Open Science: An Introduction for Biology

2022-06-14

Contents

Welcome

This text was built to accompany the first year of the Biology undergraduate degree program at UBC Okanagan. It's aim is to introduce learners to core considerations in the pursuit of open scientific practices. It's divided into three sections, the first exploring principles and concepts associated with Open Science, the second and third looking at these principles and concepts in practice with UBC and Canadian examples.

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All source files are available https://github.com/ubco-biology/OS-Introduction.

UBCO Biology open materials

This resource is part of a larger project to host UBCO Biology lab materials in an open, accessible format.

All BIOL open materials can be found at https://ubco-biology.github.io/

Conventions

Highlights and key take aways from the discussion.

Further insights or notes on the discussion.

Examples of Open Science in practice.

Exercises to work through.

OS 101

Chapter 1

Principles of Open Science

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1.1 The Burden of Proof

Science is a beautiful thing. It is a landscape of exploration and one that at its root is tasked with finding evidence, and establishing cause and effect. At a fundamental level, this implies that science should be able to answer questions like these

> If I exercise daily, how is this likely to affect my cardiovascular health?
>
> If we build a road here, how will the local population of bighorn sheep be affected?

As you'll discover throughout your degree, scientists tackle such questions through a combination of exploratory research and confirmatory research. At the exploratory stage, ideas are generated and associations are discovered. Exploratory research gives rise to hypotheses that can then be tested through confirmatory research, which requires well-designed experiments. For instance, based on observation, we have long hypothesized that there are positive associations between exercise and physical health. But establishing that daily exercise causes healthy outcomes is a different challenge.

Exploratory research gives rise to hypotheses that can then be tested through confirmatory research, which requires well-designed experiments.

Many research teams have designed studies to address various aspects of these observed benefits of physical activity. One such team, an interdisciplinary research team at UBC, tackled this question in relation to falls in an aging population. The researchers designed an experiment to to test whether strength training after experiencing a fall in an aging population would reduce injuries from a subsequent fall.

Exercise and Positive Health Outcomes After reading the following abstract from Liu-Ambrose et al's paper Effect of a Home-Based Exercise Program on Subsequent Falls Among Community-Dwelling High-Risk Older Adults After a Fall, try and answer the following questions.

- Was this study confirmatory or exploratory? How do we know this?
- Who participated in the study?
- What was the intervention?
- What were the main conclusions?

Abstract **Importance** Whether exercise reduces subsequent falls in high-risk older adults who have already experienced a fall is unknown.

Objective To assess the effect of a home-based exercise program as a fall prevention strategy in older adults who were referred to a fall prevention clinic after an index fall.

Design, Setting, and Participants A 12-month, single-blind, randomized clinical trial conducted from April 22, 2009, to June 5, 2018, among adults aged at least 70 years who had a fall within the past 12 months and were recruited from a fall prevention clinic.

Interventions Participants were randomized to receive usual care plus a home-based strength and balance retraining exercise program delivered by a physical therapist (intervention group; $n = 173$) or usual care, consisting of fall prevention care provided by a geriatrician (usual care group; $n = 172$). Both were provided for 12 months.

Main Outcomes and Measures The primary outcome was self-reported number of falls over 12 months. Adverse event data were collected in the exercise group only and consisted of falls, injuries, or muscle soreness related to the exercise intervention.

Results Among 345 randomized patients (mean age, 81.6 [SD, 6.1] years; 67% women), 296 (86%) completed the trial. During a mean follow-up of 338 (SD, 81) days, a total of 236 falls occurred among 172 participants in the exercise group vs 366 falls among 172 participants in the usual care group. Estimated incidence rates of falls per person-year were 1.4 (95% CI, 0.1-2.0) vs 2.1 (95% CI, 0.1-3.2), respectively. The absolute difference in fall incidence was 0.74 (95% CI, 0.04-1.78; $P = .006$) falls per person-year and the incident rate ratio was 0.64 (95% CI, 0.46-0.90; $P = .009$). No adverse events related to the intervention were reported.

Conclusions and Relevance Among older adults receiving care at a fall prevention clinic after a fall, a home-based strength and balance retraining exercise program significantly reduced the rate of subsequent falls compared with usual care provided by a geriatrician. These findings support the use of this home-based exercise program for secondary fall prevention but require replication in other clinical settings.

Trial Registration ClinicalTrials.gov Identifiers: NCT01029171; NCT00323596

Causal Links

Suggesting a causal link brings with it the need to show your proof. This burden of scientific proof requires both creativity and rigour; studies must be well designed and well executed. It also requires that studies be independently replicated to show that, if repeated, they will result in the same conclusions, reinforcing the validity of the original findings. On the other hand, a replication study may come to a different conclusion, potentially invalidating the conclusions of the original study.

Say, for example, that you're provided with the choice between two medications to treat a medical condition - we'll leave the details of this medical condition up to your imagination. Neither has a record of adverse side effects, but one drug, we'll be creative and call it "drug A" has findings obtained from only a single research lab, while "drug B" underwent five independently replicated studies in five different labs with five independent researchers. Which medication might you choose?

Science & Social Trust

Science does not exist independent of the rest of society. The outputs of science - the discoveries made through research - answer questions we have in all facets of life

> What is a healthy lunch option?
>
> Is lead-based paint safe?
>
> What's the safest way to perform heart surgery?
>
> What should government policy be on climate change?

If science is going to be used by the public, other scientists, and policy makers to address these questions, they need to be able both to gain access to and to trust these findings.

Trust & Access

Scientists can build public trust in science through the use of

- rigour in the scientific method and
- replication (thorough repetition) of studies to build and solidify the evidence for a conclusion.

We can assure access to science by removing barriers to access, such as fees for articles, and by tailoring communication of the outputs for specific audiences.

Stakeholders in Science

Designing accessible outputs for a particular audience means considering the prior knowledge, education, and needs of different stakeholders in science.

Who exactly is a stakeholder? Anyone who can influence or be affected by a matter. Examples of these could include government policy makers and funders, business and industry, politicians, environmentalists, patients, and the general public.

