A Study on Commercialization Postdoctoral Fellowships

Whitepaper

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Mandate

This study was commissioned by Mitacs Canada in 2022, with a mandate to examine the landscape of existing models of commercialization-focused postdoctoral programs for STEM researchers. This study finds a significant need for support for training postdocs as key players to help close the research translation gap in Canada and proposes the development of an Invention to Innovation (i2I) Commercialization Postdoc focused on the early translation and knowledge mobilization stage, using established Mitacs i2I programming as a foundation, working with the existing postdoc models under the umbrella of Mitacs in Canada.

Key Insights – Fostering Science-based Innovation at Canadian Universities

The need to accelerate research from Canadian university labs toward societal impact has never been greater. Science-based innovations – those founded on engineering, scientific, and medical discoveries as opposed to software or business innovation – are critical to tackling the most complex and urgent challenges facing the world, including climate change, sustainable energy, pandemics, equitable access to healthcare, and water and food security. Science-based innovations, however, face much higher levels of prolonged uncertainty and higher resource requirements leading to significant challenges in creating and capturing value, requiring tailored approaches to skills development and innovation support.

The current Canadian innovation ecosystem is more conducive to software and business products that can typically reach the market in three to five years. However, it is less amenable to science-based innovations emerging from universities which require much more time, and sustained commercialization training and funding supports to reach their outsized potential impact. Often overlooked in the discussion is the importance of the earliest stages of science commercialization, where many of the key translational and strategic decisions are made that will impact the ability to create value in the future while the technology is still in the academic lab.

The peer-reviewed research over the past decade, along with the qualitative evidence gathered for this report, highlights the potential embodied by Canada's highly trained postdocs and suggests that well-funded talented postdocs supported by focused innovation training and entrepreneurial mentoring can become key enablers in unlocking the science-based innovation potential of Canada's academic institutions and government research labs. However, limited nationally accessible support has been found, and a gap has been identified in the translational space where a targeted translational postdoc program leveraging existing solutions could provide the necessary innovation skills, culture change, alignment of incentives, and capacity needed to catalyze the earliest stages of Canada's innovation ecosystem, complementing other offerings.

Existing Solutions

Several models of commercialization-focused STEM postdoctoral programs exist or are under development, in the US, the UK, and Canada. By examining existing programs, this study suggests four main components of postdoctoral supports that can facilitate enhanced knowledge mobilization and research translation outcomes.

- **Postdoc Identification and Support** – Principal Investigators (PIs), their graduate students, and postdocs play a central role in the translation of science out of the academic research lab. Identifying projects and scientists to advance transformational science, such as cleantech, materials, advanced manufacturing, quantum computing, biopharmaceuticals, genomics, and others with significant potential for translation to impact is key to program success.

- **Innovation Training** – Innovation management research provides evidence that early-stage development of entrepreneurial mindset; IP strategy, prioritization of markets; and strategy development inform the foundation of strong ventures, labs, and industry projects; however, the most impactful pathways for translational scientists are often not known or fully assessed when these decisions are being made.

- **Networking and Mentoring** –Mentoring by industry experts with experience in early-stage commercialization can help build collaborative networks that foster co-creation and technology refinement through the development of a better understanding of unmet market needs, regulatory pathways, and future opportunities.

- **Access to Facilities and Additional Flexible Supports** - Translation of science-based technologies often necessitates sustained access to experts and equipment that reside within government facilities and university labs.

While existing programs are making significant contributions in their respective spaces, some gaps have come to light. The models in the US and the UK are largely venture-focused and encourage venture formation within a short period of time (often one to two years). Such an approach, which accelerates venture-formation, may not be suitable for the range of uncertainties encountered when translating scientific ideas, particularly breakthrough ideas which may hold the most potential for long-term societal impact.

Programs currently available in Canada are focused toward either industry-sponsored projects, which are rarely aligned with the timelines of radical scientific advances, or venture-focused models which require a certain level of market-readiness, the detachment of IP from the science-base, and the appropriateness of a venture business model. While important components of the Canadian innovation ecosystem, existing programs are currently not typically designed to support the early-stage exploration of ideas, strategies, and the range of commercialization or translational models appropriate to science-based innovation, leaving a significant support gap between research and existing programs.

Capacity Building – Growing Canada's Capacity to Innovate in Three Ways

Mitacs has decades of experience supporting the development of innovation skills through training engaged with the innovation community and has collaborated to create the Mitacs invention to Innovation (i2I) program, specifically designed for the translational space. The Mitacs i2I draws on extensive research on science-based innovation and has been carefully designed to train entrepreneurial scientists with a world-class capacity to identify and exploit opportunities across the entire breadth of Canada's innovation ecosystem. Our data analysis and experience points to a need for three interoperable categories of innovation-trained scientists:

- **Industry Champions** – Canadian industry has consistently lagged other OECD nations in R&D expenditures and productivity gains over time. Innovation-trained postdoctoral experts are uniquely qualified to increase the capacity within industry, including science-based companies, government, and innovation intermediaries, to onboard the new ideas and technologies required to bridge this productivity gap.

- **Venture Founders** – Entrepreneurial STEM postdocs have a unique combination of high levels of scientific training, passion for innovation, and freedom from career constraints such as focus on a doctoral thesis, or teaching obligations that may hold back many graduate students and PIs. These advantages over PIs and graduate students are reflected in observed science-based venture outcomes led by postdoc founders.

- **Translational Scientists** – Innovation-trained postdocs possess the skills to identify, develop, and exploit basic research that has significant potential for commercialization and societal impact. With tenure-track academic positions often being the leading choice for most postdocs, such innovation-trained postdocs-turned PIs are keenly focused on knowledge mobilization and spearhead the translation of scientific research from the academic lab. As PIs they also play a significant role in mentoring researchers in their lab who may then go on to form their own science-based ventures. These scientists can thus have an outsized impact on society over the longer term as has been identified in recent research.

Given the clear need for flexibility to determine the best strategy during the critical early stages of translation and commercialization, these three categories of innovation-trained scientists can provide Canada with a comprehensive set of solutions to address the uncertainties in the science commercialization process with the industry champion being the short-term, the venture founders being the medium-term, and the translational scientist being the long-term solution.

Core Recommendations

The implementation of a commercialization-focused STEM Postdoctoral Fellowship by Mitacs, focused on this early stage, is well-aligned with Canada's strategic innovation goals. Science commercialization and the adoption of new technologies by industry is a focus of ISED's lab-to-market platform, the multibillion-dollar ISED Strategic Innovation Fund (SIF) and of the Canada Innovation Corporation (CIC).

A Mitacs i2I commercialization postdoc fellowship program, focused on the underserved translational space, will build a pipeline of entrepreneurial postdocs who will help unlock and mobilize the knowledge within our nation's research labs that can help meet our national innovation goals and complement existing programming. We recommend the following supports and program components:

- **Commercialization PostDoc** – A two-year post-doctoral fellowship for STEM researchers (including HQP in physics, chemistry, chemical engineering, environmental sciences, genomics, materials engineering, and other science innovation-enabled disciplines) with a competitive stipend to focus on the de-risking of their scientific inventions.

- **Innovation Skills Training for Scientists**: Each fellowship awardee will receive innovation training to enable the development of entrepreneurial mindset and innovation skills and be accountable to advance their research translation through the Mitacs i2I

- **In-kind Commercialization Support** – In-kind support for postdoc fellows to access university or government research lab facilities (provided directly to the fellow by the host institution) to: de-risk technologies, develop IP and IP strategy, and develop marketing strategy.

- **Mentoring and Networking Facilitation** – Bespoke industry-specific entrepreneurial and scientific mentoring on an ongoing basis for each fellow, consisting of regular in-person events facilitating collisions between fellows, industry, research experts, government representatives and investors or funders.

Projected Outcomes and Impact

This program will have direct and significant impacts, catalyzing the translation of transformational science-based research at this underserved stage, transforming the culture of labs, and changing the mindsets and career trajectories of the participants.

Academic literature findings and tracking of Mitacs/SFU i2I Innovation Training graduates since 2014, indicate that the program will generate enhanced levels of knowledge and research translation within academic labs, and develop valuable capacity to identify and exploit innovation opportunities within government agencies, Canadian high-tech industries, and the investor community.

These metrics can be directly measured through translational grant success, additional IP filings, dollar value of IP licensing, secondary venture creation in labs hosting an i2I Commercialization Postdoctoral Fellow, and by career attainment of fellows that subsequently enter industry or take up translation-focused roles in the Canadian innovation ecosystem.

Based on our secondary data survey of existing programs in other jurisdictions, we project that the i2I commercialization postdoc fellowship program will generate significant measurable economic benefits in excess of program costs in the form of investments in new and growing ventures, major industry investment, and FTE creation within Canada. Developing the entrepreneurial capabilities of researchers in university labs can create engines of research and commercialization that unlock significant long-term impact for Canada.

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1. Introduction

The recent COVID-19 pandemic has highlighted the importance of knowledge mobilization and science commercialization in the rapid translation of academic research in response to complex, emerging challenges facing society (Park et al, 2022). In most instances, these solutions can be traced back to breakthrough inventions by principal investigators, graduate students, and postdoctoral fellows in the academic lab many years pre-formation (Thomas et al, 2020). Postdoctoral fellows are increasingly being recognized as playing a central role in science commercialization and yet most STEM postdocs have limited access to the innovation training needed to translate academic science into innovative products, solutions, and services addressing significant unmet societal needs (Johnson, 2018; Mitchell et al, 2013).

Canadian postdoctoral researchers represent a class of knowledge workers with an outsized capacity to contribute to the success of our nation's innovation ecosystem. Several high-profile programs internationally, as well as a few programs within Canada, have focused on harnessing the potential of postdoctoral researchers through innovation training. By examining the training and funding components of existing programs we see a significant gap in the early stages of science commercialization when translational research is still ongoing in the academic lab and appropriate pathways are still being assessed. This work highlights the need for a postdoctoral fellowship model that complements existing offerings and fills this gap to enhance science innovation in Canada by leveraging postdoctoral fellows and the intangible assets of Canadian research institutions.

Through this study we demonstrate that:

- Canada's postdoctoral Highly Qualified Personnel (HQP) has significant unrealized innovation potential.
- Existing research funding support in the form of postdoc salaries and stipends is fragmented and impacted by high levels of inflation and has not kept pace with the increasing number of postdoctoral fellows.
- The commercialization of scientific research from universities faces unique challenges that require carefully designed training and funding supports that allow refinement of research while advancing translational goals.
- The academic inventor/ scientist-entrepreneur is not well-aligned with most existing programs and access to funding supports may be limited by well-intentioned but inappropriate matching funding requirements in Canada.
- Legitimizing impact-focused translation and commercialization of scientific research in universities is an important step towards building a robust innovation culture within academia.
- Similar programs in other nations indicate the importance of nationally available commercialization-focused STEM postdoctoral training and funding supports, as well as the distinct movement away from matching requirements at any stage of the process.

- Existing solutions pre-suppose a route to translation by requiring the formation of a venture or an industry project, whereas attention is needed at the stage before those decisions are made.

- The proposed approach allows for broad benefits beyond venture creation by also acknowledging the need to have industry champions and translational scientists.

- The creation of a postdoc model that combines a successful innovation training program, such as the Mitacs i2I, with a funding model more appropriate for science-based innovation, can help alleviate many of the tensions preventing better translation of Canadian research into impact.

Such a model can serve as a foundation for broader and deeper innovation from academic settings while proving complementary to existing models.

