

## **Could Open Science stimulate industry partnerships in Chemical Engineering university research?**

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### **1.0 PROBLEM STATEMENT**

The hardest problems that engineers tackle, such as climate change, energy sustainability, food security, and water quality and quantity, cannot be solved without partnerships among universities, governments, and industry. These solutions must also be global, as low and middle income countries are particularly affected. In this Perspective, we ask the question whether the current and accepted framework for engineering research at Canadian universities is optimally structured to meet these challenges, and whether we should explore alternatives. We focus particularly on industry partnerships, knowledge translation and commercialization because these areas are central to creating societal impact from our work.

### **1.0 BACKGROUND**

To tackle real-world problems, partnerships with industry are essential. Industry brings expertise and funding, and provides critical knowledge about logistic and technical barriers to implementation of new inventions. Industry collaborations are also encouraged by universities and governments. Indeed, one of the Ontario government's ten new metrics of success for Ontario universities is the level of industry funding. Yet, the increased emphasis on industry partnerships in the university system and raises interesting questions about the academic mission. In the 6-page University of Toronto's "Statement of Institutional Purposes", the university states its primary commitment is to the principles of equal opportunity, equity and justice, and collaborations with industry are mentioned only once - as a means to contribute to the university's research aims. These perhaps conflicting aims raise interesting questions for academic engineers. How do we best ensure that our partnerships with industry conform to our academic mission?

To make real-world impact, it is also important to transfer knowledge from the universities to the private sector. And while by far the greatest economic impact of universities is contributed indirectly by our graduates entering the work-force, in recent decades there has been increased emphasis on creating more direct economic impact, including through spin-off companies. This emphasis has been supported by government innovation policies, which emphasize the value of intellectual property, as well as by the new attention on university rankings, which use patents as a proxy metric of innovation. The prevailing narrative is that

university patents are needed to drive innovation and investment, and to ensure returns on investment for taxpayers. And while patenting may stimulate some local economic growth through the creation of spin-off companies, in patenting, universities are also helping prevent the broader commercial application of the invention and its derivatives, including by scientists and engineers in developing nations. Indeed, in focusing on the few local commercial successes that might have been enabled by a patent, we are perhaps ignoring the bigger picture. [1] Nearly all universities lose money protecting their intellectual property, and the requirement to maintain confidentiality prior to patenting necessitates withholding data from peers, and not discussing ideas outside confidentiality agreements. On balance, how do we ensure that our innovation policies at universities are truly serving the common good?

These issues are particularly relevant for chemical engineers, whose expertise is central to solving many of society's big problems. Here, we argue that adopting an expansive open science view would not limit innovation, but would in fact attract more industry funding and create more opportunities to spin-off companies while also better aligning with our public good mission of the university.

## 2.0 WHAT IS OPEN SCIENCE?

Open science encompasses many related terms, from open dissemination of data and publications, to openly sharing all research data and material in real time (Figure 1). Generically, open science is sharing all information in the research process, as early as possible, and making the output available without restriction on use. At the cutting edge, open science also involves diminishing or even eliminating the use of restrictive intellectual property (IP), such as patents. [2]