1.2 A Crisis

Much of the scientific community was shocked in 2005 when researcher, John Ioannidis, wrote a paper claiming that most published research findings are false.

Ioannidis was criticizing the rigour of the scientific process used by researchers in medicine. His statement sparked a movement that started questioning whether or not published studies could be replicated: that is, could they withstand a test of their burden of proof?

Since Ioannidis published his paper, this movement has grown, seeking to transform the culture and practices of scientific research. As a society and as a species we face many challenges that require us to work together across geographical, social, political, and disciplinary boundaries. Solid science and public confidence in that science figure prominently in efforts to address such issues as health and wellness, climate change, and the need to make resource use sustainable.

A change in culture and practices to improve knowledge sharing, quality, accessibility, and trust in science is needed.

Why Most Published Research Findings are False After reading the following abstract from John Ioannidis's article, Why most published research findings are false, reflect on the following questions.

- What factors did Ioannidis identify for the lack of reliability in research studies?
- How might these problems be addressed?

Abstract There is increasing concern that most current published research findings are false. The probability that a research claim is true may depend on study power and bias, the number of other studies on the same question, and, importantly, the ratio of true to no relationships among the relationships probed in each scientific field.

In this framework, a research finding is less likely to be true when the studies conducted in a field are smaller; when effect sizes are smaller; when there is a greater number and lesser preselection of tested relationships; where there is greater flexibility in designs, definitions, outcomes, and analytical modes; when there is greater financial and other interest and prejudice; and when more teams are involved in a scientific field in chase of statistical significance. Simulations show that for most study designs and settings, it is more likely for a research claim to be false than true. Moreover, for many current scientific fields, claimed research findings may often be simply accurate measures of the prevailing bias. In this essay, I discuss the implications of these problems for the conduct and interpretation of research.

1.3 What Exactly is Open Science?

In the previous sections we discussed the burden of proof and the erosion of social and stakeholder trust in the sciences.

This next section will explore a related issue: the ability to build up evidence for a scientific claim by repeating the original study to make sure that the finding, be it correlative or causal, is a true finding and not just a fluke.

A Replication Crisis

Open Science proposes many solutions to problems with how research is done.

Open Science aims to ensure that research can be confirmed through replication, and that both new discoveries and replications of previous research are respected and rewarded.

Although scientific progress rests on the repetition and reproduction of results, efforts at this are hindered by two main factors.

First, there is a desire for the new and shiny: novel studies are more interesting. Second, many studies cannot be competently analyzed or replicated. This is because critical information about them — design, data, methods, lab notes, analyses and code — may not be made available, or may be poorly communicated.

Flashy Science or Good Science

New, positive, and original findings are exciting. Independently repeating a study and getting the same results, not so much. The consequence for science? New, positive, and flashy findings get published and a lot of attention. Retesting, or replicating these studies, and non-positive findings often attract much less attention.

The result? Novel research gets funded and published. Sometimes, it appears, the excitement factor overrides the quality (or lack of quality) of the science.

Incentives

Replication studies have traditionally been hard to fund, and many journals are not interested in publishing them. And universities and scientific institutes offer career rewards to those who publish novel findings in prestigious journals.

Academia and industry alike reward the publication of positive and so-called ”significant” results. Scientists may unwittingly ”bend the rules” of science trying to get results worthy of publication. ”Bending the rules” in this context is also known as engaging in Questionable Research Practices (QRPs).

It’s important to note that QRPs don’t normally result from deliberate efforts on the part of researchers to do bad science. QRPs arise from a complex system of interactions within and around the research process and from the need for researchers to get published. After all, publications are the bread and butter of a researcher. And unfortunately, this can mean that sometimes style trumps substance, as Daniel Engber notes in his *Slate* article Cancer Research Is Broken.

Enter Open Science

Open Science is a movement that tries to combat the replication crisis, QRPs, and style trumping substance in two ways. First, by providing different incentives and rewards for research. That is, changing what we measure as a success in research, shifting from a culture that emphasizes novel findings to one that also rewards the many other aspects of practicing good science. Second, by making all parts of the scientific research process transparent and accessible, allowing for a critical review of how a study was conducted, and ultimately enabling that study to be independently replicated.

What sort of changes, then, would we expect Open Science to bring? Imagine a world where

- publications and data are freely available [1];
- conclusions and public policy are based on solid information and analysis that are clearly evident to all;
- studies can be tested and repeated;
- researchers without extensive funding or resources can still participate and collaborate in science;
- good science — rather than flashy science — brings rewards to those who practice it; and
- the public trusts science and has opportunities to participate in research.

1.4 Core Values

In the previous section we talked about the relationship between science and society, and tried to imagine an ideal research landscape transformed by Open Science. In this section we'll dive a little deeper and get to the core beliefs that underlie OS principles and practices.

The fundamental values we'll look at include

Scientific quality and integrity

Equity

Communication

Diversity and inclusion

1.5 Core Values: Scientific Integrity

Though we haven't mentioned the phrase ”scientific integrity”, we have looked at the critical role it plays in replicability and Open Science. Integrity involves sticking to best practices for research that promote reproducibility through transparency and open access. At its root, this principle springs from a sense of responsibility for public welfare and from the honest pursuit of scientific truth.

In a literal sense, transparency is the property of an object that makes it so clear that you can see through it. But what about when we talk about transparency in government policy, or scientific research? In this context, transparency implies a high degree of disclosure — revealing clearly the exact reasoning and process

[1] There are some necessary and reasonable restrictions on data availability, such as privacy concerns, cultural and intellectual property rights, or even protection of the location of endangered species, to name a few.

used in coming to a decision or taking an action. As well, transparency means taking care to disclose important information in a respectful and responsible fashion.

Best Practices

Scientific integrity implies several practices:

- basing research conclusions and public policy on solid information and analyses that are clearly evident to everyone;
- evaluating scientific work using fair, rigorous criteria and procedures known to all involved;
- publishing good science, period (not just flashy science);
- fully disclosing study methods and outcomes regardless of the findings being ”significant”;
- following best practices for creating hypotheses, collecting data, and analyzing results;
- demonstrating sensitivity to stakeholders’ ownership of knowledge and data; and
- providing equitable access to all outputs of the research cycle.

