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## Partnering for Success: A Reproducibility Workshop Series for Biomedical Researchers

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### NUTRITION INFORMATION

While the ability to reproduce scholarly research findings has always been a core component of research practice, several recent studies have shown that much of the scientific research currently being published cannot be reproduced (Collaboration, 2015; Ioannidis, 2005; Jarvis & Williams, 2016). The problem is especially dangerous in the biomedical sciences, where research results are used to inform the design of new drugs as well as policy and regulations that directly impact human health. To address this issue, the Library at the University of California, San Francisco (UCSF) collaborated with the Graduate Division and the Open Science Group (a multi-stakeholder campus organization dedicated to promoting open science concepts and tools) to host a credit-bearing workshop series designed to give learners a solid foundation in reproducible research practices and to satisfy the National Institutes of Health's (NIH) Rigor and Reproducibility training requirements. The series, which took place in the fall of 2019, was targeted at UCSF graduate students and postdoctoral scholars (postdocs) and incorporated hands-on and interactive exercises as well as actionable steps for learners to take back with them to their respective research environments. The

eight workshops consisted of an introduction to reproducibility, rigorous experimental design, open publishing, open protocols, open code, open peer review, open data, and building a reproducible lab. Three of the workshops were taught by UCSF staff and the rest were led by open science experts from the San Francisco Bay Area and Boston. In this recipe, we summarize the results of this series and recommend steps for librarians who wish to build a similar program at their institution.

### LEARNING OUTCOMES

The overall goal of a research reproducibility series is to increase the research community's understanding of and practice of reproducible research, stimulate conversations about open science and research reproducibility, and build an open curriculum that can be replicated by other institutions. The students and researchers who attend the series should come away with both a theoretical understanding of reproducibility and practical strategies to improve the reproducibility of their work. Specifically, attendees will be able to do the following:

- Define reproducibility in the context of biomedical research.
- Describe the significance of practicing reproducible and open science.

- Identify existing practices and behaviors that require modification in order to improve reproducibility.
- Apply a range of new tools, strategies, and best practices to make their research more rigorous and reproducible.

### NUMBER SERVED

This workshop series is recommended for a cohort of approximately 45 graduate students and postdocs. At UCSF, we targeted two distinct audiences: a cohort of biomedical graduate students and postdocs that needed to attend six of the eight workshops in order to meet NIH Rigor and Reproducibility training requirements and general members of the UCSF community (including students, faculty, and staff). The NIH cohort was given priority and asked to register in advance for the series through the Graduate Division and to fill out required pre- and post-workshop assessments. At UCSF, 24 of the 49 learners who registered for the series successfully attended the required number of workshops and completed the necessary assessments to receive credit. UCSF community members were able to register for each workshop individually via the library's website, and an additional 20 people attended the workshops through this mechanism.

### COOKING TIME

Planning for the workshop series requires approximately 8 months of advanced planning in order to coordinate content, recruit speakers, book rooms, and advertise. The workshop series itself will take place over 8 weeks. Allow up to 2 additional months afterward for follow-up and assessment.

At UCSF, we began planning in February 2019 and continued through the fall of 2019, with the majority of the preparations taking place during the summer. The eight workshops were held once a week from mid-September to mid-November and were each 90 minutes in length. After the series was completed, we spent the rest of November and December gathering and analyzing assessment data and wrapping up the project.

### DIETARY GUIDELINES

Because the problem of reproducibility is especially troubling for biomedical research, this workshop series is a way for the library to collaborate with other groups on campus to provide crucial training to early career researchers in order to provide a foundation for reproducible research that can be practiced throughout their careers. The content for the workshops is informed by a broad range of reproducibility guidelines and standards, including the rigor and reproducibility principles from the National Institutes of Health, the Transparency and Openness Promotion (TOP) Guidelines, the American Statistical Association report on reproducible research, and the National Academies of Science report

on reproducibility and replicability in science (Broman et al., n.d.; *Guidance: Rigor and Reproducibility in Grant Applications* | [grants.nih.gov](https://grants.nih.gov), n.d.; National Academies of Sciences, 2019; Nosek et al., 2016). The goal is to distill the information from these guidelines into actionable steps that can be easily implemented by our learners.