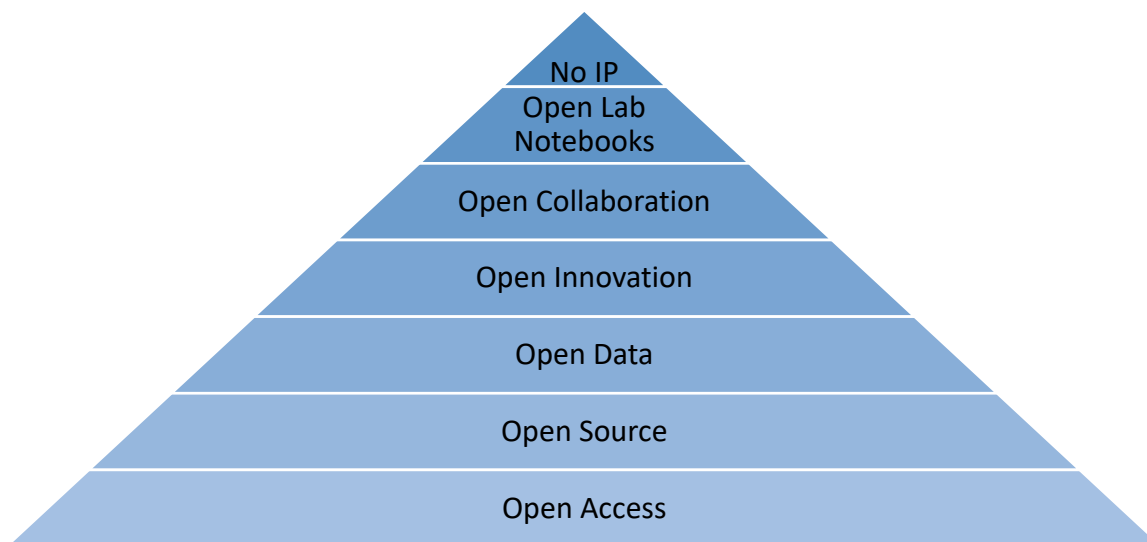


Figure 1: Open Science encompasses a range of related terminology and practices

As reflected in the base of the pyramid in Figure 1, the most widely discussed component of open science relates to publishing in Open Access journals and removing paywalls to reading such articles. Open Source is widely implemented in the context of computer software. Open

data includes the use of pre-print servers such as ArXiv and bioRxiv, and publicly accessible data repositories of all kinds (NCBI, GitHub, Zenodo, T-space, web-pages, and many others). Open innovation is a term that is applied to two or more organizations that collaborate to meet an objective, but are still free to file patents jointly and do not have to share the output broadly. Open collaboration, Open lab notebooks and not filing for IP are the most extreme embodiments of the Open movement.

## **2.1 Open Science – current focus is on academic output**

The discussion of open science in academia is currently dominated by the publication system, and how and when publications and data should be made available to the public. In the academic environment, there is now broad support for the idea that academic publications should be made available to the public soon, even immediately, after publication. However, full implementation will require a re-think of the current publication system which is dominated by for-profit publishers and non-profit learned societies, both of whose income derives mostly from publication fees. In essence the debate is not whether academic publications should be made available immediately, but simply who pays for the real costs associated with publishing. The debate is also currently complicated by the fact that many of the for-profit publishers, whose business model is currently inconsistent with immediate open access, control some of the journals held in high esteem by academics, who in turn resist efforts by funders to mandate their publishing in open access journals. A new business model will undoubtedly emerge in the next few years, and in the meantime, making late versions of papers freely available on pre-print servers offers a temporary solution.

The other dominating issue relates to data, and to its availability and reusability. [4] The concept of FAIR (findable, accessible, interoperable and reusable) has emerged as a driving principle in this area. And while there is now general support for the idea, there are few labs and universities that have the infrastructure and resources to make their data conform to these principles, and not even broad agreement about which data are valuable enough to share.

## **2.2 Our academic reward system is slowing progress toward open data and publications**

One of the most significant obstacles to the aims of open science is the current incentive system for researchers. The academic system greatly rewards “discovery”, defined as the first to publish. Much less attention is given to those that do the detailed, foundational work, to those that reproduce discoveries or correct incorrect discoveries, and to those that contribute knowledge outside the traditional academic venues. The fear of being scooped and the personal and professional rewards in being “first” cause many to be reticent to share their data, even after publication. This culture is exacerbated by the emphasis on bibliometrics and other publication metrics in promotion, hiring and funding. Few of these structures truly recognize the value of open science or reward sharing. [5] The aggregate result of these incentive systems is that research becomes about achieving higher metrics, such as publishing in journals with high impact factors, and not about widely disseminating scientific discoveries. This is most evident in early career researchers, who aim to publish in well-known journals to boost their reputation and advance their careers. [5]