As we saw in the last section, these form key elements of our ideal research ecosystem, where the public trusts science and studies can be tested and repeated.

One case where students want and need transparency is in grading. Most of you probably appreciate knowing how marks were given to questions on a midterm exam and what criteria the marker used to score each question. This provides you with both a *reason* for the assigned grade and a means of *comparing* your grade with those of your classmates.

Ultimately, this specific information can help you to address gaps in your knowledge and perform better on future assessments (such as the final exam). In the same way, transparency in research allows scientists to improve future studies and add to accumulated knowledge.

1.6 Core Values: Equity & Communication

What is equity? Does equity equal equality?

Equity and equality are similar, but there is a key distinction: under equality everyone is treated in an identical manner, whereas under equity everyone is treated fairly according to their abilities and needs.

The following image nicely illustrates the concept of equity

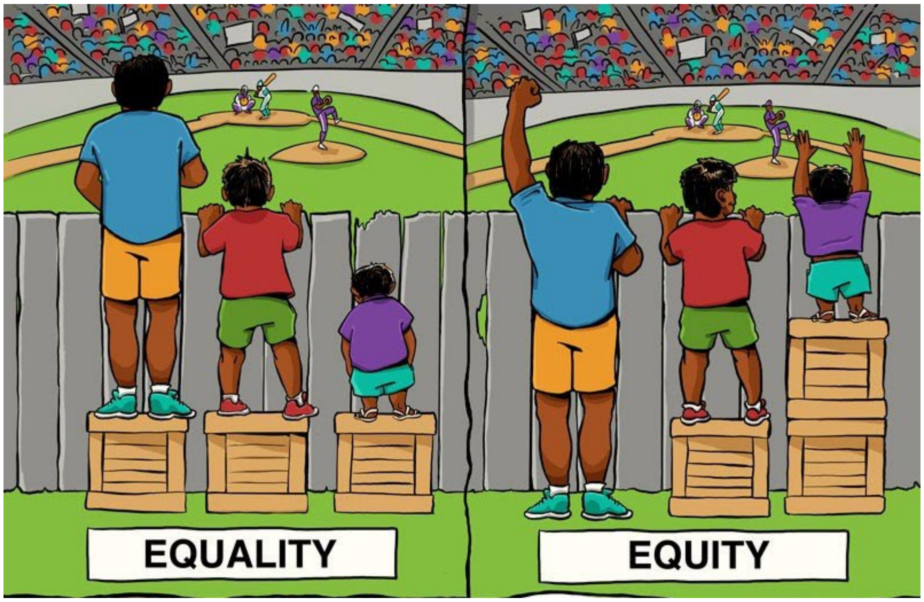

Image attribution: Universalincome [cropped] by Leigh Blackall under Attribution 2.0 Generic (CC BY 2.0).

Communication

We do research to learn; we share our findings to build a culture of learning and to enhance the future of our disciplines. We also share to build community with researchers and other stakeholders.

But because there can be a range of stakeholders with different needs, values, and backgrounds, it is important to communicate science in ways that consider these specific attributes. Processes and findings need to be *contextualized* (put into a context meaningful to the particular stakeholder) and *made accessible*, both in message (the content of the communication) and medium (the way the message is conveyed). The more avenues we use to share and engage and the fewer barriers to access we put up, the more equitably our discoveries can be shared.

Because there can be a range of stakeholders with different needs, values, and backgrounds, it is important to communicate science in ways that consider these specific attributes.

Equity in science communication can be explored in many ways; none addresses all issues of equitable access, but each helps to enhance scientific literacies in our society. For example,

- Open access publications help to make research available to those who cannot afford costly journal subscriptions.

- Citizen science engages members of the public in the research process, contributing their voices to projects.
- Novel ways of sharing a message, like podcasts or Twitter, can reach communities with unique access needs or preferences.

Audiences

The language and techniques your Biology professor uses to communicate scientific information will vary according to her audience. Depending on whom she's interacting with, your Biology professor will use different language and techniques to convey scientific information. For example, in the course of her work, she may be

- engaging you and your classmates in learning in the classroom;
- talking to a member of the public;
- working on research with a departmental colleague; or
- advising a government employee involved in writing policy.

In each case, she adjusts her communication to match her audience's needs, educational background, and experience. Her message isn't fundamentally changed or simplified, but it does need to be delivered in a way that is understanding and respectful of her audience.

Consider each of the following three explanations of how DDT affects birds in terms of its intended audience.

Aimed at Researchers in the Discipline

Dichlorodiphenyltrichloroethane (DDT) is a persistent organochlorine compound found worldwide that causes significant anatomical, physiological and behavioural abnormalities in humans and wildlife.

– The Effects of Environmental Exposure to DDT on the Brain of a Songbird: Changes in Structures Associated with Mating and Song.

Aimed at Post-Secondary Science Students

DDT and its metabolites cause eggs to have thin shells and reduce levels of a hormone necessary for female birds to lay eggs. Population declines and local disappearance of peregrine falcons, bald and golden eagles, ospreys, kestrels, and other predatory birds were recorded.

— Pesticides and Birds: From DDT to Today's Poisons.

Aimed at the General Public

High concentrations of DDT in birds cause weakness in the shells of their eggs, which leads to a reduction in their population. DDT is now banned because of this.

— Food Chains and Food Webs.

1.7 Core Values: Diversity & Inclusion

You've almost certainly heard these terms, but may wonder if there's a difference between them.

In the context of Open Science diversity is the practice or quality of engaging in research with individuals who vary in terms of social class, ethnic background, sexual orientation, gender, ability, etc.

Inclusion takes this diverse engagement further: it looks at the individual in relation to the community, organization, or society, and ensures that they not only participate in, but guide the research process, especially as the research impacts these diverse communities as stakeholders in the research process and the implementation of findings from research.

