts. Procedurally, the authors determined that an opt-in process for depositing the transcripts would be appropriate; this reduced the number of final transcripts in the open repository significantly. Twenty-six were deposited on September 28, 2023.

This project's findings are limited in terms of generalizability due to the demographics and breadth of participation. Because of the exploratory nature of the project, the authors did not aim for saturation in the data gathering phase. Instead, data gathering was restricted by the selected recruitment tactics and time. This means that there are individuals who were not invited to participate in the project and for whom this project may have been of interest. Likewise, the authors determined that a criterion for participation is that participants must be engaged with open science in some way; this limited the findings of this report to those who have knowledge and experience with open science. In this regard it is not representative of the broader research landscape at the university.

Finally, the authors did not collect data about participants' race, gender, or other identities. While some important and critical questions emerged about identity and its intersections with open science, this project is unable to report on these findings. Thus, this project evades some critical questions that underpin the nature of open science, including geopolitics of academic knowledge, gender and race dimensions, and access to scientific literacy. There are ethical and equity considerations about which this project barely scratched the surface. These limitations identify the scope of the project and point to other facets of open science that are worth engaging with critically.

The core finding of this study is that there is no singular manifestation of open science at the UofT. Instead, the qualitative findings reflect a diversity of opinions, practices, and relationships to open science. This complexity is made more obvious by the fact that there is not a single definition of what constitutes open science: it means something different to each participant of this project. This diversity reflects the individual experience and disciplinary differences. Indeed, an insight that this project brought

forward is that participants' experience of open science is deeply tied to their discipline's conventions and investment in open science adoption. This is consistent with the lack of a singular definition in the literature (Chan, 2019; Bosman & Kramer, 2017). This schism is most apparent between the sciences and social sciences, but it also manifests at the level of departments and labs.

The sentiments that drive engagement with open science are similar across the participant population. On the one hand, participants often feel frustrated with the status quo within their scientific or scholarly community: the reproducibility crisis, the lack of transparency, the "publish or perish" mentality, and the wastefulness of siloed research were echoed throughout this project. Participants see open science practices as a positive solution to these concerns. On the other hand, participants feel hopeful that open science can facilitate changes that they wish to see: a higher level of productivity, more value out of research dollar investments, more access to scientific discoveries, and robust learnings about society.

Conclusion

This project is the first study of its kind in Canada, and therefore provides a significant contribution to the literature. It is also timely, given the recent federal mandates and commitments to open science. These findings may be helpful for libraries as they can inform their services and knowledge about open science within their own communities. Further research in this domain could expand the reach to individuals who are not engaged with open science; this may present further insights into the barriers to open science. Future research may also rely on methods that yield quantitative findings, such that local data can be compared against other institutions. For open science practices and scholarship to maintain longevity, there must be systemic changes to adopt open science activities. With all of this in mind, the UofT is well-positioned to guide the transition and harness open science principles moving into the future.

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Appendix A: Invitation Template

Email Subject: “Invitation: Current Open Science Practices at UofT”

Dear [Invitee’s name],

My name is Madelin Burt-D'Agnillo. I am a student in the Faculty of Information and a Library Intern (TALint). Together with my supervisor, Mindy Thuna, the Associate Chief Librarian for Science Research & Information, I’m conducting a research project about Open Science Practices at the University of Toronto.

We identified you as a [researcher/student/librarian/staff person] who is engaging with Open Science practices at the University of Toronto, and we would like to invite you to participate in our project.

If you accept this invitation, you will be interviewed by a member of the research team via Zoom. The interview will be recorded. The approximate time commitment is 45 minutes or less.

This research project has been approved by the Human Research & Ethics Unit (HREU) at the University of Toronto. You’ll find attached to this email the informed consent form. Please also direct any questions to me or Mindy Thuna (cc’d) via email.

If you are interested in participating, please respond to this email by [date].

Kindly,

Madelin Burt-D’Agnillo and Mindy Thuna

Appendix B: Semi-structured interview questions

Researcher Questions:

1. Which faculty or faculties are you part of? What is your research focus?
2. How many years have you been working as a researcher in an academic setting?
3. How do you define Open Science?
4. What is your experience with Open Science practices? How do you interact with them?
5. Where do you learn about Open Science practices?
6. Are there any barriers that prevent you from adopting Open Science practices in your work?
    a. Do you experience any of the barriers on this list? [Interviewer will share the list of barriers on page 2]
    b. What could help you overcome these barriers?

7. Are there barriers that prevent researchers (including students), faculty, librarians, and administrators in your discipline from adopting Open Science practices in their research?
    a. [Interviewee can reference the list of barriers on page 2]
    b. What could help them overcome these barriers?
8. Have you received research support relating to Open Science practices from the University of Toronto Library system?
    a. If so, what type of support did you request/receive and at what stage of the research cycle?
9. In your opinion, how important are Open Science initiatives at the University of Toronto?
10. Who else do you recommend that I speak with about Open Science at the university?

Librarians & Administrators Questions:

Three questions were modified for these participants – 1, 2 and 8. The rest were identical.