2. Objectives and Methods

The study is motivated by observations that significant gaps exist in our nation's training and funding supports for STEM postdocs (Advisory Panel on Federal Support for Fundamental Science (Canada), 2017; Charbonneau, 2018). A recent report specifically highlights the training and funding challenges faced by postdoctoral fellows and early career researchers and recommends the identification of training supports to help build the innovation skills of these researchers for the translation of scientific research into societal impact for Canada (Innovation, Science and Economic Development Canada, 2023).

2.1 Objectives of the Study

This white paper is part of a Mitacs-funded study commissioned to examine commercialization-focused STEM postdoctoral fellowships and suggest a training and funding model better suited to the needs of the Canadian science innovation ecosystem and designed to enhance the capacity of Canadian postdocs to translate their scientific research for societal impact.

2.2 Methods

Given the exploratory nature of the study, the research team conducted an in-depth literature review on science commercialization from university settings with a specific focus on the translational role of postdoctoral fellows in this process. The team also compiled and analyzed secondary data on commercialization-focused STEM postdoctoral programs in the US, the UK, and Canada. The team conducted extensive, in-depth interviews with a range of science-based innovation ecosystem stakeholders, the learnings from which were combined with insights gained from the delivery of the existing Mitacs/SFU i2I innovation training program, launched as a graduate certificate in 2014 and a national skills training initiative in 2019. A focus group and workshop event, bringing together a diverse group of stakeholders, was also conducted to get feedback on initial research and collaboratively refine a commercialization postdoctoral fellowship model specific to the Canadian science innovation context.

This rich synthesis of qualitative and quantitative data enabled the team to uncover gaps in current postdoctoral funding models and assisted in identifying challenges to, and opportunities for, science-based innovation within Canadian research institutions.

Phase 1

The study began with a focused literature review supplemented with an analysis of current commercialization-focused STEM postdoctoral programs and supports. The team gathered secondary data and compiled metrics on five existing commercialization postdoctoral fellowships: Cyclotron Road (US), Research Runway (US), ICURe (UK), the Scientific Venture Program (QC), and the Innovation Catalyst Grant (AB). We also compiled outcome metrics from the SFU and Mitacs i2I cohorts since 2014 and 2019 respectively, as it specifically focuses on the early stage of science commercialization. This approach enables a qualitative examination of how a Mitacs i2I commercialization postdoctoral fellowship can enhance translational success if implemented.

Phase 2

The research team further uncovered the barriers and challenges faced by stakeholders through an extensive series of 50 interviews with program designers and delivery personnel, program participants, PIs, university administrators, granting organizations, and investors (Table 1).

Finally, the research team conducted a university-wide focus group at the Dunin-Deshpande Queen's Innovation Centre to bring together key stakeholders in a collaborative setting to validate and extend the research findings and inform the recommendations for a commercialization postdoctoral fellowship for STEM researchers in Canada.

Table 1: Stakeholder Profile and Number of Interviews

STAKEHOLDER	NO. OF INTERVIEWS
i2I Innovation Training Participants & Postdoc Spin-off Founders	15
Faculty Researchers	16
University Administrators	6
Program Developers	9
Investors and Funders	4
Total	**50**

3. The Science Commercialization Imperative

It is increasingly being recognized that the commercialization of science from university and research institutions offers pathways to address some of the most pressing challenges of our time (Standing Committee on Science and Research, 2022). Central participants in the commercialization of science from university settings are the principal investigators (PIs), graduate students, and postdoctoral fellows (Thomas et al, 2020).

Postdoctoral fellows have completed their PhDs and are in an extended training period during which they work closely, sometimes for several years, with their PI and academic peers. As highly qualified STEM personnel, postdoctoral fellows are important contributors to the science commercialization effort particularly as many PIs prefer (and in fact, are encouraged) to focus on academic goals in the lab, and graduate students are encouraged to focus on their doctoral dissertations (Johnson, 2018). Moreover, grant peer-review, renewal/tenure/promotion frameworks, and culture are primarily focused on publications and HQP academic research training, with the culture slowly shifting as granting agencies and the academy implement the San Francisco Declaration of Research Assessment (DORA). While the tri-council agencies in Canada have adopted the DORA, few universities in Canada have formally adopted this agreement, and culture change within the academy is slow. This section outlines the unique challenges in the science commercialization process and uncovers the critical role played by postdoctoral fellows in this process. The section further discusses the state of postdoctoral fellows in Canada and identifies the main challenges they face. This section thus provides the context within which to situate the further examination of commercialization-focused STEM postdoctoral fellowships.

3.1 The unique challenges in science commercialization

Science-based innovation is increasingly recognized as having significantly higher levels of scientific and market uncertainties and long development timelines (Maine and Garnsey, 2006; Pisano, 2006; Pisano, 2010; Maine and Thomas, 2017). Science-based innovations such as in the biotechnology, nanotechnology, or advanced materials sectors often spend more than a decade percolating within academic and government labs before their value is recognized (Pisano; 2006; Maine et al, 2014; Maine and Seegopaul, 2016; Maine and Thomas, 2017; Thomas et al, 2020; Park et al, 2022).

Figure 1 further elaborates the higher levels of uncertainty, R&D and commercialization costs, and commercialization timelines of science-based ventures or projects when compared to standard technology ventures. This development lag time prior to venture formation is only partly due to technological development hurdles. Science-based inventions are often generic in nature and have broad applicability across many different markets (Maine and Garnsey, 2006). In such cases, the problem of identifying a first application requires the confluence of a deep understanding of the technology along with a significant knowledge of the challenges in bringing breakthrough products and services to a specific market.

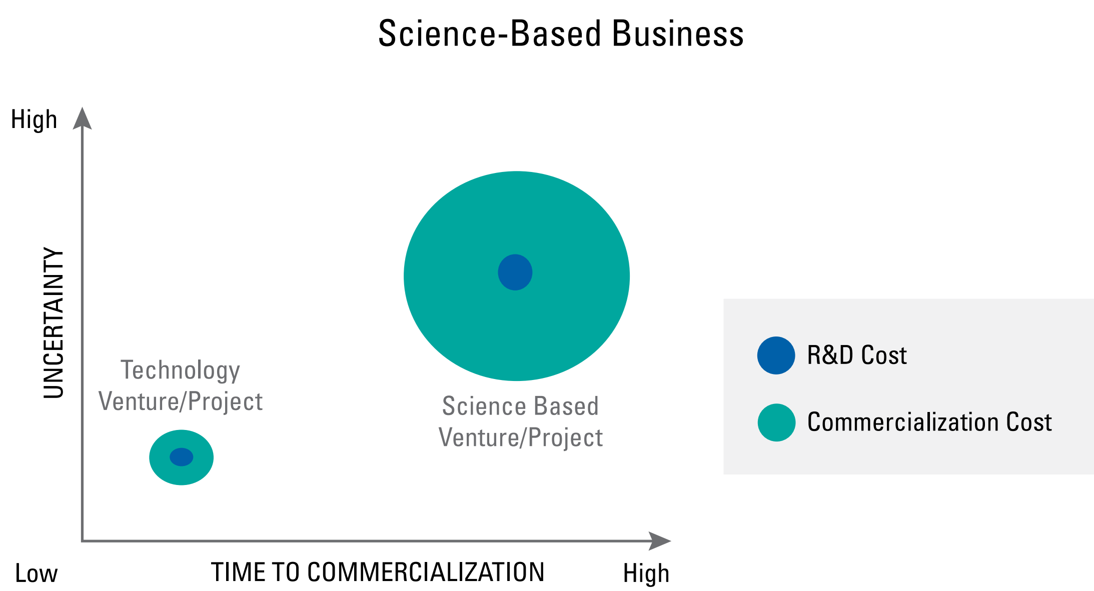


Fig. 1: Comparing science-based ventures with technology ventures (Maine, 2015)

This process of technology-market matching is a critical aspect in the translation of science-based research out of the academic lab (Freeman, 1982; Maine and Garnsey, 2006; Thomas et al, 2020) and is often delayed by a lack of capacity to identify market opportunities. Several scholars have noted that most academic scientists have limited skills in identifying market opportunities (Vohora et al, 2004; Gurdon and Samsom, 2010), although some researchers having developed a mix of technical and business expertise, have demonstrated a long-term ability to spin out multiple science-based ventures from university settings (Thomas et al, 2020). This observation indicates that such skills can be developed and refined over time, particularly if appropriate innovation training is provided in the early stage of a scientist's career.

3.1.1 Academia and Industry Incentive Mismatch

The incentives for academic researchers are often not well-aligned with commercialization goals. The rules and conventions that govern academia, both at the researcher and administrative level, may hamper innovation (Johnson, 2018). These include, but are not limited to, metrics and key performance indicators (KPIs), culture mismatch, administrative barriers, and an inability to effectively communicate the value of scientific breakthroughs beyond the academic realm.

The metrics which govern a researcher's career success in the university setting focus heavily on measures of publication impact and HQP training, and less on the regional and national economic impact of research translation and industry contacts. Scholars note that while many researchers have some academic engagement with industry in the form of contract research or consulting, fewer PIs have significant engagement in science commercialization (Perkmann et al, 2013). In many universities, the pursuit of commercialization indicators, such as patents or spin-out companies may not only not count toward tenure and promotion but may often be seen as distractions.

Despite the limited number of PI positions available to graduate students and postdocs, the culture in many labs and departments is unsupportive of careers outside academia. Industry and entrepreneurial careers are often seen as “alternative” pathways for those who cannot secure an academic position (Council of Canadian Academies, 2021). Researcher culture often attributes entrepreneurial ambition to self-interested motives that compromises the goals of open inquiry and collective benefits to society. Furthermore, culture within academia rewards contributions to disciplinary knowledge more than translational innovation. However, this view may be somewhat simplistic as recent research shows that entrepreneurial academics may pursue commercialization to address significant unmet societal needs (Thomas et al, 2020). Moreover, the number of PhDs awarded annually in science and engineering has dramatically outpaced the number of faculty positions available. Shillebeeckx et al (2013) note that between 1982 and 2011, the annual awarding of PhDs grew from ~11,000 per year to 36,000 per year, while the number of faculty positions created remained relatively constant at 3,000 per year.

Other barriers to research translation are commonly found at the administrative level of universities and granting agencies. Many technology transfer offices adhere to licensing and IP ownership policies which are seen as “rent-seeking” by investors and deter investment opportunities and most research grants explicitly forbid the use of funds to protect IP. Further, though access to specialized equipment and laboratory facilities is a critical need for early-stage science-based innovation success, there are often many policy barriers to accessing these spaces within institutions.

Engagement with industry often tends to have a short-term focus and academics tend to be skeptical of the impact of industry on research trajectories and the broader academic goals of the creation of new knowledge (Johnson, 2018).

Academic researchers may also lack the ability to balance and sequence the academic culture of the creation and sharing of new knowledge with the ability to recognize and appropriate value from scientific inventions through intellectual property protection. Such entrepreneurial capabilities of claiming and protecting inventions while maintaining academic research outputs such as publications have been noted most recently among star scientist entrepreneurs (Thomas et al, 2020).

As has been noted earlier, most academic scientists are not trained to communicate the value of their scientific inventions and may often lack an understanding of market needs (Vohora et al, 2004; Wright et al, 2004; Gurdon and Samsom, 2010). Conversely, some investors lack the technical understanding needed to adequately value emerging state-of-the-art scientific discoveries with significant long-term potential for societal impact (Auerswald and Branscomb, 2003). Investors may thus gravitate to more easily understood opportunities, with less undefined risk, to the detriment of important, impactful science-based innovation. In Canada, the lack of access to patient capital further exacerbates this problem (Kronick and Bafale, 2022). This problem can thus further widen the science-based innovation funding gap, detailed in the next section.