The UCSF Library has long been an advocate for open access publishing through support for the University of California open access policies and funding for publishing in open access journals. Our Data Science Initiative (DSI) teaches UCSF researchers how to organize, analyze, and share their research data through data management, statistical analysis, and programming consultations and classes. The workshop series incorporated all these services and focused more intently on the reproducibility aspects of them.

### INGREDIENTS & EQUIPMENT

Partnerships are key in successfully carrying out a workshop series. Libraries should identify partners early on to ensure a robust collaboration. Potential partners include graduate programs, the Office of Research, and research groups involved with open science or reproducibility. At UCSF, the library team worked closely with the UCSF Graduate Division and the Open Science Group. The Graduate Division partnered on this initiative because it helped them meet their requirements to provide NIH Rigor and Reproducibility training. The Open Science Group and our library team supported it because it was

an opportunity to increase campus awareness of reproducible methods and tools. We were also excited to work with the Graduate Division to offer a formal course, as the library does not have the ability to offer credit-bearing courses on its own. While the library took the lead on this project, our partners helped us identify workshop speakers and content, schedule and promote the series, and assess student learning.

The budget for this workshop series will likely include speaker honoraria, funding for refreshments at workshops, and funds to reserve rooms as needed. At UCSF, the budget was split between the library and the Graduate Division and went toward refreshments for the opening event's reception and honoraria or travel expenses for the non-UCSF instructors. All sessions took place in a multimedia classroom at UCSF's Mission Bay campus and were therefore free of charge. In order to keep the costs down, we decided against recording the workshops and openly shared all of the learning materials on the university's learning management system.

### PREPARATION

#### *Eight months before*

- Review background information from relevant articles, guidelines, and requirements on open science and reproducibility. Once you have an understanding of the landscape as it applies to your stakeholder community, establish collaborations with groups and individuals at your institution that you'll partner

with to run and promote the series.

#### **Seven months before**

- Identify the topical areas and learning objectives and outline the content for each of your workshops. The first event should be a kick-off overview event and the last should be one that ties everything together with targeted exercises.
- Identify and rank a minimum of three potential speakers for each topic, including a mix of diverse presenters from your institution, neighboring institutions, and industry partners.
- Estimate your budget and secure funding.

#### **Six months before**

- Set the workshop dates, ideally so that they repeat weekly on the same day and at the same time over a several-week span. Allow for flexibility in the sequence of topics according to speaker availability.
- Begin inviting presenters and secure commitments for set dates.

#### **Three to four months before**

- Book rooms and equipment for your series and set up registration page(s).
- Begin creating a course website or central repository for class materials.

#### **Two months before**

- Start promoting the workshops through regular and specialized newsletters, direct emails, flyers, kiosks, and other

relevant methods.

- Meet with the presenters to solidify the content and exercises.

#### **One month before**

- Place catering orders and confirm room bookings.

#### **One week before**

- Confirm details of the event, including location and room logistics with presenters.
- Send out pre-workshop assessment surveys.

#### **One week after the series**

- Gather slides and materials from instructors to share on the course website.
- Send out post-workshop assessment surveys.

### **COOKING METHOD**

Kick off the series with a session introducing the concept of reproducibility and highlighting the themes that will be covered in the following workshops. Each of the subsequent workshops will dive deep into a particular aspect of reproducibility and incorporate active learning throughout. Provide summaries and learning objectives in promotional materials following the model for UCSF's series outlined below. Remember to share all of the workshop materials publicly on the class website (e.g., Reproducibility for Biomedical Researchers, n.d. <https://courses.ucsf.edu/course/view.php?id=6933>).