Looking back at our discussion in the previous section, diversity and inclusion seem to be natural partners of equity.

Diverse criticism of scientific ideas makes research more robust, and challenges biases and assumptions that might otherwise pass unchecked.

Diversity in Research Culture

Divergent perspectives, skill sets, and ideas introduce the "outside-of-the-box" thinking that drives research forward. Involving a diversity of views and people enriches research.

Diversity and inclusion show up in many types of research activities that involve participation and collaboration. Participation and collaboration can take many forms. For example,

- Citizen science engages the public in data collection and processing.
- Partnership research turns the relationship between researcher and subject into a partnership, where both contribute to the research question, methods, and outcomes.
- International collaborations increase cultural diversity and can address problems that cross borders, like disease epidemics or pollution.
- Interdisciplinary research, such as collaborations between medical researchers on the one hand and veterinarians and animal specialists on the other, can help investigate complex questions like how the COVID-19 coronavirus evolves in intermediate hosts before being transferred to humans.

Partnership Research: Integrated Knowledge Translation (IKT) Historically, there has been an imbalanced power relationship between people with differing physical abilities or medical conditions and the experts responsible for their care, medical treatment or research of their conditions.

In recent years, however, patient rights movements have focused on returning power to people undergoing medical care. And researchers and practitioners are adapting their practices, recognizing that people living with a medical condition hold unique knowledge about how it affects them, and this lived experience can be used to improve both research and outcomes.

An interdisciplinary panel of researchers from both UBC campuses, led by Dr. Kathleen Martin-Ginis, has engaged with people living with spinal cord injury (SCI) to set up guidelines for collaboration that give those with SCI a voice in the research process, from the choice of avenues to investigate to decisions on the implementation of research results. This model of collaborative research, which is known as Integrated Knowledge Translation, has been shown to:

- improve the quality of science;
- increase the probability that findings will be used in real life in policy or practice;
- facilitate learning among all parties involved; and
- make research more relevant to patient needs.

You can check out one output from this research, the Integrated Knowledge Translation (IKT) Guiding Principles for Conducting Spinal Cord Injury (SCI) Research in Partnership.

— Integrated Knowledge Translation Guiding Principles for Conducting and Disseminating Spinal Cord Injury Research in Partnership

1.8 An Equitable and Inclusive Open Science

In the past few years, the core values of equity, diversity, and inclusion have come to play an increasingly important role in the Open Science movement. It has also begun to recognize and account for the legacy of colonization: the historical, ingrained differences in power that exist between the Global North and Global South, among countries, and within countries between dominant groups and those that have been marginalized.

Sometimes, solutions involve using multiple ways of knowing to make and carry out science policy.

Government Policy: Diverse Teams Informing Species Risk Assessment Dr. Jeannette Armstrong was born and raised in the South Okanagan, on the Penticton Indian reserve. Dr. Armstrong is well known as an author, poet, educator, and Indigenous rights activist.

At UBC Okanagan, she holds a Canada Research Chair in Okanagan Indigenous Knowledge and Philosophy. She is also one of several people on a subcommittee of The Committee on the Status of Endangered Wildlife in Canada (COSEWIC), which advises the Minister of Environment and Climate Change Canada on designation of species at risk.

The COSEWIC website states:

> Incorporating Aboriginal Traditional Knowledge into COSEWIC's assessment of species at risk improves the process, and therefore the quality of designations made by COSEWIC, by bringing information and perspectives on wildlife species that are not available in published scientific literature.

Countering Systemic Bias

However, more work is needed to really shift the systemic imbalance that has resulted from the legacies of our society holding the white, heterosexual, male, middle-class or higher, able-bodied adult up as the "norm" - the norm around which our society constructs its practices and institutions, including its universities, employment law, and research design, to name a few.

When this favouritism is enshrined in legislation, administrative processes, career advancements, our education systems, etc., we call it systemic bias.

If we differ in terms of any of the characteristics listed above - whether in our ethnicity, gender, sexual orientation, social class, or ability - we lack that the level of privilege their possession confers. Equitable practices try to shift this imbalance.

Systemic bias, and the norms these biases engender, infiltrate many aspects of how research is undertaken. Sometimes this manifests in the conduct of science itself, where as recently as the end of the Second World War, some scientists helped to promote "scientific racism", encoding these norms through taxonomies and classification systems that grouped humankind into different races. Another discipline that we would now call "pseudoscience" - phrenology - attempted to correlate intelligence and personality to observable features of the human skull.

This discriminatory system, as we've discussed, can even prevent people from engaging in the practice of scientific research from the outset.

In 2016, 6% of Kelowna's population identified as Aboriginal (a term including a number of more specific Indigenous identities, such as Metis, Inuk, and First Nations). If there were no bias in the school and post-secondary educational systems, and assuming that Indigenous people are just as capable as non-Indigenous people at doing science, we would expect to see a comparable percentage of Indigenous people studying and teaching science in colleges and universities. But we don't.

Consider the following questions.

- What implications might this have for how research is conducted at UBC?
- How can we change this?

1.9 Wrap up

This has been a very short introduction to the world of Open Science; the crisis that launched a movement to address underlying issues in reproducibility, transparency, access, and equity and diversity in scientific research.

In subsequent chapters and terms, we'll explore some of the challenges researchers face in implementing practices related to Open Science as well as some of the successes that have emerged from within UBC as our faculty and students embrace methods for well done research rooted in transparent, reproducible methods that integrate alternative ways of viewing our environments, and evaluate research goals and outcomes base on diverse perspectives that result from different experiences.

OS 102

Chapter 2

Open Science in Action: Benefits

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2.1 Introduction

In the previous chapter we talked a lot about what Open Science is, and about some of the core values that underlie it. In this chapter we'll survey, through tangible examples, some of the many benefits OS can bring when these core values are put into practice, including:

Accelerated innovation Increasing efficiencies in research and development.

CollaborationFacilitating large-scale data projects.

More responsive policy and research Addressing public needs as a consequence of better and more inclusive research.

Diversification of science Through inclusive collaborations.