3.1.2 Science-Based Innovation Funding Gap

A consequence of the misalignment of incentives in academia and industry described above is the concentration of funding opportunities for science-based translation at opposite ends of the development spectrum (Figure 2). Research grants, investors and industry funders are appropriate at different stages and for different strategies; however, they leave a significant gap in the crucial early stages of translation.

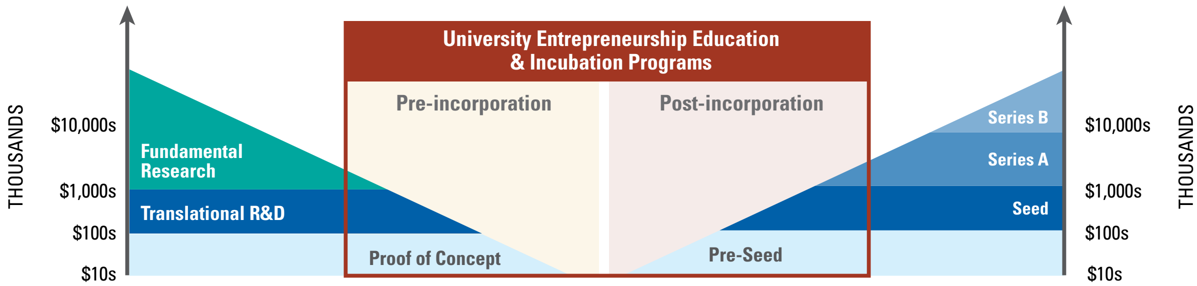


Fig. 2. Funding gaps for science-based Innovation (Innovosource, 2022)

Most of the research supports and grants available to scientists and engineers, particularly at Canadian universities, are dedicated to basic research that yields journal publications and scientific training for HQP. This incentivises academic researchers to de-prioritize translational pursuits in favour these metrics which are heavily weighted by research grant adjudicators and university tenure and promotion committees.

Conversely, investors and incumbent industry players, and translational granting bodies often concentrate their R&D spending in areas with less risk and shorter time horizons (Auerswald and Branscomb, 2003; Franzoni et al, 2022). This is reflected in the lack of science-based innovation within industry, and the prevalence of the matching fund requirements in most Canadian translational grant models.

3.1.3 Matching Funding Requirements for Industry Collaboration

Most industry-academia partnerships are guided by the principle that industry knows what industry needs and that matches from industry create a check and balance system to ensure research matches industry needs. Though this translational framework supports existing industry well, new incentives and funding models are required to address the needs of researcher innovators in the early stages of research translation and science commercialization.

In these early stages, there is limited interest from industry as well as VC investors (Auerswald and Branscomb, 2003) and existing incentives are not matched to the longer timelines of commercializing breakthrough science with high technical and market risks though such scientific research may have significant societal impact (Advisory Panel on Federal Support for Fundamental Science (Canada), 2017).

Matching funding requirements of most translational grant models may also inadvertently favor provinces, regions, universities, and later stage researchers with access to more matching funds leaving researchers from underrepresented groups and institutions from regions with less munificence struggling to participate and secure federal funds (Advisory Panel on Federal Support for Fundamental Science (Canada), 2017). More recently, scholars have suggested that a substantial and powerful role can be played by the government and government funders who often have the power to drive development of key, long-term sectors and even shape markets (Lazonick and Mazzucato, 2013) beyond the timeframe of typical industry collaborations.

3.1.4 Resource Requirements and Science Innovation Timelines

The complexity underlying most science-based innovations lead to challenging development efforts, as costs and timelines cannot be adequately modeled due to the inherent uncertainties of cutting-edge R&D (Auerswald and Branscomb, 2003). Typically, science-based innovations can take 10-15 years of development and tens of millions of dollars of investment to de-risk (Maine and Seegopaul, 2016).

Academics seeking to commercialize such inventions face the daunting challenge of competing for investment dollars in markets that are ill-suited to the uncertainty and long timelines of science-based innovation (Fig. 3). Even breakthrough inventions that have been significantly de-risked can struggle to reach the market when an investor withdraws their support unexpectedly as in the case of BIND Therapeutics (Maine and Thomas, 2017).

Fig. 4 shows the decades of research and early-stage translation underpinning the formation of science-based venture BIND Therapeutics. Even after securing several patents and partnerships with leading pharmaceutical companies, BIND Therapeutics went into bankruptcy ten years after founding after one of its creditors demanded that it pay its loan ahead of schedule in 2016 (Maine & Thomas, 2017; Ledford, 2016).

Fig. 3. Timeline for Science-based Innovation

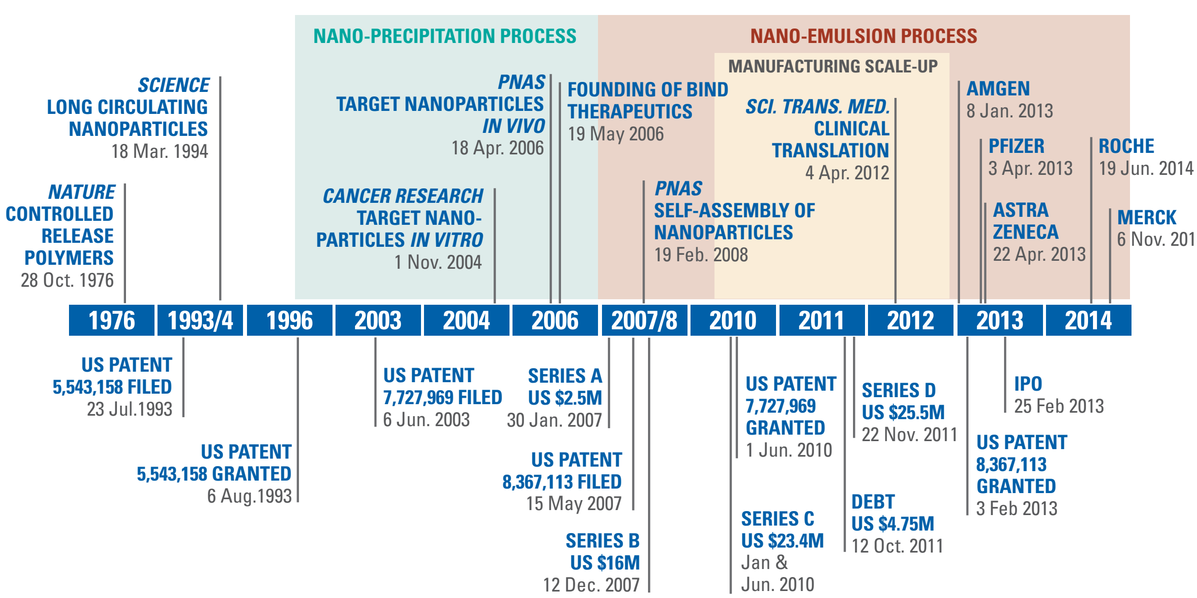


Fig. 4. Timeline for Science-based Innovation at BIND Therapeutics (Source: Maine & Thomas, 2017)

Such challenges faced by science-based innovators are compounded by the fact that most of the scientists and engineers with the world-leading technical skills required to develop science-based inventions lack innovation skills training, and so cannot navigate the complexities of early and pre-commercialization development critical to venture success. As has been noted earlier, postdoctoral fellows are central participants at these early stages, both pre-formation and post venture formation (Johnson, 2018; Thomas et al, 2020). Thus, innovation training for postdoctoral fellows in these early stages can help them to be significantly better prepared to manage scientific and market uncertainties, and investor expectations.

> **“Basically, the dynamics of tech transferring universities and one of the things that we recognize, is that in most of the cases of these technologies being transferred out of universities, people that were key to that process or that were involved in that process were postdocs.”**

3.2 The Role of Postdocs in Science and Science Commercialization

Research has recognized the critical role played by postdoctoral fellows in high-quality scientific research (Black and Stephan, 2010) and in science commercialization from academic research labs (Park et al, 2023; Thomas et al, 2020; Maine and Thomas, 2017; Johnson, 2018; Murray, 2004). While principal investigators (PIs) play a key role in mentoring postdoctoral fellows (Park et al, 2022), most PIs prefer to work in the academic lab focused on academic publications. Thus, it falls on the postdoctoral fellows to be the key players in the translation of academic science in fledgling science-based ventures (Maine and Thomas, 2017).

While postdoctoral fellows have advanced scientific training and skills, they typically lack commercialization training (Hayter and Parker, 2019; Johnson, 2018). Similar gaps have been noted for STEM PhD students in the US (Ganapati and Ritchie, 2021). Often, even if the postdocs have interests in commercialization, that may not be encouraged by the PI (Hayter and Parker, 2019). With most postdoctoral fellows having limited autonomy to engage in commercialization training, the buy-in of PIs may be essential to unlock this pathway to societal impact through science commercialization.

3.3 The Current State of Postdocs in Canada

The Canadian postdoc landscape holds a significant number of challenges in terms of numbers, outlook, funding and more; however, it may also represent a substantial opportunity to create far more innovation capacity across the country.

A large proportion of Canada’s doctoral degrees are granted in the sciences and engineering (Council of Canadian Academies, 2014). Furthermore, the Canadian Association of Postdoctoral Scholars estimates that there are over 9000 postdocs employed in Canada (Mitchell et al, 2013). Periodic surveys of Canada’s postdoc researchers show that most of these knowledge workers are active in life sciences and physical sciences (Fig. 5).

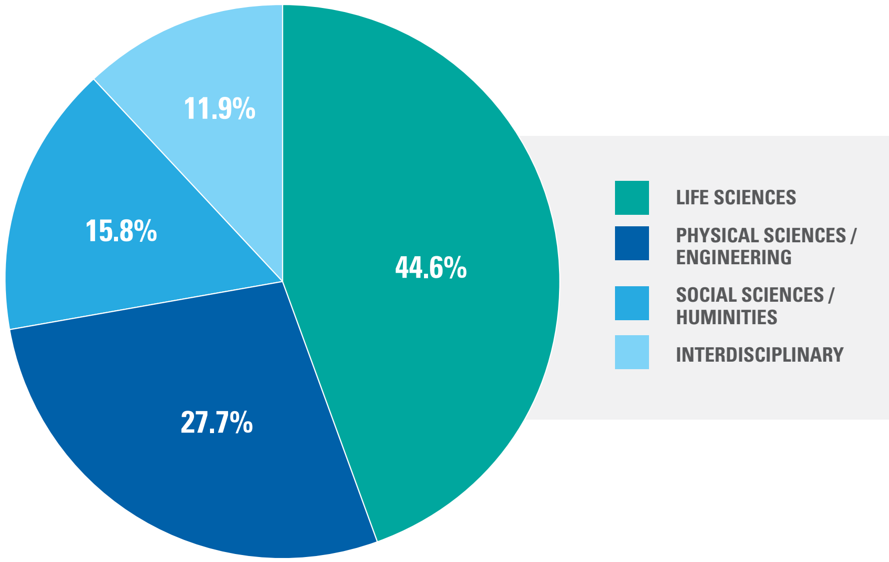


Fig. 5. Canadian PD Field of Research (Jadavji et al, 2016)

The sources of postdoc support are myriad, but the majority are through direct supervisor support or CIHR/NSERC/SSHRC fellowships.

Mitacs Fellowships account for approximately 9% of all PD funding (Jadavji et al, 2016).