The concerns surrounding traditional metrics have become well known, and high-profile efforts have tried to address them, such as the San Francisco Declaration on Research Assessment (DORA). [5] DORA signatories promise to assess research on its own merits and to end the use of Journal Impact Factors (JIF) in funding, hiring and promotion decisions. DORA currently has 2022 organisational and 16,376 individual signatories. [6]

The Canadian science and engineering communities have not been significant players in open science. The Canadian tri-councils only signed DORA in 2019, and many Canadian universities are yet to sign. [7] And while the United States and European governments have made significant commitments to data sharing over the years (NCBI, EBI) and the European Commission is pushing Plan S, a policy that will mandate that any publication funded by the EC must be open at time of publication, the Tri-Council funding agencies mandated open access only in 2015, and they required only that any peer reviewed journal publications arising from full or partial agency support be freely accessible within 12 months, which is among the longest period of any country with an open science policy. [8 – 9] Canada is now making more of a push toward open science, and the federal government released a Federal Roadmap for Open Science. However, this relates only to federal department research, and it is not clear how or if the government will ensure compliance, or will provide the resources to implement. [8]

### **3.0 OPEN SCIENCE, INDUSTRY AND COMMERCIALIZATION**

Most of the important global problems must be tackled in partnership with industry. These collaborations introduce complexity in trying to balance the interests of industry with academic freedom, and on how to share any future intellectual property rights and any commercial benefit. These complexities are based on the premises that industry requires intellectual property rights and that patents are important for the university mission. We argue that neither premise is strongly supported by the evidence.

There are many preconceptions about intellectual property and its role in translating research and attracting industry partners, and that there is a strong argument that adopting a more expansive view of open science, in which we partner with industry only on projects that eschew patents, will allow academic engineers to create greater social and economic impact. [9]

Examples of common misconceptions are provided below.

#### **3.1 Industry and other end-users require IP to collaborate.**

Conducting research in partnership with industry or other end-users is clearly beneficial, particularly in engineering. Funding mechanisms to leverage such partnership are common. However, there is a frequent misconception that a main reason that industry seeks these collaborations is to obtain and protect IP. By contrast, multiple surveys of research managers in industry rank intellectual property rights as lower priority than access to new ideas, know-how and technologies, and tacit knowledge through direct interactions with researchers. In a survey of 355 firms participating in Engineering Research Centres in the US, only, only 15 per cent reported that the ability to license inventions and/or software as a motivating factor in their decision to participate. [10]

Of course, if either the university or the industry partner(s) seek intellectual property, then the other will insist on equal rights. But the inference that industry would not partner in the absence of IP rights is not borne out by the evidence.

#### **3.2 Governments require researchers to protect IP and to file patents.**

The Bayh-Dole act, which ceded intellectual property rights from U.S. federal funders to universities, and is the international model for technology transfer, makes no requirement for

university researchers to patent. It merely requires the universities to use best efforts to transfer technology to the community *if* there is a patented invention. Similarly, in Canada, although federal or provincial laws also do not require university researchers to patent, government innovation policies and university rankings emphasize patenting as a metric of innovation, and this creates an incentive for universities to file for patents. Accordingly, many universities have employment contracts that require employees to disclose to the university of any potentially patentable invention, and documents produced by university technology transfer and commercialization offices (TTOs) emphasize the need to report and file invention disclosures for every new “discovery”. [11] Many academics believe that their universities enforce these policies or that they will be in breach of contract if they do not comply. The reality is that TTOs at Universities are highly supportive of open science, and the requirement to disclose inventions has never been enforced (and is likely also unenforceable). Publishing papers and reports, presenting seminars and workshops and at conferences and teaching remain the primary means of dissemination of University research. Nevertheless, patenting has become ingrained in researchers’ way of thinking. [11]

### **3.3 University patents are required to start a company from University Research.**

Universities create the most local economic impact passively through their graduates. In recent years, government have been promoting the concept of universities as more active participants in the innovation process, and focusing on technology start-ups as a visible consequence. The start-up innovation narrative classically involves a patented university invention, venture capital investment and a new spin-off company. While this story can be true, and should be celebrated, it is far from the norm. In fact, in a study of almost 2,000 professors in the U.S. who had started a business, two thirds launched the company without a patent. [12] In Canada, at the Montreal Neurological Institute (see Section 4.0), of 15 spin-off companies, only 7 were formed around a foundational patent, and of these only one reported that the patent was a key part of their business.