Career benefits For individual researchers.

2.2 Accelerated Innovation

Creating Efficiencies

Open Science offers opportunities to increase the rate of scientific discovery.

For example, in drug development, frequently multiple researchers and companies are developing very similar drugs to address the same issue, with each research team or company drug trial running independently of the next and little to no disclosure of what they're testing. Working in isolation limits the size of the trials, increasing bias while simultaneously increasing overhead as similar approaches are independently generated and trialed. During COVID, the open publication of vaccine related data helped to limit redundancies and allow researchers to quickly propose novel solutions.

In other contexts, the publication and dissemination of reproducible workflows and non-significant findings means replication studies to support the evidence base are more easily undertaken while known failed attempts at discovering true relationships between phenomena can be added to a researchers 'No need to investigate this…' list.

In short OS…

Solidifies the foundation of scientific knowledge As reproducible, robust research can be understood and replicated more easily.

Has the potential to make the research process more efficient As data, methods, analytical techniques, and code can be reused.

Limits unnecessary or redundant research As the publication of studies that include both successful and failed techniques helps others to avoid wasting time and energy.

From Patents to Open Science

But let's take this back a bit and ask, why is science closed in the first place?

On a practical level, research in the lab can lead to industrial applications, whether it's a new vaccine, a drone that uses remote sensing technology to identify tree species, or a solar-powered train. In many cases, creators of such applications - or the organizations that employ them - will apply for a patent, a legal document that gives them the sole right to manufacture and sell the product - their intellectual property.

So, in many ways in modern history, patents, first issued in the 15th century, helped to close off science. Under patent law, only the inventor can improve the product. This limits the ability of society at large to explore and expand on the techniques and technologies applied.

The restriction of scientific knowledge throughout Western history is certainly more nuanced than this, but it is interesting to note that in spite of efforts to increase access to information - through public education and public libraries for example - the distribution and use of existing knowledge or discoveries remains tightly bound to a specific economic model.

In contrast, when we open up our practices to share intellectual property, we allow for accelerated innovation, which means less expensive industrial products that take less time to get to market.

Open Source Design and Accelerated Production of Medical Grade Face Shields at UBCO Accelerated innovation is driven by both shared knowledge and shared tools of production.

makerspace UBCO offers equipment and peer assistance to turn ideas into prototyped realities. When the COVID-19 outbreak hit early in 2020, health workers on the front lines faced a critical shortage of personal protective equipment (PPE). Under the guidance of Cortney Chulo, makerspace manager, the makerspace partnered with the School of Engineering and with the Interior Health Authority to produce face shields for health workers using the makerspace's 3D printers, open-source designs, and improvements suggested by the engineering students to meet Interior Health specifications.

The team looked at the following open source designs on the Web, combining the best points of each and making some additional changes of their own:

- Prusa Shield
- CoronaVirusMakers Shield
- Tinkerine Shield

Read more about the makerspace project at https://news.ok.ubc.ca/2020/04/16/ubco-teams-up-with-community-partners-to-design-medical-ppe/

2.3 Collaboration

Through the pooling of resources and, in particular, data, a project that would remain a distant dream if dependent on a single actor can become a reality.

Such collaborations can involve different research organizations, researchers from different disciplines, citizen science participation, or international cooperation.

The Tree of Life The digital Tree of Life uses published data to visualize how over two billion living things on Earth have evolved in relation to each other … going back 3.5 billion years!

A collaboration of scientists from 11 different research organizations and funding through the U.S. National Science Foundation made this huge online tool possible. One of the scientists involved, genetics professor Douglas Soltis, observed

> Twenty-five years ago people said this goal of huge trees was impossible. The open tree of life is an important starting point that other investigators can now refine and improve for decades to come.
>
> — (Shekhtman, 2015)

The Tree of Life can be used or edited by anyone, free of charge. Explore the Tree of Life website.

COVID-19 Collaboration Since the global COVID-19 pandemic was declared on March 11, 2020, we've been witnessing its sweeping health, social, and economic impacts.

Sequencing the virus's genome and making a vaccine became urgent priorities. However, preparation of vaccines normally takes years, sometimes up to 15! Nevertheless, to the amazement of many, the first COVID-19 vaccine was approved for use in China in June 2020, and as of February 23, 2021, 11 vaccines were in use worldwide. What made this possible?

International partnerships, starting with the public release of the first COVID-19 genome sequence by China in January of 2020, shortened the road to vaccination considerably. The United Nations World Health Organization spearheaded a huge international clinical trial they called the Solidarity Trial, which involved over 75 countries and reduced the time taken for clinical trials by 80%.

2.4 Responsive Policy and Research

Involvement of citizens in research can help steer science in ways that help society and make science communication and science-based public policy more responsive to public needs. Naturally, this also increases public trust in science.

The "Patient Expert" model of health care, in which patients participating in studies or treatments assume a good amount of responsibility for their own care and contribute feedback that can influence the course of future studies is an excellent example of this.

The CHILD-BRIGHT Network CHILD-BRIGHT, headquartered in Montreal, networks health practitioners, patients, families, and research scientists across Canada to advance patient-oriented care of children with brain-based developmental disabilities. This network was born out of consultation with patients and their families. The CHILD_BRIGHT website clearly outlines the importance of citizen engagement to the network's projects:

> At CHILD-BRIGHT, 'patients' have been at the centre of our work since before our network was even established. We understand that

> patients and families are experts on their health experiences and needs and we look to them to provide us with insightful input that will influence our priorities, research study design, the outcome measures we use, as well as the interpretation and use of our findings.
>
> As a network working under Canada's Strategy for Patient-Oriented Research, we aim to engage all people touched by brain-based developmental disabilities, especially patients and families, as meaningfully as possible in all aspects of our work.

CHILD-BRIGHT holds summer camps for children at research centres in Calgary, Edmonton, and Toronto under the SPORT (Stimulation for Perinatal Stroke Optimizing Recovery Trajectory) program. Children in the camp receive trial treatments aimed at improving their motor function, as well as undergoing testing and imaging for research. Their participation helps to build data sets for studies, and guides the direction of future research. Of course, some fun is involved as well! Many of the children have reported improved function through the camp's treatments.