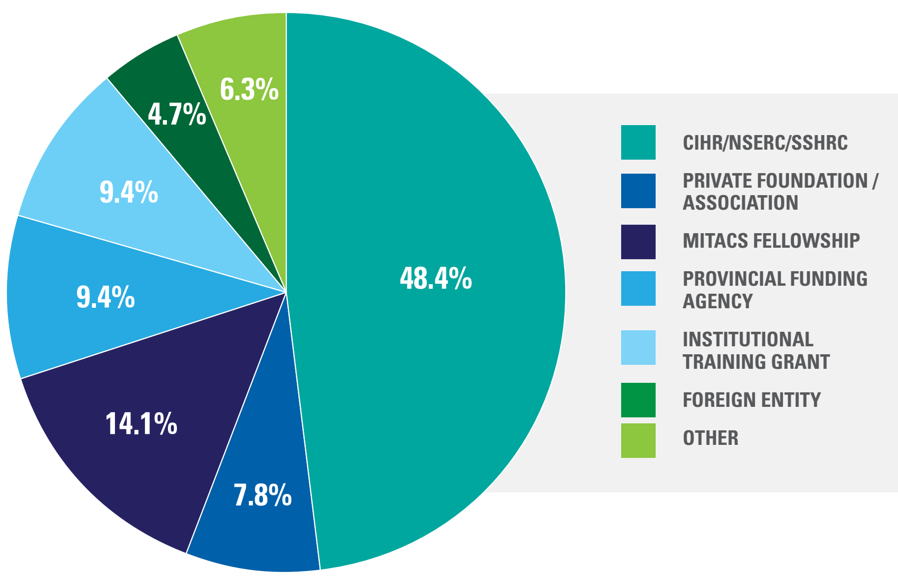


Fig. 6. Canadian PD Funding Sources (Jadavji et al, 2016)

The average postdoctoral salary in Canada was approximately $46,000 in 2016 with an average age of 34 (Jadavji et al, 2016). In comparison, the average salary for all Canadians ages 25 to 34 was $46,600 and the median salary was $39,800 (Jadavji et al, 2016). Unsurprisingly, postdocs report dissatisfaction with their compensation, which is not commensurate with their level of specialized talent. Additionally, while the numbers of postdoctoral fellows in Canada have been increasing the funding support has stayed somewhat stagnant. With increasing inflation and postdoctoral salaries being taxed in Canada, the funding support for postdoctoral fellows in Canada struggles to maintain parity with other advanced countries (Advisory Panel on Federal Support for Fundamental Science (Canada), 2017).

Though postdoc salaries are slightly higher for Canadian researchers working outside the country ($55,200), this dissatisfaction is observed across 93 countries (Woolston, 2020). Globally, postdocs report that their appointments did not meet expectations at almost 3 times the rate of postdocs whose tenure exceeded their expectations, and 56% of postdocs surveyed had a negative view of their career outlook.

Statistically, this negative career outlook is justified. In 2016, 73% of Canadian postdocs surveyed indicated a tenure-track position as a career goal, but postdoc placement rates are declining and, in the US where rates are tracked by the NSF, only 10% of postdocs achieve a tenure track faculty position within 5 years (Sauermann and Roach, 2016). In Canada, the placement rate must be approximated from available data on full time faculty positions and estimated turnover rates. According to the University and College Academic Staff System (UCASS) survey there are 38,211 full time faculty positions held by PhD graduates in Canada (Statistics Canada, 2023). Assuming a generous average turnover of 3% annually yields a postdoc placement rate in Canada of approximately 13%.

The misalignment of career goals and available employment opportunities for postdocs in university faculty positions, combined with low compensation and benefits is aligned with reported job dissatisfaction. The declining state of affairs within the postdoc sphere globally has been termed the “postdoc pileup” (Powell, 2015) and reflects the misaligned incentives driving academic research productivity versus the desire of (increasingly less) young researchers to secure tenure-track faculty positions.

Alternative employment options for HQP in industry is a primary alternative for postdocs who cannot find academic positions, but, in the Canadian case, the capacity to onboard postdoctoral talent matched to innovation-focused industry positions is insufficient and many scientists are underemployed within their fields (Bonikowska et al, 2022). A major challenge for Canada is increasing the national capacity to effectively employ science and engineering graduates in occupations that leverage capacity to enhance Canadian innovation success. As noted by CAPS-ACSP and Mitacs (Mitchell et al, 2013), many postdocs in Canada receive insufficient training in general, and the training that is received is often tailored to academic positions they are unlikely to get. Much needed science translation and commercialization training is often lacking or not easily accessible. This suggests while capacity and opportunity exist, much scientific research may not reach the market due to lack of trained and motivated students who can support the translation of scientific research from the lab to the market.

3.3.1 Exploring Education and Training for Postdocs in Canada

Canada’s research HQP lack the training important to the successful translation of research out of the labs. The Council of Canadian Academies report Degrees of

Success (CCA 2021) thoroughly examines national graduate and post graduate training strategies, finding that HQP are being trained for an academic landscape that no longer exists. Powell (2015) identifies the "postdoc pileup" phenomenon but highlights that lack of industry-oriented skills training is hampering scientist success leading to underemployment and lack of career opportunities. Notably there is a lack of ability to articulate their differentiated value proposition, little or no knowledge of IP strategy, regulatory challenges, market prioritization or financing.

A large majority of talented graduates lack an entrepreneurial mindset, innovation skills and an awareness of unmet market needs, all critical skills required for science-based innovation success. While entrepreneurial capabilities are critical to effective early-stage decision making along the translational journey (Thomas et al, 2020), translational innovation and entrepreneurial training are not equally accessible in all Canadian institutions and labs.

3.4 Opportunities in Postdoctoral Training and Funding Supports in Canada

It is increasingly being acknowledged that postdoctoral fellows are among the best placed to be the key actors in science commercialization. While there can be a significant amount of ambiguity around job status for post-docs (Mitchell et al, 2013; Johnson, 2018), there is a great deal of flexibility with the role of a post-doc and their outputs. With most academic PIs focused on advancing science and PhD students engaged in completing their doctoral dissertations, postdoctoral fellows with extensive scientific training are ideally positioned to generate value through engagement with industry or through participation in the formation of science-based university spin-offs.

> **"The typical academic path is not for everybody, nor is it even available to everybody because people need training. And just starting right from the get-go, we should be telling people that they should probably be thinking about an alternative and we shouldn't even call it an alternative career path. You should just call it a career path and how you can use the skills you learned here now for better."**

This also offers several alternative paths for postdocs who do not, or do not want to, secure a job in academia, helping to unblock the "postdoc pileup" while maintaining Canada's innovation capacity.

However, this type of value creation is only possible when postdoctoral fellows develop the entrepreneurial capabilities to recognize or create new opportunities to address unmet market needs. Such training is also particularly valuable to postdoctoral fellows as only a fraction of postdoctoral fellows can secure full-time tenure-track academic positions in research universities.

> **I can't even imagine the idea of me doing a startup, my students did it because they're fresh and graduate, and they have time. There is no way a university professor who is so busy could do their own startups.**

> **Research gets done and then forgotten in the lab, not enough communication, so a lot of things get wasted.**

Specialized commercialization training is needed to unlock the value in highly skilled postdoctoral fellows to enable them to translate scientific research from academic settings. This gap was part of the motivation behind the development of the Mitacs invention to Innovation (i2I) program, detailed further in Section 4.3.

3.5 Summary

The process of science-based translation and spin-off formation is characterized by high levels of uncertainty, substantial resource requirements, and long timelines, often with a sharp focus on solving targeted unmet market and societal needs beyond the horizon typically pursued by industry. This requires active translation between ground-breaking scientific research and those needs; however, the current academic system experiences significant misalignment in culture, success metrics, and funding that inhibit improvement of the translation of science to impact.

Highly skilled postdoctoral fellows represent a substantial opportunity for the Canadian innovation ecosystem. They hold advanced scientific knowledge, are highly trained (though often lack the skills to succeed in non-academic positions) and are ideally positioned to pursue translation and commercialization activities if given appropriate commercialization training and funding. Targeted commercialization training for STEM postdoctoral fellows specific to the significant sectoral differences between a range of science-based industries (Maine and Seegopaul, 2016) can unlock much value for postdoctoral fellows, PIs, universities, and local economies. In the next section, we explore extant commercialization-focused STEM postdoctoral fellowship models intended to help unlock this latent potential.

4. Existing commercialization-focused STEM postdoc support models and their challenges

Several models have been developed or are in development to address this challenge and the scale of the opportunity. We focus specifically on postdocs targeted at STEM, as the structure of the commercialization-focused STEM postdoctoral fellowships is critical to the development of entrepreneurial capabilities needed for the formation and scale-up of science-based university spin-offs. Fellowships with training components which do not distinguish between the differential timelines and resource requirements of science-based sectors, or which do not account for the unique commercialization context of each nation or region may not be fully able to unlock the potential value inherent in STEM postdoctoral fellows, as detailed in section 3.

4.1 Commercialization-focused STEM Postdoc models in US, UK, and Canada

We examine key components of select commercialization-focused STEM postdoctoral fellowships which are then individually described further in each sub-section (Table 2).

Table 2: Comparison of Full-time Commercialization-focussed STEM Postdoctoral Fellowships

CHARACTERISTICS	INNOVATION CATALYST GRANT (2004)	ICURe (2013)	CORNELL RUNWAY STARTUPS PROGRAM (2014)	CYCLOTRON ROAD (2015)	SVP CONCORDIA (2021)	MITACS ACCELERATE ENTREPRENEUR (2019)
Jurisdiction	Alberta, Canada	UK	US	US	Quebec, Canada	Canada
Focus	Clean tech now science-based	Research broadly	Digital	Science-based	Science-based	Entrepreneurship broadly
Duration (months)	24	3-36	24	24	24	4-24
Salary p.a.	CAD 60K	GBP 35K	USD 100K	USD 90K	CAD 45K	CAD 15K
No. of positions	8	10-15/3mo	Up to 6	10	2-4/6mo	100s
Total Flex funds for commercialization	CAD 130K	GBP 300K~	USD 325K	USD 100K + 300K*	CAD ~52K	CAD 5K^
TRL	Early Stage	2-6	Early Stage	Early Stage	Early Stage	Incorporated◊

table continued on next page

CHARACTERISTICS	INNOVATION CATALYST GRANT (2004)	ICURe (2013)	CORNELL RUNWAY STARTUPS PROGRAM (2014)	CYCLOTRON ROAD (2015)	SVP CONCORDIA (2021)	MITACS ACCELERATE ENTREPRENEUR (2019)
Facilities Access	6 months/ Negotiated	University specific/ Self -directed	USD 50K/p.a.	USD 100K	Workspace access for participants, Lab access on a case-by-case basis	Self-directed
Training	1 to 1	5-day bootcamp + market validation	3 Months half-day intensive	90 mins weekly	Workshops + partner programs	Mitacs offerings optional
Mentoring	Leverages local accelerators/ incubators	Embedded mentor in team	Weekly office hours	Quarterly events, weekly invitees	Bi-weekly 1 on 1, + advisory council, and PI	Self-Directed
Model	Modified Fellowship	Staged	Modified Fellowship	Modified Fellowship	Modified Fellowship	Staged (Renewable)
SAFE Agreement≠	No	No	Yes	Optional	Yes	No
Matched funding requirement	No	Yes	No	No	No	Yes
Intellectual Property	Pre-Negotiated with host TTO	According to host institution TTO	Blanket license from TTO, IP for equity, SAFE	None/ pre-existing	SAFE/ According to host institution TTO	Pre- Negotiated with Host TTO
Initial funder	Provincial gov.	UK research and innovation	Jacobs Institute (endowment)	Philanthropy/ DOE	Canada Economic Dev. for QC.	Mitacs Canada

~ Requires a 30% matched funding contribution.