#### **Introduction to Reproducibility + Panel**

This workshop starts with an overview of the reproducibility “crisis” and highlights solutions for making research more reproducible. Next, open it up to a panel of biomedical researchers who can share their efforts to improve reproducibility in their work. Finally, conclude the event with a reception giving everyone a chance to connect with fellow researchers over food and drink. By the end of this session, learners should be able to define reproducibility in the context of the biomedical sciences, describe two causes of non-reproducible research, and identify one practice or tool to explore further during the series.

At UCSF, the opening talk was led by Ariel Deardorff, UCSF Library, and the panel consisted of two UCSF faculty—one Stanford University faculty and one researcher from the Gladstone Institutes. Ariel moderated the panel with both prepared questions and live questions from the audience.

#### **Rigorous Experimental Design**

The scientific community, and many publishers, are increasingly demanding that experimental results be reproducible in order to be considered valid and valuable contributions. To achieve this, researchers must design their experiments carefully. This week, introduce rigorous research design so that learners will be aware of different types of experimental biases, know how to develop a good analysis plan, and be able to identify the key components of a well-written methods section.

*UCSF series instructor:* Karla Lindquist, PhD, UCSF Library.

*Activity:* Learners worked in small groups to identify potential areas of bias in three biomedical research articles.

### **Open Publishing**

Scholarly communication is steadily moving toward an open environment through open access publishing, self-archiving, and increased transparency around the work that goes into scholarly research outputs. In this workshop, explore new forms of publishing, such as micropublications, null and data results, and registered research reports and preprints. Share how rigorous scholarly publishing guidelines can help improve reproducibility. Learners should leave this session with the ability to define the economics of scholarly publishing and the hurdles to publishing open access, explain how emerging models of scholarly communication improve reproducibility, describe the best ways forward to an open research communication system, and identify scholarly communication tools to help manage their online presence.

*UCSF series instructors:* Veronique Kiermer, PhD, and Dan Morgan, Public Library of Science (PLOS)

*Activity:* Through group discussions, learners shared how the economic model of academic publishing had influenced how they conducted science, discussed whether or not they would be able to reproduce and access everything they

are currently working on in ten years, and brainstormed ideas for what they would do differently now to improve that situation.

### **Open Protocols**

One of the barriers to the reproducibility of research is the lack of detailed methods in published articles and in the lab environment. Open sharing of research protocols improves replication by making research processes accessible, dynamic, and open to discussion, modification, and optimization. Use this week to address how protocol sharing meets openness and transparency guidelines, such as TOP (Transparency and Openness Promotion), so that learners can describe the benefits of making research protocols open, identify guidelines and best practices for research methods and protocols, and prepare, share, and modify a research protocol.

*UCSF series instructor:* Lenny Teytelman, PhD, protocols.io

*Activity:* In order to demonstrate the importance of accurate and detailed protocols, learners worked in small groups to draw a picture and then write step-by-step drawing instructions. Then they attempted to recreate their partner's drawing using the instructions. This was followed by a reflective group discussion.

### **Open Code**

Most modern advances in science have been made possible thanks to use of software. De-

spite the importance of research software for science, a majority of scientists do not have sufficient training and understanding of best practices that allow for reuse and reproducibility of software artifacts. In this workshop, demonstrate how researchers should set up their work so others can easily reproduce their computational steps and generate outputs in a variety of formats. Introduce best practices for sharing code, including when to turn a loose collection of scripts into a software package and how to get academic credit for such work. By the end of the workshops, learners should feel confident explaining several ways in which to share their work as reproducible notebooks and be able to share and archive code/software associated with papers.

*UCSF series instructor:* Karthik Ram, PhD, Berkeley Institute of Data Science

*Activity:* Learners engaged in group discussion and participated in a demo of a reproducible scientific code writing and packaging pipeline.

### **Peer Review**

Peer review is an essential mechanism for validating research results. In this workshop, examine the function of peer review, its shortcomings, and efforts to make peer review more transparent, inclusive, unbiased, and robust. Describe peer-review training opportunities and mechanisms to get recognition for review work so that learners can name emerging peer-review models, get credit for peer-reviewing, and provide feedback on a publicly posted preprint.