2.5 Diversification of Science

Economic acceleration, the growth of large-scale projects, and responsive public policy improve the welfare of the public. But what about leveling the playing field in science for people who belong to groups that have historically been the targets of racism, colonization, and discrimination, and recognizing Indigenous worldviews and approaches to understanding our world?

In its efforts to limit bias and to foster systems that support transparency and reproducibility Open Science needs to constantly evaluate the underlying social norms and historical processes that ingrain bias into the scientific process. This, alongside an emphasis on science that is guided and led by those who will be most impacted by its outcomes and with partnerships and collaboration being core elements of practice, means that Open Science offers the opportunity to critically engage with and promote equity, diversity, and inclusivity in science.

Braiding Traditional Knowledge with Western Science As one step on the path to reconciliation, UBC Okanagan has established a research cluster — Enhancing Ecosystem Sustainability: A Syilx/Settler Science Collaboration — to combine Western science and Traditional Indigenous Knowledge to inform policy and practice that will fight climate change and ecological disruption. The cluster is co-lead by Dr. Jeannette Armstrong of the Syilx Okanagan Nation and Associate Professor of Indigenous Studies and Dr. Lael Parrott, Professor in Sustainability who directs the Okanagan Institute for Biodiversity, Resilience and Ecosystem Services (BRAES).

The researchers approach ecology as a complex web of relationships among humans, non-human animals, plants, and the land. Initially, the team will look at management and restoration of the grizzly bear and salmon habitats in the Okanagan Syilx territory.

Concern for the non-human beings with whom we share the Earth has always been central to the Syilx worldview. In January 2021, as a panelist in the *Science and Systemic Racism: Indigenous Perspectives* webinar, Dr. Armstrong spoke of the Syilx responsibility to *tmixw* (nsyilxcen for all lifeforms)

> In the Syilx view, the human duty is to perceive how the *tmixw* are regenerating themselves and how therefore the human must move forward in unity with them. Immersion in the knowledge of *tmixw* allows us to view its reality and makes it possible for the aliveness of each separate life form (University of British Columbia, 2021).

The UBC Strategic Plan website quotes Dr. Parrott on some of the motivations for the partnership:

> I'm hoping that we'll serve as a model for how we, as academics, can do a better job of collaborating respectfully with Indigenous communities – with new ways of moving forward that treat the different ways of knowing equally and respectfully – and come up with perhaps a third way of viewing the world.
>
> What really excites me is the opportunity to engage with the Syilx knowledge holders, to learn from their knowledge of the Okanagan landscape and the wildlife.

The Enhancing Ecosystem Sustainability project has taken an active role in engaging Indigenous youth. Its activities range from helping to weave traditional knowledge into elementary school education to planning for Indigenous science camps for teens. Indigenous graduate students are funded through the project, and play central roles in the research.

Interested in learning more about the work Drs. Armstrong and Parrott are doing together? A recording of the presentation they made at Green College (UBC Vancouver), hosted on YouTube, gives a good introduction to their project.

2.6 Career Benefits for Researchers

Being more transparent in one's research and engaging with the principles and practices of Open Science can also bring with it career benefits – especially for those in the early stages of their careers.

Some of these benefits include

Increased visibility Where fewer barriers to access means more ready access - for example, publishing open can increase the impact and uptake of one's research.

— Open Access Increases Citations of Papers in Ecology.

Enhanced networks Where chances to make connections, exchange, and collaborate, create opportunities for advancement.

Greater employability As both universities and institutions outside of the academic world - such as in industry and government - have begun to integrate the tools and philosophies of open science into their hiring expectations.

Funding and publishing opportunities Where many funders and journals now require that researchers make their data public and participate in other Open practices. In fact, the Canadian Tri-Agencies - the major federal research funding bodies - require manuscripts resulting from funded research to be published Open Access and have recently released a road map for similar requirements for data.

Mandeep Mann on Open Notebooks Mandeep Mann, a PhD candidate at the University of Toronto has been working since 2017 with the Structural Genomics Consortium (SGC). The SGC, a public-private partnership, focuses on discovering and producing new medications for diseases and conditions that are hard to treat. It is also a groundbreaker in Open Science practices.

We interviewed Mandeep about her use of an Open Science practice called Open Notebooks, which involves

- Publishing or linking to data on an online platform before results are published in a peer-reviewed journal
- Making information about the methodology and equipment used in a study publicly available
- Openly discussing both positive and negative results in real time, as they are obtained.

What are you studying?

My research focuses on developing drug-like molecules to use as tools to study targets implicated in disease, such as cancer. Disease targets for drugs are usually proteins.

How did you get started using open notebooks?

The laboratory where I chose to do my research is at the Structural Genomics Consortium (SGC), which is a firm believer in open science - sharing data, and tools openly with the world to accelerate research. The idea of open science was new to me at the time, but nonetheless intriguing. I started off using an electronic notebook through the SGC, where we record all our experiments/research and findings in an electronic notebook, which gets uploaded to an in-house database. My mentor in the lab, Dr. Rachel Harding, showed me the ropes when I first started graduate school—how to navigate things in the lab and with graduate research in general. Rachel had been sharing her research through a blog for years. The SGC decided to adopt Rachel's ideas and further our open science principles by starting open lab notebooks. I volunteered to be one of the first users of the open notebook, as I had seen what a positive experience it had been for Rachel.

What platform are you using?

We use a blog (https://openlabnotebooks.org/) operated through Wordpress to express our research in terms that can be understood by the general public and scientific audiences that are not experts in the field. We link our blog posts to a data repository called Zenodo, where we upload the raw data, analyses, and findings in much more detail.

How do you use Zenodo and social media to amplify the power of open notebooks?

Any time someone posts on our open notebook platform, a regulator of the site will share the post through twitter.

How did you feel initially about using open notebooks? Did you have any reservations?