^ This funding is the allowed portion of the CAD 15K for flex funding.

* USD 300K is external funding available from partner VC investors.

◊ Must have incorporated a venture prior to award.

≠ A SAFE agreement is a form of early-stage investment in a venture that converts to equity In future funding rounds

4.1.1 Innovation Catalyst Grant (ICG)

The Innovation Catalyst Grant (ICG) program traces its roots back to the early 2000s, with the establishment of a program known as Mystery, the Microsystems Technology Research Initiative at the University of Alberta (UA), Canada. This initiative was created to support late-stage research projects in the emerging field of microsystems and nanotechnology, offering grants ranging from $25,000 to $40,000. However, the program also started to provide funding to recent graduates working on their own projects, a novel approach that yielded some surprisingly successful outcomes. The Mystery program was eventually replaced by Nanobridge in 2010, which expanded the funding options and placed an emphasis on nanotechnology projects. Again, a portion of the funding was directed to support recent graduates, resulting in several successful ventures.

This trend of supporting graduate entrepreneurs continued when the Nanobridge program concluded and was succeeded by the Green STEM program. Now funded by revenues from Alberta's carbon tax, the program focused exclusively on supporting recent graduates interested in commercializing their technologies, providing each project with up to $250,000 over two years. This program was run collaboratively across three Alberta universities and saw significant success, with all 9 UA projects funded still operational and collectively raising over $80 million in external funding since 2018. Despite changes in government and the removal of the carbon tax, the program's success led to an extension for five years and a doubling of the number of grants available, resulting in the evolution into the current Innovation Catalyst Grant program. Now, the program focuses on supporting any hardware-related innovations, continuing the tradition of fostering entrepreneurship among recent graduates.

4.1.2 ICURe Program

The Innovate UK Commercialisation of Research (ICURe) program is a component of the UK's strategy to foster innovation and entrepreneurship within the academic community. Founded in 2013, ICURe was designed to promote the translation of the best ideas and research into beneficial real-world applications, with a focus on 2- and 3-year awards and training for post-bachelor's, graduate students, and postdocs. The program provides teams of academic researchers with funding and intensive training to explore and validate the market potential of their research. ICURe embodies a proactive approach to innovation, encouraging researchers to step out of their laboratories and engage with potential customers and industry stakeholders to understand the commercial viability of their research through a two-stage approach.

The initial stage, known as Explore, is a three-month phase where academic researcher teams (early career researcher (ECR) led, with PI and embedded mentor) are granted the opportunity to engage directly with industry stakeholders, potential customers, and end-users. This stage, characterized by an in-depth market discovery process, aims to ascertain the commercial viability and potential of their research findings. Upon completion of the Explore phase, teams present their market findings and commercialization strategy to an experienced panel in an 'Options Roundabout'. If a market for the proposed innovation is validated, teams may progress to the Exploit phase. Here, they are supported to develop an execution plan to reach the market, exploring pathways such as licensing, creating a spin-out, or establishing partnerships with existing companies and are eligible for £300K in follow-on-funding with a 30% matched funding requirement (Ipsos, 2020).

4.1.3 Cornell Runway Startups Program (RSP)

The Runway Fellowship program, conceived in 2014, was born out of a timely convergence of resources and research interests. At the time, Cornell was developing its new campus in Roseville, generating an atmosphere of enthusiasm and anticipation. Concurrently, the Jacobs Institute, a collaborative venture between Cornell and the Technion, was established through a significant endowment from the Jacobs family. The Institute's remit was to explore and experiment with entrepreneurship, providing the perfect backdrop for the development of the Fellowship program. A study by Technion professor Uzi de Haan et al (2020), which underscored the vital role of postdocs in technology transfer, served as the catalyst for the program's formation. De Haan's insights led to the recruitment of the first cohort of five postdocs in 2014, who were tasked with translating their deep technological knowledge into actionable business ventures, with minimal programmatic scaffolding and no prescribed curriculum.

As the program evolved, its structure and support mechanisms underwent significant enhancement. Initially, the fellowship relied heavily on mentoring, leveraging the expansive network of academics, industry professionals, and venture capitalists known to the founders. However, a gap in academic scaffolding was recognized, leading to the introduction of a more structured curriculum in 2017. This curriculum was built to address common commercialization challenges for researchers, incorporating modules on customer discovery, decision-making, self-marketing, and startup finance, among others. The structure of the program evolved to provide intensive curriculum-based training for the first few months, followed by a shift towards one-on-one mentorship and engagement with venture capitalists and entrepreneurs. The program also recognized the need to secure more philanthropic funding to support the expanded curriculum and resources, leading to the development of additional avenues to attract such funding. The Runway Fellowship program has transitioned from a loosely structured, mentor-focused initiative to a more comprehensive, curriculum-driven platform, better equipped to support postdocs in their journey from academic scientists to scientist-entrepreneurs (Gómez-Baquero 2023).

4.1.4 Cyclotron Road (CR)

Cyclotron Road was created with the ambition to fill a critical gap in the translation of hard science to market-ready products. Driven by Ilan Gur, the founder, the program was initially developed as a public-private partnership between Lawrence Berkeley National Lab and they aimed at supporting scientists who sought to commercialize their innovations. Through Cyclotron Road, fellows were granted two-year residencies at Berkeley Lab, affording them the necessary time and resources to de-risk their technology and begin their entrepreneurial journey. However, realizing the need to expand the model and facilitate a broader geographical reach, the program transitioned into 'Activate,' an independent organization with diversified funding sources including the US Department of Defense (DOD), philanthropic entities, and other government agencies.

Activate's evolution saw the establishment of new geographical extensions, such as Activate Boston in 2019, followed by New York City and the Activate Anywhere program. The latter provides support to scientist-entrepreneurs across the nation, underlining Activate's commitment to harnessing talent irrespective of location. This initiative has been met with enthusiastic response, with applications exceeding those of any other cohort. The

Activate Anywhere program hosts its fellows physically once a quarter, complementing ongoing virtual interactions, thus providing them with valuable networking opportunities.

Funding strategies have evolved in tandem with the program's expansion, with the National Science Foundation (NSF) emerging as a key partner, committed to advancing Activate's science-based commercialization focus. With NSF's robust backing, Activate has been able to grow its footprint further, establishing a new site in Houston.

4.1.5 Scientific Ventures Program (SVP)

Concordia University's Scientific Ventures Program, an initiative developed by the V1 Studio, is a wholly owned non-profit subsidiary of Concordia with an independent board. This is an innovative fellowship model, drawing inspiration from the success of the Cornell RSP. The program is supported by Canada Economic Development for Quebec Regions and Mitacs Canada, piloting the first cohorts in the Concordia area and planning for a province-wide expansion 2024 onward.

The up to two-year fellowship engages a cohort of 2-4 postdoctoral researchers every six months, with the pioneer cohort scheduled to conclude the program in October 2023. The fellows are offered a capped SAFE-contingent stipend package amounting to around CAD 71K/yr, apportioned between salary ($45,000), flexible de-risking funds, services and access to facilities (~$52,000), which can also be leveraged to secure additional funding, such as Mitacs. In order to move to the second year of the program, the ventures go through a review process with a committee and sign the initial SAFE for the amount of the first year. A second SAFE for $71K is signed at the end of the second year for a total of $142K at the end of the program. To fund the program, V1 matches government funding (75%) with private funding (25%).

To cultivate an innovation culture among faculty collaborators and within the broader university ecosystem, V1 Studio and Concordia negotiate an IP agreement that typically grants ventures full rights to intellectual property developed on campus, to lay clear foundations for its ventures in their commercial progress. The participants' original research PI may become a co-founder in this process.

The Scientific Ventures Program operates a rigorous applicant screening process, encompassing multiple in-person interviews scrutinizing team dynamics, technical competencies, and entrepreneurial characteristics. While most ventures accepted to the program are already incorporated, some high potential applicants are accepted pre-incorporation, and then assisted with incorporation as one of their first goals within the first three months of the program. Similarly, the program focuses on building the teams of and around the ventures, assisting with co-founders meeting and selection where appropriate. The program's first-year curriculum also includes compulsory innovation training (e.g., accounting, leadership, resilience), pairing fellows with mentors, an advisory council, and bi-weekly interactions with a program director, coupled with monthly goal-setting sessions and meetups, and quarterly reviews with their advisory council. There is a faculty PI at Concordia who is responsible for all the fellows, and a scientific co-PI will be matched if an appropriate one can be found. The subsequent year focuses on the venture's long-term sustainability, supplemented with tailored training and networking activities. The program leads also provide a concierge service to match fellows with appropriate external activities and complementary programs.

While SVP has successful ventures as a primary objective, other outcomes viewed as positive include researchers who go through the process and then go back to the lab as entrepreneurial faculty, or participants who transition successfully into industry after the experience.

4.1.6 Mitacs Offerings - Accelerate Entrepreneur (EA) and Elevate

While Mitacs does not currently have a science-based commercialization postdoc, it has offerings being used by postdocs in the science-entrepreneurship space - Mitacs Accelerate Entrepreneur internship and Mitacs Elevate Postdoc. These offerings provide opportunity for work-integrated-learning (WIL) and evolution in this space.

Among WIL providers, Mitacs has a unique mandate that prioritizes the advancement of innovation, relying on WIL experiences to build and strengthen innovation networks connecting diverse industry, civil-society, and academic partners. In contrast, other organizations tend to be more focused on the intrinsic value of providing work opportunities to PSE students. In other words, Mitacs is not motivated simply to deliver WIL experiences for their own sake, but rather to use WIL experiences as a primary tool to achieve another objective: strengthening Canadian innovation.

Mitacs's delivery method is shaped by this innovation-focused mandate in two important ways: First, Mitacs's approach to WIL employs a focus on mobilizing academic knowledge that is not seen in many other WIL programs, including through the meaningful involvement of academic supervisors and a research-review requirement for most of its projects. Secondly, Mitacs is more engaged than most other WIL providers in expanding and maintaining its own network of WIL partners (which it does through its BD network), rather than relying on secondary delivery partners or online matchmaking, as is common in many other large programs. This means that Mitacs uses WIL experiences to establish new networks, in contrast to more typical approaches where existing networks are used to create WIL experiences.

The Mitacs Accelerate Entrepreneur Internship, launched the 2019-2020 academic year, represents a strategic evolution of the Mitacs Accelerate Internship program in Canada. Mirroring the original's objective of fostering industry-academic partnerships through matched funding, the Entrepreneur version extends this financial support to ventures founded and led by students. Mitacs supports students doing research for their own start-ups, provided the incubators and accelerators in which they are housed provide appropriate supervision and interaction. This internship is also not limited to post-doc founded start-ups but open to other student-led ventures.

The Accelerate Entrepreneur Internship bridges the gap between industry & academia, promotes R & D in Canada and give students real-world experience, provide opportunities for students and PDFs to do research in a non-academic environment, and builds connections and promotes interaction between industry and academia. The intent is to ensure continuity of access to university resources such as laboratories and equipment post-venture creation via the existing Accelerate mechanisms. Internships under this scheme, renewable every four months, span up to two years, with the applicant required to match half of the CAD 15K/term grant. In its inaugural year, 391 internships were piloted under this program, accounting for 4.6% of total Accelerate program awards.

The Accelerate Entrepreneur program is further augmented by a spectrum of optional, ancillary Mitacs supports. These include the Mitacs Invention to Innovation (i2I) program offering holistic innovation training, the Mitacs Entrepreneur International (MEI) program that finances international customer discovery and networking, and a suite of online professional development courses spanning diverse areas like project management and equity, diversity, and inclusion. Through strategic partnerships with a range of accelerators and incubators facilitated by Mitacs, participants in the program are given the opportunity to tap into local networks for access to business mentors and potential investors.