*UCSF series instructor:* Jessica Polka, PhD, ASAPbio

*Activities:* Learners identified and evaluated an online preprint article and shared their feedback and ideas via live polling with Slido.com

### **Data Publishing**

Research data is increasingly valued as a necessary component of reproducible and open science. Initiatives focused on the usability of data like “FAIR,” coupled with mandates from funders and publishers that require data to be openly accessible, increase the need for a data-savvy research workforce. This week, share best practices for publishing research data so that learners can describe the value of publishing research data openly and can use data publishing resources like Dryad.

*UCSF series instructor:* Daniella Lowenberg, California Digital Library

*Activity:* Learners described the data generated in their current research project and discussed what others would need to understand and document the data. Then they identified a public research dataset in NCBI Genbank or Dryad and assessed whether or not they would be able to reproduce it.

### **Trust and Transparency**

Aspects of the culture of academic research can be at odds with efforts to improve rigor and reproducibility, from hyper-competition for jobs, funding, and fame to the every-

day devaluing of “administrative tasks” as a part of scientific practice. In this workshop, explore the cultural barriers to implementing rigorous and reproducible practice so that learners can identify at least one cultural barrier that is impeding their own practice in rigor and reproducibility and develop a strategy to implement in everyday practice for improvement of rigor and reproducibility.

*UCSF series instructor:* Elizabeth Silva, PhD, UCSF Graduate Division

*Activity:* Learners wrote down one change in practice they wanted to implement to improve the reproducibility of their own work and then identified potential barriers to that change. These barriers were shared as Post-it Notes and sparked a class-wide discussion. Finally, learners worked in small groups to develop solutions to overcome their barriers.

### **ALLERGY WARNING**

While we were very pleased with all instructors and the results of the workshop series, there are a couple of things we will do differently the next time we offer the series. Because the majority of the workshop instructors were from outside the university, we recognize that it will be unsustainable to secure so many outside presenters every time. It also proved challenging to include hands-on activities for some topics. The exercises that asked the learners to reflect on their current practices and consider what needed changing sparked significant engagement. In the class feedback, participants shared that

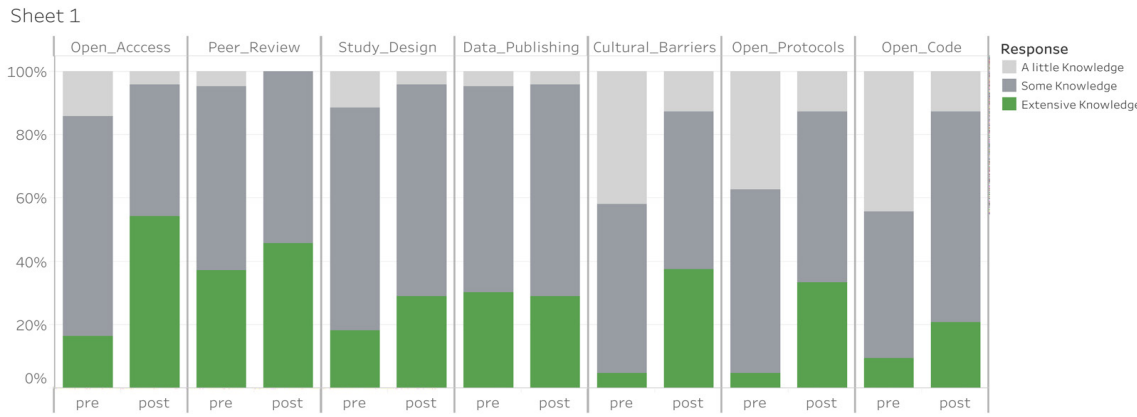
they wanted more guidance on convincing others to practice more reproducible research, more specific examples of reproducible workflows and practices, shorter talks, and a wider variety of speakers for each topic to avoid promoting one tool over another.