Even though I was one of the first users of the open notebook, at first, I was nervous. As a graduate student, you often hear, ”publish or perish”, where the success of your research relies on how many publications you get. What if I get ”scooped'? What if someone sees my research in the open notebook and then uses it to get further than me in my research - what does that mean for my research? What if they don't credit me with my ideas? I had all these thoughts. Over time, some of these worries were alleviated. A time stamp and doi are assigned to a post on Zenodo - so people can cite your work. About a year and a half after I started the open notebook, I published my work in a respectable journal, even having shared all that data in my open notebook earlier. Luckily, I have never been scooped, but I'm more comfortable in the knowledge that if someone figures something out first, it could also benefit me.

What connections have you made through this open practice?

I've been invited to several events over the last couple of years to give talks on my experience with open science and the open notebook, which has led me to meeting with scientists in other disciplines and improving my network.

What sort of feedback have you had on your work?

In the blog portion of the open notebook, there is a comments section. The public can ask questions or raise concerns that they might have; they can also do this through twitter. For example, my work has been acknowledged through twitter by associates at pharma companies. In addition, you can see the statistics of how many times your work has been viewed or downloaded. One of my posts has 1289 views and 608 downloads!

What other open practices, if any, have you been involved in?

Other than the open notebook, I follow SGC's lead in open science practices - sharing my data, tools with those that are interested. For example, we share our inhibitors with other research labs that would like to test them.

How do you feel about Open Science?

I think open science will be adopted much more widely in the future. As we have seen with the COVID-19 pandemic, sharing data and making data more accessible accelerates research.

How would you respond to someone who felt concerned that using an open notebook might expose mistakes made in research?

The point of research is to learn - learn what works and doesn't work. If someone exposes a mistake made in your research, especially in the open notebook I would consider that a plus. You have a chance to go back and address that mistake - make changes to your protocol or analyses and consider the data from another angle. I think that will make you a better researcher.

Do you have any advice for scientists at earlier stages of their careers?

Don't be afraid to fail. It happens, especially in the early stages of research for scientists. If you're not afraid to ask for help and keep trying, you'll make an excellent scientist!

(Personal communication with Sharon Hanna, March 14, 2021).

Chapter 3

Open Science in Action: Challenges

Last updated 2022-06-14

3.1 Introduction

If Open Science is so great, why isn't everyone doing it?

This next section looks at some of the barriers to practicing Open Science, in particular those areas related to transparency and reproducibility. It will also explore some strategies to overcome these.

Some of the issues we'll explore include:

Incentives and rewards

Awareness and training

Intellectual property rights

3.2 Incentives & Rewards

The Current Reward System

As we have seen, flashy science may trump good science.

Many of the underlying reasons for this are a result of the reward system in academia. The reward system in academic research has four main players: researchers, publishers, employers, and funders. Traditional research outputs (academic papers) are coordinated by publishers, while researcher rewards - tenure, wages, and grants - are handled by their employers, funders, and peers.

As you'll recall, journals want to publish exciting research. You could say this is good business sense - I mean, who wants to pay for a journal full of research articles that say 'we conducted an experiment, but didn't find anything.'?

Funders, as well, want their projects to achieve clear, novel, and measurable results; they obviously want to be able to justify *why* they invested in a given project. Interestingly, this often results in 'the next big thing' being awarded significant funding while the niche, but potentially novel project is overlooked. This is equally problematic for replication studies.

Employers want to know that their institution is having an impact - researcher funding dollars and researcher impact are proxy measures of institutional success and impact.

Researcher impact is gauged largely by the number of times their research is cited by others, the prestige of the journals they publish in, and the level of funding they can get. Thus, the rewards a researcher receives depend largely on the outputs of journals.

Journals want to publish exciting research. Funders want their projects to achieve clear, novel, and measurable results. Employers want to know that their institution is having an impact. Researcher impact is gauged largely by measures of citation impact.

You can see we have a bit of a quandary here.

Researchers may want to change their practices - say explore an unlikely, but potentially exciting avenue of inquiry, re-address an already published study and attempt a replication, or invest more time in making their research methods computationaly reproducible or undertake their next project with a level of care and direction that supports the needs of those impacted by their research - but if such changes negatively affect whether they're published - or where they're published - they risk falling out of favour with their employers or face greater challenges getting research funding.

At the same time, funders and employers struggle to find other ways to *measure* research impact to coordinate funding and to demonstrate value - citation metrics are the easy option.

Strategies for Change

Strategies for change centre on how *value* and *impact* are interpreted and understood in the context of research. And many large organizations representing researchers, publishers, employers, and funders have started to change the way in which they evaluate these factors.

Changes in Assessment Criteria

In 2012, the Annual Meeting of the American Society for Cell Biology in San Francisco gave rise to the Declaration on Research Assessment (DORA). This document calls on all parties involved in the research process to critically re-evaluate how research is assessed for merit. It has since turned into a worldwide initiative with thousands of individual and organizational supporters. You can read more about DORA here.

UBC is currently not a signatory, however.

Funder Requirements

Since 2015, the three major Canadian research agencies - the National Sciences and Engineering Research Council (NSERC), the Social Sciences and Humanities Research Council (SSHRC), and the Canadian Institutes of Health Research (CIHR) - have required that recipients of their research grants provide open access to the resulting papers within a year of publication. These same agencies are currently working on a similar policy for research data. You can read more about the Tri-Agencies Open Access Policy here.

UBC invests significantly in ensuring that researchers have the resources needed to be able to adhere to these funder requirements.

Journal Efforts

In 2014, the journal *Psychological Science* broke new ground by giving authors the opportunity to signal their use of open practices by awarding badges to their papers. Under the guidance of UBC Vancouver's Dr. Eric Eich, editor-in-chief of the journal at that time, authors began to receive badges for three types of OS practices: open data, open materials, and preregistration. These badges were then added as images to the paper.

Before badges were introduced, fewer than 3% of papers in *Psychological Science* reported that their data was open. By mid 2015, this percentage had grown by a factor of 13 to 39 percent!

— Badges to Acknowledge Open Practices: A Simple, Low-Cost, Effective Method for Increasing Transparency.