1. Which library/unit are you part of? What is your role?
2. How many years have you been an academic librarian/ administrator?
8. Do you offer research support relating to Open Science practices?
    a. If so, what type of support do you offer and at what stage of the research cycle?

Appendix C: List of Statements from Beaudry et al., 2019

Here is a list of barriers articulated in a faculty survey conducted in Australia. Do any of these barriers resonate with you?

1. Lack of funding for open access publishing
2. Lack of credit in my institution for engaging in open science
3. Lack of recognition in my field about the value of open science practices
4. Lack of mandates from funders, institutions or other regulators
5. Lack of information about open science practices
6. Lack of professional staff that provide support for open science practices
7. Lack of research funding to support open science practices
8. Lack of training required to implement open science practices
9. Lack of supporting infrastructure (e.g., open data platforms)
10. Lack of time to engage in open science practices
11. Lack of time to learn open science practices
12. Lack of expertise to engage in open science practices (e.g., assignment of metadata)
13. Researchers are discouraged from engaging in open science practices by their colleagues
14. Students are discouraged from engaging in open science practices by thesis supervisors

15. The open science community is intimidating
16. Researchers don't want to be told how to do their research
17. Lack of interest from researchers
18. I do not perceive any barriers
19. Other

Appendix D: Data Management Plan

Data Collection

Describe the type(s) of data that you will collect, including all survey, interview and/or focus group data. If there are any additional types of data that will be collected or generated describe these as well.

The primary form of data collected in this project will be interview video recording and transcripts, based on researchers' interviews with participants. Additional data will include:

- Participant's contact information (email and/or phone number) to facilitate communication
- Signed consent forms

It is important to identify and understand as early as possible the methods which you will employ in collecting your data to ensure that they will support your needs, including supporting the secure collection of sensitive data if applicable.

Describe the method(s) that you will use to collect your data.

Zoom may collect some personal data, which will not be retained by the researchers. Zoom's privacy policy is available here: https://explore.zoom.us/en/privacy/

Otter.ai will be used to transcribe the interviews. Otter.ai's privacy policy is available here: https://blog.otter.ai/privacy-policy/

If interview and/or focus group audio recordings will be transcribed, describe how this will securely occur, including if it will be performed internally to the research team or externally (outsourced), and/or if any software and/or electronic platforms or services will be used for transcribing.

Transcription will be performed internally by members of the research team using Otter.ai.

Describe how your data will be securely transferred, including from data collection devices/platforms and, if applicable, to/from transcriptionists.

Data will be transferred between Zoom (i.e. videos) and Otter.ai (i.e. transcription) and stored on OneDrive. We will not transfer data between researchers via email, but rather save and share them through OneDrive

Describe all of the file formats that your data will exist in, including for the various versions of both survey and qualitative interview/focus group data. Will these formats allow for data re-use, sharing and long-term access to the data?

- contact information stored in Excel (CSV)
- scanned copies of consent forms (PDF)
- video files (MP4)
- transcripts (RTF or .docx)

Documentation and Metadata

Describe any documentation and metadata that will be used in order to ensure that data are able to be read and understood both during the active phases of the project and in the future.

- Anonymized transcripts will require a legend for researchers to reference, which will be kept on the researchers' personal computer in a password-protected file.

Storage, Access, and Backup

Describe where, how, and for how long data will be securely stored during the active phases of the research project. If any data are to be collected through the use of electronic platforms, account for their usage within your data storage description. Include a description of any policies and procedures that will be in place to ensure that data are regularly backed-up.

Project data will be stored on individual computers for daily workflow, backed up on a cloud-based server (OneDrive), and housed on servers at the University of Toronto

Due to the cloud-based server, there will not be any procedures for backing up data to physical storage devices.

The research team will retain the data for 3 years post conclusion of the data collection period to ensure there is sufficient time to complete coding and analysis of said data and reporting/publication of results of the study.

Anonymization practices for confidential and sensitive data will be in accordance with the University of Toronto's Research Ethics Board Data (REB) Security Policies.

Final anonymized data will be stored in an open access data repository

Anonymized data generated through the project may be shared with the University of Toronto Libraries executive and other institutional actors.

Describe how members of the research team will securely access and work with data during the active phases of the research project.

Researchers will have access to a OneDrive folder.

Preservation

Describe where you will preserve your data for long-term preservation, including any research data repositories that you may be considering to use. If there are any costs associated with the preservation of your data, include those details.

We are considering the use of University of Toronto's Institutional Repository or Dataverse for data storage.

Sharing and Reuse

Describe what data you will be sharing, including which version(s) (e.g., raw, processed, analyzed) and in what format(s).

Processed and anonymized data (transcripts) will be shared with the Data Repository. The final data will be shared as PDF files.

Responsibilities and Resources

Who will be responsible for data management during the project (i.e., during collection, processing, analysis, documentation)? Identify staff and organizational roles and their responsibilities for carrying out the data management plan (DMP), including time allocations and training requirements.

Madelin Burt-D'Agnillo will be responsible for the data during collection, processing, analysis, and documentation.