Mitacs has also initiated thematic calls in Government of Canada priority areas for their Elevate postdoc, raising the usually $60K/year matched internship to $80K/year. It was done on a pilot basis but has now reverted to the standard funding level ($60k). Rather than targeting ventures, the pilot was intended to support research in strategic areas identified by the Canadian government. Mitacs postdocs generally require an industry match between 33%-50%, with some flexibility for pilots, focal areas, or challenges under special circumstances (e.g., during the COVID-19 pandemic).

4.2 Key Components of Existing Models

As universities, funders, and policymakers are beginning to recognize the role of postdoctoral fellows in the science commercialization process, these commercialization-focused training and funding programs have been developed to explicitly focus on STEM postdoctoral fellows. It should be noted that each of these programs was developed in its own geographic and, in most university context.

Comparing the programs, several common components or elements become clear, which are detailed further below. These include:

- a selection process - a fundamental mechanism to ensure that appropriate applicants are identified for bespoke commercialization training and funding supports;
- the type and frequency of training and mentoring supports;
- the amount of flexible commercialization funding and access to critical research facilities;
- clear guidelines on intellectual property management;
- program governance and leadership to ensure that the selected postdoctoral fellows have the guidance and resources to take high quality ideas forward to commercialization for societal impact.

These are unpacked further in the following sub-sections to identify common approaches as well as gaps in the ecosystem of support.

4.2.1 Selection Criteria and Process

The selection process of these programs can be broadly classified into two categories: a staged approach (ICURe, MEA), or a modified fellowship approach (CR, RSP, IGC, SVP). In the staged model (SM), the initial phase has a low barrier to entry allowing a filtering of applicants who progress to later program stages[1]. This filtering effect leads to low venture creation rates overall (ICURe reports an ~11% spin-out rate), but a much larger number of program participants.

In contrast to a staged and filtering approach, the modified fellowship model (MFM) instead uses large stipends and generous ancillary supports to invite many applicants, who will then go through an intensive adjudication.

1 Accelerate Entrepreneur (Mitacs) does not have later program stages.

The perceived prestige of the award may also increase attraction to such programs with the Cyclotron Road (now Activate) program growing from less than 150 applicants for 10 positions at inception to ~800 today. MFM programs achieve very high spin-out rates but serve a much smaller number of highly curated Fellows.

4.2.2 Training and Mentoring

Programs in the MFM group were characterized by intensive entrepreneurial training both in course-based learning and bespoke instruction relevant to the science and stage of development of the idea. Program directors highlighted the need to refine and improve training to improve outcomes and interviewees also described the important role of program staff in maintaining high levels of engagement between fellows and mentors, investors, industry, and interdisciplinary technical experts.

> **"Biggest barrier is understanding the applications of your work. I didn't even really see the possibility for commercialization of our work. We were doing fundamental work, I was lucky to meet with these great scientists who helped us see the possibilities and then having patent agents and commercialization specialists at a university that can help you with that."**

Staged programs, with many more participants, exhibited a lower level of mentoring and networking support. The ICURe explore phase incorporates a 5-day bootcamp innovation training session and a single mentor assigned by the host institution. The Mitacs Accelerate Entrepreneur program has a requirement that supervision and interaction are provided to the intern by the incubator/accelerator in which they are housed. The Accelerate Entrepreneur program is also still very much focused on research, and innovation training is optional.

4.2.3 Resources Provided: Funding, Facilities Access, and SAFEs

The extant models also provide a range of resources: salary or stipend, and access to facilities, which may also come with additional requirements.

Though the proliferation of postdocs within the STEM field has led to stagnant compensation relative to inflation and widespread dissatisfaction among researchers, PI's report great difficulty in attracting elite postdoctoral researchers (Woolston, 2020). In contrast, the number of applicants to selected candidates ratio of the MFM commercialization models indicates that sufficient funding and support, as well as prestige, can overcome this challenge. Each of the models above provide an annual salary or stipend above the average (~50K) that postdocs generally receive in Canada. The higher stipend also serves to address in some measure the taxation of postdoctoral funding as salaries as well as inflation in Canada.

Another clearly critical aspect of science commercialization is the access to scientific equipment, lab space and facilities to further extend and de-risk high quality ideas. Universities and PIs can play an important role in advocating for and providing such access. In doing so, they can participate in the process of science commercialization, with the postdoctoral fellow being the agent engaging with the business and investor community, leaving the PI free to engage in further research while maintaining their connections to the science-based venture through their role on the Scientific Advisory Board or as one of the founders along with the postdoctoral fellow.

In several cases, participation in the program comes with the requirement for a SAFE funding model, developed by Y-Combinator. This type of model may be a requirement of the program funders, often with the logic that successful fundraising and exits can provide further investment in the program. This may not always be aligned with the timelines and challenges of science-based ventures, as typical investing objectives, favour the shortest commercialization timelines and the least technological risk. It may be appropriate in funding ecosystems with a high appetite for risk, and/or patient capital.

4.2.4 Managing IP

Protecting appropriability of academic-led innovation through patent filings is a well-studied aspect of successful research commercialization (Maine and Thomas, 2017). Streamlining the often-slow patenting pace of academic research institutions was an important element of program design highlighted during the interview process.

> **“No reason not to support it but found this the most frustrating experience of my life, very negative, whole IP, patent, licensing processes. In theory, it’s a noble cause, but so many barriers.”**

> **“I vaguely remember hearing from my colleagues how frustrating the process can be. Squabbling with the university’s IP office about how much each party owned, sort of dragging on for a while and preventing publication.”**

While commercialization processes need streamlining, some researchers acknowledge the important role played by the university in supporting the translation of scientific research.

> **“We did actually explore the option of commercializing on our own so that we didn’t have to share any of the profits with <University> and we quickly determined that wasn’t going to work.”**

The Cyclotron Road and Runway Startup programs consider IP status during the adjudication process, limiting IP risks to success. Further, the Runway Startup and Alberta’s Innovation Catalyst Grant programs leverage relationships with host universities to pre-negotiate access to IP and provide funding for rapid patent filings outside of the regular university TTO pathways. Though CR does not provide funds for IP filings, no cap SAFE-secured funding mechanisms available to most applicants can be leveraged to that purpose. The ICURe and MEA programs follow the IP policies of host institutions. Following the lead of the Cornell Research Runway program, it is suggested that IP management be collaboratively managed by the postdoctoral fellow and the funder (de Haan et al, 2020).

4.2.5 Program Governance

It is well recognized that PIs are incentivized to focus on research publications, grant applications, and supporting the scientific training of their graduate students. More often than not the academic system considers innovation and entrepreneurship activities as peripheral to the mission of the university (Johnson, 2018), though recent initiatives suggest that this perspective is changing (Carter et al, 2021).

> **“Faculty members care about graduating graduate students. They care about publishing papers. They're oftentimes very poorly rewarded for having patents or creating startups. If anything, they're penalized for doing those kinds of things based on the performance reviews that they have to go through.”**

Recognizing the numerous demands on the time of PIs as well as the limited academic incentives they have to engage directly in commercialization activities, several programs have some embedded support in the form of program directors or similar roles such as commercialization investigators (CIs) to serve as the link between the PI, the postdoc, and other internal and external stakeholders. Such a supporting role can be critical in maintaining a smoother transition of ideas from the academic lab into the real world through various pathways.

4.2.6 Focus and gaps among STEM postdoctoral fellowship models

We further highlight the specific focus of each of the selected STEM postdoctoral fellowships and note that those in the US and the UK have an exclusive venture formation focus (fig. 7). Given the prominence of entrepreneurship in US policy and culture, this does not come as a surprise. The availability of venture capital in the US, presence of the programs like the Small Business Innovation Research (SBIR grants) which build pathways for ventures to partner with government entities and the National Science Foundation's Innovation Corps (I-Corps) do suggest a bias toward venturing the US. Only Alberta Innovates' Innovation Catalyst Grant, Concordia's SVP and Mitacs' Accelerate Entrepreneur are available in Canada, with the former two currently available in their respective provinces, and the latter available nationally. The SVP model can also begin pre-venture, with formation as an initial activity for those with substantial fit in other areas. The Mitacs offerings have focus on industry projects, though the Accelerate Entrepreneur allows an entrepreneurial venture to be its own industry partner, with a self-matching funding component.

The Mitacs programs (Elevate and Accelerate) predominantly focus on partnering with existing companies, though formation of a new science-based university spin-off is also possible. The focus on partnering with existing ventures is valuable as several reports note the lack of business expenditures on research and development (BERD) in Canada. However, as mentioned before, the emphasis on matching funding can continue to hold back many researchers and perhaps research with the potential for most societal impact (Advisory Panel on Federal Support for Fundamental Science (Canada), 2017).

Referring back to Section 3.1.2 and the importance of support early in the commercialization journey, one aspect that seems to be missing is the ***translational scientist*** focus. Given the large number of postdoctoral fellows and the comparatively limited number of such high-value fellowships, it would be fair to assume that the postdoctoral fellows selected for such funding may often hold an academic position as one of their goals. Such an academic focus may be common among almost all postdocs. While most of the existing programs remain focused on venture formation, a translational scientist focus recognizes the long-term value created by scientist-entrepreneurs from the academic lab. Not only does the PI have the ability to refine their research trajectory and launch multiple science-based university spin-offs over the course of their career, but the mentoring provided by such translational scientists can guide graduate students and postdocs to form their own ventures or become translational scientists as they progress in their careers (Thomas et al, 2020). This approach though longer-term holds the potential to create a positive feedback loop which can generate significant value and societal impact (Thomas et al., 2020).

There is one complementary national program found in this space, the Mitacs invention to Innovation (i2I) skills-training program, which has been designed to work in concert with existing STEM postdoctoral training to balance advancing research development and commercialization development.

The current commercialization postdoc program models and their focus is summarized in fig. 7.

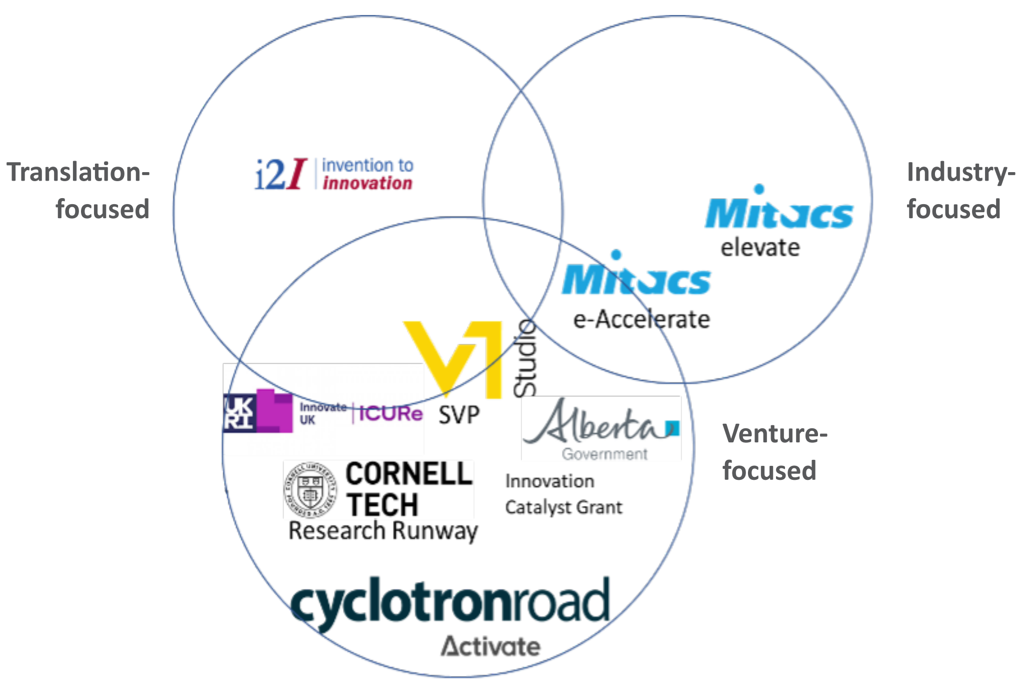


Fig. 7. Comparing the specific focus of the selected STEM postdoctoral programming

4.3 Mitacs i2I – An early-stage solution to unlock Canadian innovation capacity

The Mitacs' Invention to Innovation program is a rigorous training curriculum, dedicated to fostering an entrepreneurial mindset within scientific communities. The educational blueprint for this program has its origins at the Beedie School of Business at SFU, building on research spearheaded by Elicia Maine and her team. The research undertaken by Maine and her collaborators pointed towards a distinct training void in the landscape of Canada's science-based innovation ecosystem, enabling the crafting of an innovative educational structure designed to cater to the distinct requirements of STEM researchers complementing existing training. The introduction of this novel pedagogical framework is a strategic effort to better equip our scientific community, thereby strengthening our overall innovation ecosystem.