Our goal is to offer this workshop series again in the spring of 2021, covering similar topics. We plan to have library and other UCSF experts teach more of the content and work more closely with invited instructors to ensure that the content includes active learning exercises and more specific examples.

### **CHEF’S NOTES**

Assessment is an essential tool in judging the success and impact of a workshop series. Consider administering pre- and post-workshop surveys to measure knowledge of reproducibility topics and current behaviors related to reproducibility. In the post-workshop survey, give learners a chance to share one thing they will do differently as a result of the series to measure immediate change in practice.

At UCSF, we administered a survey before and after the workshop series to assess the impact of the workshop on the NIH cohort. The first set of questions asked the participants to rate their knowledge on the topic of each workshop on a scale from “a little knowledge” to “some knowledge” to “extensive knowledge.” Before participating in the workshops, the majority of participants rated themselves as having “some knowledge” on



**Figure 1. Topic knowledge before and after the workshop series**

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most topics. After completing the workshops, many more participants rated themselves as having “extensive knowledge” of the topics (see figure 1).

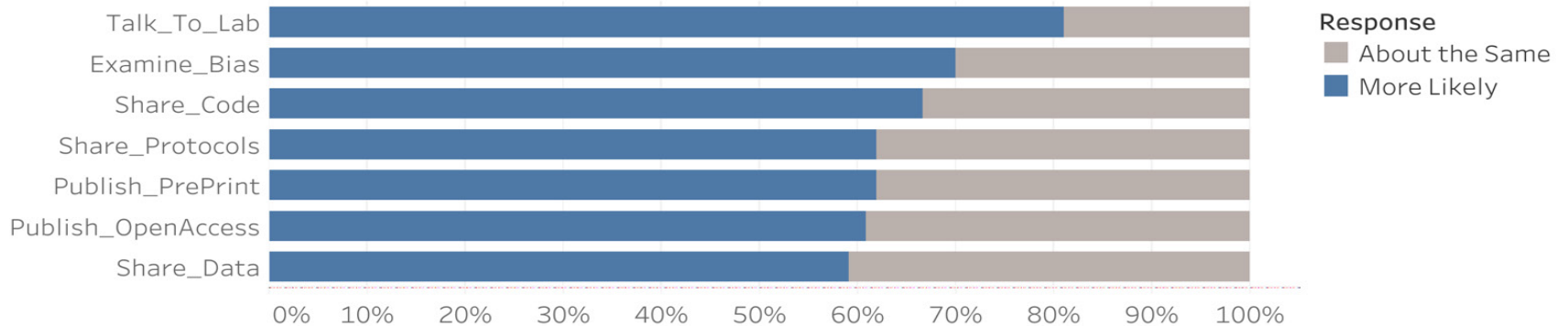
The second set of questions on the post-workshop survey asked participants

whether they were “less likely,” “about the same,” or “more likely” to engage in certain reproducible behaviors after completing the workshop series. Here we also saw substantial impact, with 80 percent of participants reporting that they were more likely to talk with their lab about reproducibility,

70 percent saying they were more likely to examine their research for bias, 66 percent were more likely to share their code, and approximately 60 percent saying they were more likely to share their protocols, publish a preprint, publish in an open access journal, and share their research data (see figure 2 below).

Finally, we asked participants to share one change they planned to implement to improve the reproducibility of their work. At least 50 percent of respondents (n=12) mentioned that they planned on keeping better records and documenting their protocols more thoroughly. Other popular responses included publishing their protocols on protocols.io (5), implementing better version control (4), spending more time documenting their code (4), and switching to electronic lab notebooks (3).

Sheet 1



**Figure 2. Change in behavior after the series**

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**ADDITIONAL RESOURCES**

Broman, K., Cetinkaya-Rundel, M., Nussbaum, A., Paciorek, C., Peng, R., Turek, D., & Wickham, H. (n.d.). *Recommendations to funding agencies for supporting reproducible research*, 4.

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Guidance: *Rigor and reproducibility in grant applications* | [grants.nih.gov](https://grants.nih.gov). (n.d.).

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