It would not be sound science to suggest that badging directly resulted in a 13 fold increase in open data - some of this data may have already been intentioned to be open. However, given the opportunity to signal that one is undertaking this open activity helps to encourage and normalize the process among peers.

So, while the full increase should not be attributed exclusively to badging, the act of badging made it possible to connect open data directly to published research findings, increasing transparency and reproducibility.

3.3 Awareness & Training

Most researchers today haven't been trained in Open Science practices. To be fair, they would likely agree philosophically with much of what we have thus far suggested engender open practices in the sciences - after all, much of Open Science is really just good science. But part of the history of Open Science is tied to the increasing use of computational resources in scientific practices - and what this means for both providing opportunities to increase transparency, reproducibility, and inclusion, but also for hindering each of these.

When it comes to adopting the set of practices enabled and potentially normalized by the tools, technologies, and services currently available to researchers, many researchers may not know where to start in terms of modifying their practices or adopting these tools and building the relationships needed for this kind of engagement.

And those in the later stages of their careers may think that the effort required to change is too significant a barrier to overcome, even if their graduate students try to engage them in talking about Open Science.

A Learning Curve

Learning a new way of conducting science involves time and effort.

Depending on where you are in your career, this time and effort is more or less valuable and easier or harder to come by. For example, longtime researchers may struggle with taking time away from their current responsibilities that have grown over the years, including managing students, administrative tasks, applying for grants, and teaching.

The fact is, Open Science practices involve investing more time at the start of a research project, because they require you to think through the entire project, collaborate in meaningful ways with research partners, map out what you're going to do, and to try to foresee where errors could happen so you can prevent them or soften their impact. However, the investment pays off in increased scientific rigour, less time spent on the end of the project, outcomes with greater social impact, and increased efficiencies in future projects.

Embracing Open Science education may also mean having to grasp new technologies, and some people, even in the sciences, feel discomfort with learning new tech.

Advocating for Open

To help researchers clear the learning curve, advocates of Open Science seek to make information about Open Science benefits, tools, and practices available to researchers at all levels.

Initiatives in this direction include

Free, easy-to-use tools that don't require coding Like OSF, a project management and networking site that allows researchers to display and interact with all products of their research.

Free storage for researchers Whether through third parties like OSF or Zenodo, or through their institution. At UBC, we have cIRcle for publications and Dataverse for data. We also have an institutional portal into OSF

OS education programs Including this one - at universities aimed at undergraduates, graduates, and early career researchers.

Mentoring programs That team a researcher experienced with OS methods with colleagues new to OS.

Courses in specific aspects of Open Science Such as those offered by the FOSTER portal (a project of the European Union).

3.4 Intellectual Property Rights

Our economy and legal system have long recognized the rights of creators of ideas, methods, products, and other brainchildren to own the products of their creation. These rights provide a strong incentive for research and innovation, both for individual creators and for society through the production of new knowledge, goods, and services.

However, as we know, Open Science also provides strong stimulation to the economy by improving the quality of science and industrial products and services, facilitating more rapid discovery, and making scientific knowledge broadly available to creators or potential creators.

Intellectual property rights and Open Science exist together in a tense but interdependent relationship; policy makers and all of the actors in the culture of science must work to strike a balance between these two concepts.

The Open COVID Pledge: IP for Free in a Time of Crisis

In April 2020, in response to the threat of the COVID-19 pandemic, an international coalition of intellectual property law experts, researchers, and tech giants such as Amazon and Microsoft launched the Open COVID Pledge to call researchers and research organizations to make COVID-related intellectual property available free of charge.

These efforts have sped the development of tests, vaccines, medications, equipment, and software.

Selling Open Science at the Neuro The Montreal Neurological Institute and hospital, aka The Neuro, has established itself as the first academic research institution fully dedicated to Open Science principles and practices. The Institute's activities include the Early Drug Discovery unit, which develops OS tools, technologies, training, and protocols with industry and university partners. The Neuro accelerates research and innovation by making its data and biological samples openly available and creating new intellectual property models for the marketing of open source discoveries.

However, the transition to Open hasn't always been easy - even at the Neuro. This five-minute video introduces Open Science changes happening at The Neuro. Dr. Guy Rouleau, the Neuro's director, discusses the difficulties involved in convincing researchers to adopt OS practices and the strategies used to achieve consensus on the decision to change the Neuro's practices.

3.5 Conclusion

Open Science encompasses a diverse set of principles and practices. How these are prioritized, articulated and implemented shifts between disciplines and contexts of practice. And we've only just touched on a few of these over the last several chapters. If you're interested in exploring in more detail how Open Science has been articulated in practice, an excellent resource is Open Science: One Term, Five Schools of Thought, by Benedikt and Sascha Friesike.

The tools by which we engage in Open Science are equally as diverse and context and discipline specific. However, we hope we have conveyed that certain over-arching approaches, however they may be implemented, set the stage for better science and better evidence. Keeping things organized and documented underpin reproducibility and communication. Using tools and computational approaches that ensure things are both machine and human readable facilitate accessibility and longevity - an extension of this, literate programming, will be explored in more depth in future classes. Re-framing research to be diverse and inclusive enriches the kinds of questions we ask, how we ask them, and the implications this research has on the world around us. Context and audience specific science communication increases literacies and helps to build partnerships.

In this module we've seen a number of challenges to the uptake and implementation of these principles. We've seen a number of examples of researchers and research teams at UBC and in Canada who have tried to overcome these challenges. We've also seen examples of policy and organizational efforts to persuade researchers to adopt these principles and practices and to adapt the ways in which they conduct research. Lastly, we've seen attempts at changing funding models and reward systems that help to shift how research efforts, inputs, and outputs are recognized and awarded. A shift of practice of this scale is not a small undertaking. As food for thought, we'll leave you with a visualization articulating what is needed to shift to Open Science from the founder of the Center for Open Science, Brian Nosek.

Embedded image. Source: Nosek, B. (2019, June 11). Strategy for Culture Change. Blog post.

Chapter 4

References

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