4.3.1 i2I Founding

Proposed in 2014 and launched in 2015, the Graduate Certificate in Science and Technology Commercialization (GCSTC), later called invention to Innovation (i2I), was unusual as an entrepreneurial program, founded on the premise of

> **"provid[ing] commercialization socialization and knowledge for research scientists during or directly after their Graduate programs in order to commercialize their work and prepare them to work as agents of commercialization in industry. As approximately 80% of science and Engineering PhD graduates do not work in academia, it is even more vital that they graduate with an understanding of the industrial relevance of their research. This certificate will enable students to examine the commercialization potential of their own research first by learning relevant theories and frameworks, then by exploring and selecting markets in order to build customer value earlier into their product development work, lead teams that are more effective in this effort and build valuation strategies for the intellectual property created.[2]"**

The program was developed to be taken alongside graduate and postdoc work, one

2 From the "Proposal for a certificate in Science and Technology Commercialization" presented to Simon Fraser University's Senate in 2014.

evening per week, in person, for one year. Rather than beginning with traditional entrepreneurship models that often prioritize quick to market and digital projects, i2I purposefully met graduate students and other key players where they were comfortable, notably:

1) Realizing that PIs were reluctant and not incentivized to allow their students too much time away from their research, i2I was built as a part-time program that allowed them to work on their own innovation idea, balancing skills development with continuing research, which also allowed it to shape early ideas.

2) Ideas could be far from market or have uncertain market application.

3) Realizing many labs, PIs and participants would not immediately identify positively with business or ventures, i2I emphasized mindset shift and translational skills needed to broaden employment opportunities in industry, science, and entrepreneurship.

4) Speaking researcher to researcher, i2I presented participants with the theories, frameworks, and case studies from academic work directly on science-commercialization.

5) Realizing that academics valued academic credentials, i2I was originally developed as a certificate participants could convocate with. Most of these credits count toward a Management of Technology MBA.

The program originally consisted of eight half-courses targeted at the specific needs of scientists, including Lab to Market (science innovation and early decision making), Opportunity Identification and Assessment (Matching research to needs and value chains) and more.

Valuing the translational stage where important pre-commercial decisions are made, the goal was to develop STEM grad students and postdocs as nascent scientist-entrepreneurs and innovation leaders and to realize the benefits associated with successful translation and application of novel technologies to address important challenges with societal impact. Rather than focusing on a venture, industry partnership or translational science outcome, i2I provides the conditions for those pathways to be explored, research to be refined and strategic choices to be made, training participants to build their innovation capacity, and apply it where it is needed and most suitable in the innovation ecosystem.

4.3.2 Evolution

As new cohorts came into the program evidence of culture change emerged, in addition to increased entrepreneurial mindset and translational skills, faculty members originally skeptical or opposed to their students' participation started to send their students, and in some cases, pursue the training themselves. I2I was seen as an opportunity explore the possibilities of transformational research.

> **"i2I forces you to think about your research by taking a step back and looking at the bigger picture. It had a permanent influence on how I consider research. Now, whenever someone gives me a suggestion**

or an idea, I think first about where that is going to go. It is definitely helping to shape the entrepreneurial mindset that we've been talking about, and I found that super helpful. ”

MITACS ELEVATE FELLOW 2017–19

In 2019, Mitacs and SFU Beedie partnered to create a non-credit version of the program to be delivered online and across Canada, laddering into the i2I graduate certificate and further credit (figure 8).

In 2020, in partnership with Queens university, an Eastern Cohort was launched and in 2021, an additional Atlantic cohort was launched with Memorial and Dalhousie Universities. A French cohort was launched in 2023. Each cohort has one or two Regional Academic Leads: connected entrepreneurial academics who help lead outreach, support local students, and provide links into the local ecosystem. While the regional partners help with recruitment and delivery, the program was designed to be accessible to participants from any Canadian university, with participants from over 25+ Canadian universities thus far. To further support collaboration and networking across the country, small national learning groups were launched in 2020, pairing groups of students with mentors in their sectors. A network of twenty-five highly connected industry and academic mentors has been assembled from coast to coast with a variety of specialties detailed in figure 9.

To ensure all students could continue the path into the graduate certificate if desired, the grad certificate portion also became online and national in 2023.

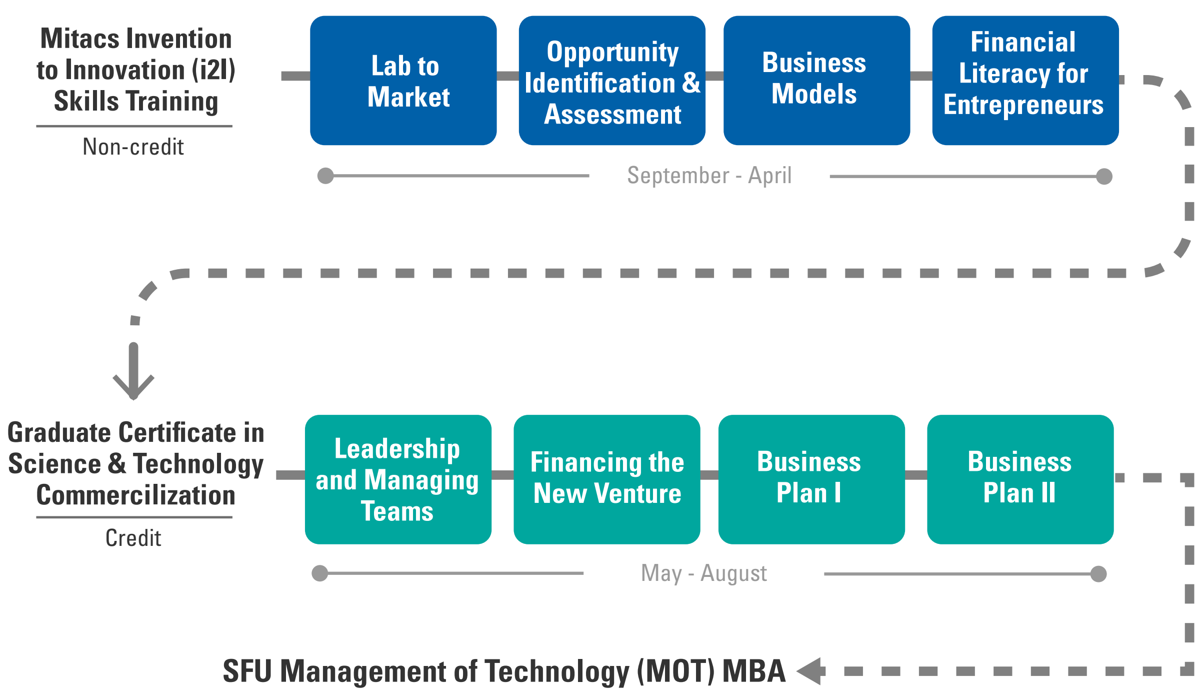


Fig. 8. i2I Training

4.3.3 Insights from the delivery of the Mitacs i2I

Regular feedback has been collected from the participants in the Mitacs i2I program. This feedback can assist in better understanding the perspectives of participants and PIs and provides critical insights that can inform the development of a commercialization-focused STEM postdoctoral fellowship which is more appropriate for the Canadian context. While i2I received significant positive feedback in its one day per week form, several other insights emerged:

1) **Desire for more time:** Feedback from other participants showed they could usefully devote much more time to the commercialization and translation side of their activities.

2) **Lab culture and activity change**: Labs that had no history of translational or commercialization activities, began changing trajectory.

3) **Learning extending past the program**: Participants began to be asked to present their learnings to their labs and/or research networks.

4) **Expansion of participants further changing university culture**: Participants began joining programs from technology transfer offices and core facilities in order to build internal capacity at the university.

5) **Modification of deliverables to reduce tensions with academic outputs**: Participants of the program also managed to use the outputs of the program in several academic outputs of use to their labs and PIs, including journal publications on a commercialization strategy for an emerging technology, a commercialization chapter in a PhD thesis, or assisting with the commercialization section of a translational grant (eg. CIHR).

6) **Equity, Diversity and Inclusion outcomes**: Students who had not been socialized to entrepreneurship and previously seen themselves as not entrepreneurial, but simply not likely to pursue the academic life, realized their own potential to found ventures.

While i2I has shown considerable traction, this research has shown that there is still significant latent demand for translational skills training in labs. Many of the PIs interviewed explained that they were teaching entrepreneurial material, making connections themselves or being incredibly flexible with funding to provide their students and postdocs with opportunities to gain this type of experience. However, it was largely specific to the PI and outside of the normal models and metrics they were generally held to.

Participants from the i2I program have gone on to participate in the other pathways and existing complementary programs. This shows the fit and the need for a translational, pre-commercial postdoc program that can be complementary to existing research postdocs and other commercialization postdocs.

Regular feedback has been collected from the participants in the Mitacs i2I program. This feedback can assist in better understanding the perspectives of participants and PIs and provides critical insights that can inform the development of a commercialization-focused STEM postdoctoral fellowship which is more appropriate for the Canadian context.