It is critically important on this point to distinguish patenting strategies for research done at a university (in collaboration with a company or not) from research done entirely within a company. University, particularly public universities, patent as one means to promote technology transfer, and licensing income is merely a potential consequence, not the driver - patents are not essential to the university mission. By contrast, patents are one of a number of tools used by companies to compete in the marketplace. Patents may be necessary for companies when taking a large financial risk to complete the invention to make it suitable for market [13], or can serve act as bargaining tools in negotiations, and can serve as a proxy measure of corporate innovation to investors. Patenting also correlates with company growth; small and medium sized enterprises (SMEs) that obtain patents are more likely to grow into larger companies; SMEs with patents are also four times more likely to export their product. [13]

### **3.4 Patents are easy to file.**

Academics who have been through the patent process almost universally agree that it was more time-consuming than imagined, especially if the invention resulted from a collaboration. In some cases, decisions about inventorship can cause distress. Furthermore, patents need to be filed in multiple jurisdictions and filing, maintenance and litigation fees can quickly add up. Initial patent applications can cost from \$5,000 – \$15,000 in Canada, in addition to similar costs incurred to file in the US and Europe [14] - and this does not include maintenance fees, and patent litigation. [14]

And what about the returns? Ninety seven percent (97%) of patents do not recoup the cost of filing them, [15] and in terms of university patenting, nearly all technology transfer offices lose money for the university. To be fair, this economic analysis does not account for the economic impact of the start-up companies that were based on university patents, but it also does not factor in the hidden costs associated with the intention to patent, such as the requirement for ancillary legal contracts, such as material transfer agreements (MTAs).

MTAs are contracts that provide legal provenance over materials transferred between legally distinct institutions. Canadian universities and hospitals execute over 5,000 MTA's each year. On average, they can take months to complete. The economic cost to the research system in time and lost opportunity is not inconsequential. Five weeks for each of 5,000 MTAs inserts ~500 person-years of delay to research and translation.

### **3.5 Open science will not benefit Canadians**

Government investments in university research are correlated with growth in the knowledge industries, and there is an idea that by not protecting the university's intellectual property, the benefits would flow to other countries. Let us set aside the arguments that in fact the role of the university is to benefit others, and that our responsibility as one of the wealthiest nations on earth to be generous with our knowledge, and focus on the economic case. It is in fact difficult to track how much local economic benefit results from licensing activity, as compared to benefiting from general flow of people and knowledge from the university to the local environment. There are indeed counter-argument that by creating an open science cluster with industry, there will be more economic spin-offs. What is certain is that patenting and licensing a technology to a local start-up does not in any way guarantee that the technology will developed, and create high-quality jobs and tax revenue, in Canada [4].

## **4.0 EXCEPTIONS PROVE THE RULE: OPEN SCIENCE ATTRACTS INDUSTRY PARTNERS**

We imagine working collaboratively with industry partners to tackle important problems, and to structure these collaborations according to open science principles in which all the output will be placed into the public domain, without restriction one use and without patents. And while this might seem unusual, there are many Canadian projects that are implementing this strategy.

The Structural Genomics Consortium (SGC), the Montreal Neurological Institute (MNI), and Meds 4 Kids (M4K Pharma), all with strong ties to the pharmaceutical sector, have explicitly embraced open science with a mission to accelerate medical discovery or to price medicines more affordably, and with a commitment not to patent any of their research.[2, 17-18] SGC and the MNI primarily focus on the discovery process of medical research, while M4K aims to complete the entire research and development process – from early drug discovery to a final commercial product. [16] These initiatives, which practice open science in perhaps the discipline most concerned about IP, are a model for other disciplines. Their efforts include other open science innovations, including open lab notebooks and bespoke collaboration agreements that facilitate data sharing.[2, 17-18] Notably, despite an aggressive commitment to open science, a large fraction of the research funding for these projects derives from the private sector, including SME's, who participate to openly showcase capabilities to clients and provide training opportunities. [17]

These new industry partnerships explicitly adhere to and promote open science, but there are also long-standing academic-industry research partnerships in engineering that have followed open science principles without explicitly stating so in their vision or mission. The Pulp and Paper Centre (PPC) at the University of Toronto is a prime example. [18] The PPC has not filed for a patent in 20 years, but has been funded continuously by over twenty companies in that sector.

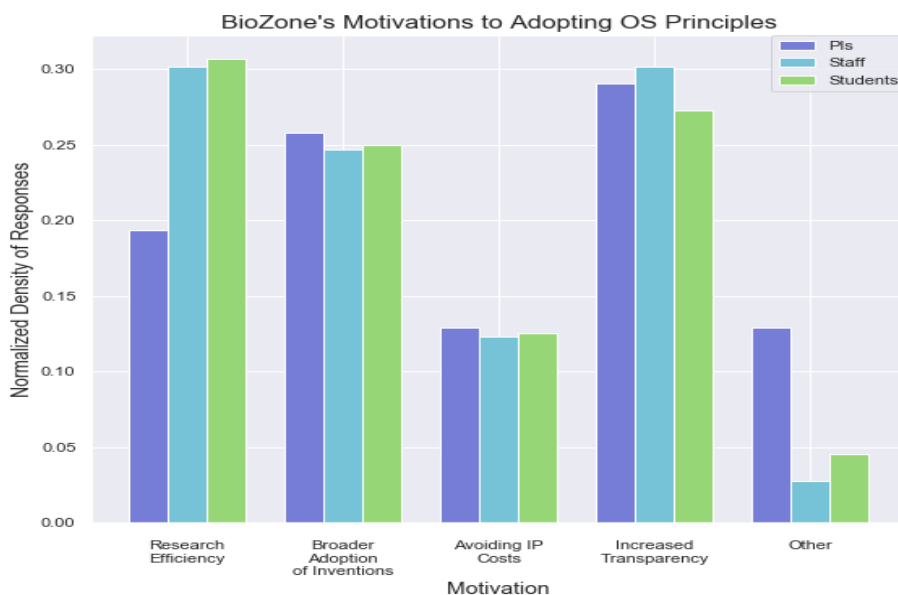
Why do the companies continue to support the PPC? The PPC attracts industry because together they work on important problems that encompass fundamental principles, and are relevant and common to all companies. [19] The PPC engages the industry partners at every step, working side-by-side, providing transparency and thus ensuring that the research is accurate and trustworthy. Each year 30-50 students are closely engaged with their partners in industry, including frequent mill visits, culminating in an annual 3-day November meeting attracting consistently more than 20 companies for decades, irrespective of economic downturns. The primary reasons the companies keep returning to the PPC are: to get basic and fundamental understanding of operational and technical problems they are facing; to distribute the cost of addressing problems together, through a consortium; to share industrial experiences and to learn from one another; and to meet students. Notably, intellectual property ownership through patents is not their priority.

BioZone, which is a Bioscience and Bioengineering Research Centre within the Chemical Engineering Department at the University of Toronto, [20] provides another example where several academic-industry partnerships have been consistent with open science principles. BioZone comprises ~9 professors and over 100 students and research staff with a wide range of expertise, and who work in open shared space to encouraging wide ranging and interdisciplinary discussions. Officially inaugurated in 2011, the driving force behind BioZone was to find a way to effectively capitalize on the tremendous advances in genomics and associated technologies, with application in the circular bioeconomy.

Like many engineering groups, BioZone works closely with industry. Indeed, over the past decade, more than 30 industry partners have contributed \$2.5 million in funding to support collaborative projects. The vast majority of the research has been simply published and disseminated through presentations at project meetings, and relatively few patent applications have been pursued. But we'd like to do better. This thinking has prompted us to embark on a program to explore the various levels of open science principles in BioZone. Our vision is to create an environment conducive to working with industry on "global" problems and our idea is that by committing to open science principles we might both more easily collaborate with leading industry scientists, and also more effectively translate research into practice. The first step in this process is being supported by a new CREATE training grant from NSERC. Using this funding, we will develop data fluency, entrepreneurship, communication and leadership skills through the lens of open science. Together with our students and colleagues in law, we will attempt to define metrics for evaluating true impact in engineering. We held our first workshop on Open Access and Publishing in January 2020 (<https://www.biozone.utoronto.ca/news/nserc-create-open-science-workshop-on-open-publishing-and-data-sharing/>) and plan a second workshop on Open Science and Innovation that was temporarily postponed due to COVID-19.

Over the 2020 summer, three law students worked together with students from Chemical Engineering to explore perceptions of open science within BioZone. They conducted a survey to evaluate and try to understand perceptions of open science among members of BioZone.

The survey obtained 67 responses from 10 Principal Investigators, 27 Staff members, and 30 Students. Open science was perceived very positively among all who took the survey.



**Figure 2:** BioZone’s motivations to adopting open science practices. The y-axis displays the proportion of responders within respective groups: dark blue for *Principal Investigators*; light blue for *Staff*, and green for *Students*.

“Research Efficiency” and “Increased Transparency” were the most frequently selected reasons for adopting open science principles (Figure 2). In this case, both received over 80% of all survey responders’ votes, with “Broader Adoption of inventions” coming in as a close third.

Our BioZone survey also revealed that some researchers are afraid of being scooped, particularly if they practice open science. This fear is generally pervasive among academic researchers, and is in large part a consequence of the same misplaced incentive structures rewarding first report of a discovery in a high impact factor journal and devaluing high quality and confirmatory results. But consider for a moment if research were truly open? We would then know what others are doing and thus less likely to be in a position to get scooped and more likely to collaborate effectively. Open science may actually reduce rather than exacerbate this concern.

## 5.0 FINAL COMMENTS

Reflecting on collective years of research at the University of Toronto, we have come to the following observations:

- Research is difficult; to get reproducible, defensible, interpretable data takes a long time and a lot of money. And it is a collaborative endeavour – we all build on what has been done before.



- Our industry partners recognize that research is difficult; they want to learn too, just like us, and wish for clear results and freedom to operate
- Often it is difficult to reproduce results from published data or paper is missing critical information... What do you do then?
- It is difficult to publish negative or contradictory results. But if you don't publish what didn't work, it will get repeated....
- The pressure to publish "trendy" work in "widely read" journals are real, although we know that peer review is not a "truth serum."
- There is little recognition for publishing datasets or detailed protocols, or for making reagents available, or publishing negative results (except perhaps in PhD theses).

We at BioZone are looking to try to do things a little differently by adopting open science principles, particularly with respect to publications, data deposition and not filing for patents. The sudden and urgent need to share research brought to light with the COVID-19 pandemic might be just the push that we need to realize that open science is actually the best approach *to solve major urgent challenges we are facing*, including climate change and sustainability. A first consortium is being considered around a community of practice in Anaerobic Digestion (AD), bringing industrial, municipal, government and academic partners together to bridge fundamental knowledge of the AD microbiome with process performance, and to expand the applications of the technology for Canada. Other consortia are also being considered around CO<sub>2</sub> fixation and the circular bioeconomy. We would love to hear from other groups who are interested in signing up to open science as well, so that perhaps together we can develop and share best practices for effectively translating academic research to solve big problems. We welcome your participation.

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