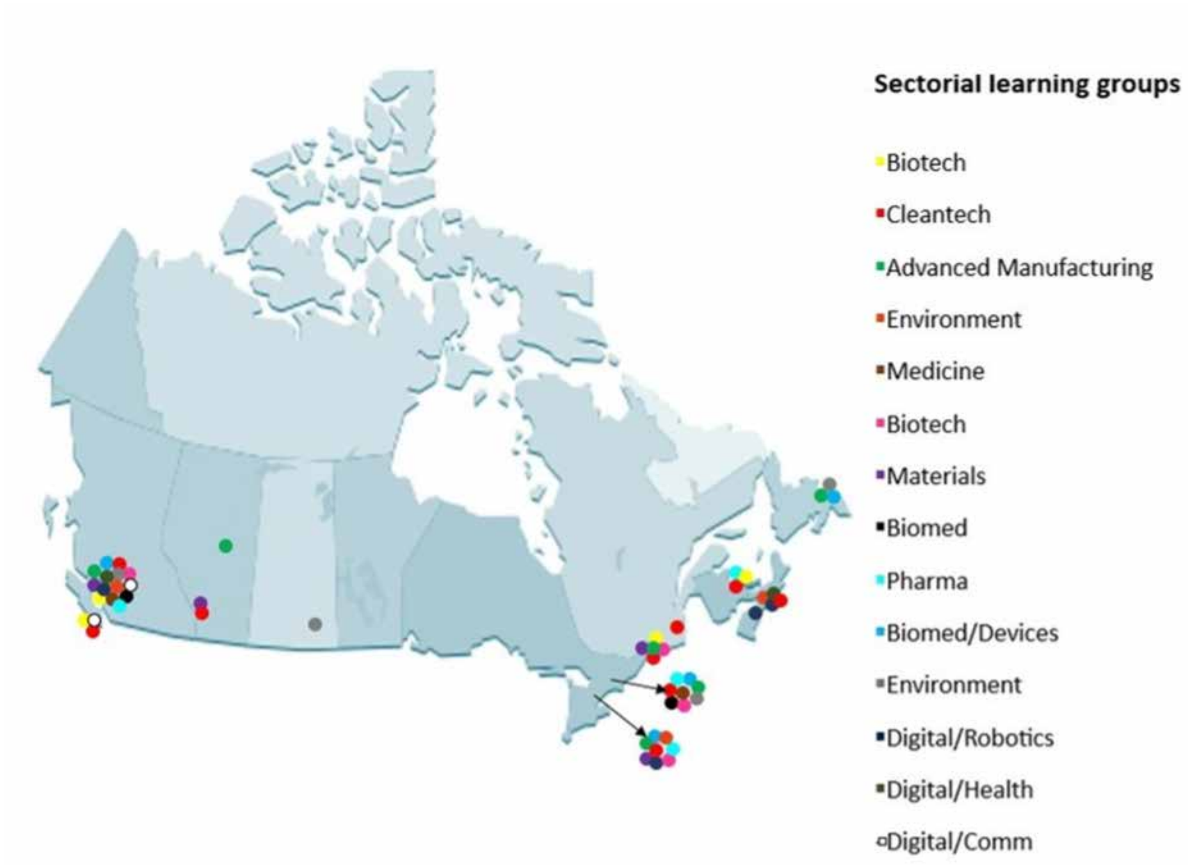


Fig. 9. i2I learning groups across Canada

The Buy-in from PIs for commercialization training

One element that was emphasized was the need for PIs to buy-in to the concept of science commercialization and get on board with the idea of postdoctoral fellows developing their commercialization skills through bespoke training relevant to their scientific ideas.

> **“And you need faculty that will also support that as well, because there is a time investment there. So yeah, that can also be a challenge.”**

> **“The i2I program is great, I think we need to make every grad student even interested at all in this entrepreneurial world take it. I knew other grad students that had very strict professors who weren’t able to spend the time to take that program. Some students were too afraid to even bring it up to their professors.”**

The Constant Search for Additional Funding

As has been noted earlier, with high levels of inflation, stagnant funding, and higher levels of competition, more time is spent by postdoctoral fellows in securing additional funding to survive. This approach of taking up peripheral jobs for additional funding may at times detract from the overall science commercialization effort and dilute the passion and the skills of the postdoctoral fellows.

> **“… It was kind of figuring it out and we had good mentors that helped, but how do you get the validation, when no one has money to pay you.”**

> **“When I saw the [i2I], I mistakenly understood they’d pay me. So at that time, I was not getting paid through the company, and then I started the program, but I didn’t have time because I had to go through other jobs to make a little money to work for my company.”**

However, some postdoctoral fellows are able to leverage the training to raise additional funding for their ventures.

> **“We did [i2I] last fall to spring, and then in the summer, we incorporated the company. So it was just after. But because of the skills we got in this program and the amplification of our message before we incorporated it. We also were awarded this <innovator prize>. The prize gave our company a head start by giving us lab space and some mentorship. So I think that could be partly attributed to our participation in this program.”**

Need for access to specialized research facilities

The ability to raise funding has direct implications for the progression and refinement of early-stage ideas from lab to market. One of the most significant uses of funds raised is getting access to specialized equipment. It is often prohibitively expensive to acquire new equipment and set up high standard research facilities for specific commercialization goals. Thus, many scientist-entrepreneurs are on the lookout for sustained access to high-quality low-cost research facilities which are fully installed and operational. This is particularly important as in several instances the procurement, installation and approval process for specialized new equipment can be extremely complex and time-consuming.

> "You can't just go and set up shop in a warehouse to do chemistry, need the equipment."

> "There are some other places where you can rent lab space, but it's so expensive and it's just very cost prohibitive for that gap phase."

> "People would always share anecdotal experience but there's never like a: here is where you go when you're at this stage of the lab."

> "The other thing that would be helpful is -this is going to be self serving, but- money or grants to use facilities or whatever they need to be, not necessarily just for labs, but to use facilities, especially at universities."

The abilities to access research facilities at universities allows science-based ventures to lower the costs of research and further development and have the added advantage of maintaining connections with PIs, postdocs, and graduate students from related domains[3]. Access to such specialized research networks and intangible assets can be particularly helpful in the pre-formation stage of venture emergence (Thomas et al, 2020; Park et al, 2022; Park et al, 2023).

Networking and mentorship

While access to lab facilities is essential, emerging scientist-entrepreneurs, particularly those from university settings, need to keep a close eye on market needs and changing market dynamics such as competition, funding announcements, and regulations. Mentors with extensive science-based industry experience and networks are particularly valuable for these emerging science-based ventures as these scientists typically are less connected with relevant industry partners and stakeholders.

> "In the academic world, there's not a lot of professors that have commercialized, so it's hard to find that mentorship piece until you find the programs, like i2I, which was really helpful."

3 The ability to access labs and research facilities is often contingent on IP going through the university TTO, with significant variation in policies and the ease of doing this between universities.

> **“I would say one of the most important things that i2I gave me was mentors.”**

> **“My mentor introduced us to a person that he was very well connected to in the tech industry and he’s an executive in residence of a large company and he recommended us to other people. So, it was great.”**

Based on the literature view, analysis of existing programs and these insights from the delivery of the Mitacs i2I programs, we propose a Mitacs i2I commercialization postdoctoral fellowship with the following foundations.

5. Proposed Model – Mitacs i2I Commercialization Postdoctoral Fellowship

Given the challenges of early-stage science commercialization and the gaps in support for postdoctoral commercialization training, the following section outlines the proposed model of the commercialization postdoc program, addressing the key components as identified in the comparison of existing programs. There is a clear opportunity to match the existing Mitacs i2I program with the existing model of a Mitacs postdoc while removing the constraints of matching funding that have been shown to be inappropriate at this stage. This proposed model can be complementary to existing postdoc programs developed to support later stages of commercialization.

5.1 Focus– Built for Translation, Knowledge Mobilization and Commercialization

Many researchers working on high potential scientific research need support before the typical stages of venture formation or industrial partnership are viable, or even clearly the most appropriate path. With the standard 24-month duration for most commercialization postdocs, there is an implicit requirement that the technology and business case is sufficiently advanced to achieve some level of commercial interest for a very broad range of technologies, even if they are early stage. Given the significant challenges of research commercialization, such requirements may unfortunately serve to filter out much of the most ambitious and potentially impactful research which may not be ready for a venture path, and require technology de-risking, intellectual property generation, raising financing, production scale-up, and sector-specific regulatory approvals. This is especially true of translational research in advanced materials, chemistry, chemical engineering, novel therapeutics, nanotechnology, physics, and quantum computing, which face much longer timelines to commercialization but offer enormous potential for societal and economic value creation (Maine and Garnsey, 2006; Pisano, 2010; Thomas et al, 2020; Park et al, 2022). The following model, including structure, candidate selection, milestones and more, is uniquely appropriate at this important and under-supported stage of commercialization where the venture focus of existing modified fellowships proves to be a limitation. Given the significant commercialization challenges articulated earlier, a 24-month training and refinement period may not be enough to de-risk and form a science-based venture based on some of the most impactful technologies.

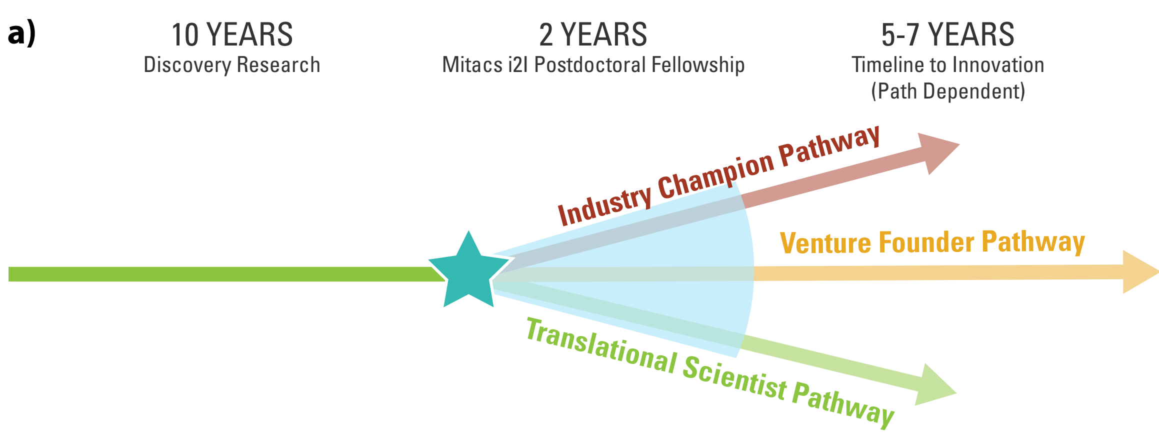
> **“We are hesitant to take things where we feel like they’re going to graduate from the fellowship in two years and have nowhere to go. If they’re still 10 years away, when they come out of the fellowship, either because the market’s not there yet, or it’s just such a long road that it needs to be supported in some other way…”**

A holistic approach, complementary to existing commercialization postdoc programs, would allow for focus on translation, knowledge mobilization and the development of early commercial knowledge and decisions while accounting for the differential timelines for technology de-risking and scale-up, as well as for the funding and regulatory nuances specific to each sector. Such an approach allows for more robust pathways to eventual commercialization of breakthrough science from the lab. It also does not assume that venture formation is the ultimate goal of every research project or researcher. By starting the program without an imposed destination in mind and exploring and shaping the possibilities and the personnel, capacity can be built across the innovation ecosystem, and appropriate milestones can be chosen along the way as evidence is gathered and possible paths emerge.

In addition to a possible ***venture path;*** an ***industry champions'*** pathway which guides postdoctoral fellows to rapidly translate academic inventions by taking roles in established firms, government or innovation intermediates; as well as a longer-term ***translational scientists'*** pathway for academic scientists in universities who can co-found *multiple* science-based ventures through their academic labs, can provide much needed flexibility to account for technology and market uncertainties. Both these pathways also build much needed science innovation capacity across the entire Canadian ecosystem. The industry champions' pathway, in particular, can help address the well-known productivity gap that is known to exist in Canadian industry when compared to peer nations (OECD, 2023).

Figure 10 shows how the proposed Mitacs i2I commercialization postdoctoral fellowship can broaden the scope of science commercialization beyond venture formation, to an industry champion pathway and a translational scientist pathway. In this manner, no presupposition is made that venture founding is the only option and allows for the possibility for uptake by industry or for a longer-term high impact pathway where the postdoctoral fellow joins a research institution as a PI and can not only build platform technologies but can also mentor other researchers to further expand the platform and address significant unmet needs. This high impact approach to science commercialization from universities has recently been noted in the case of the Langer lab (Thomas et al, 2020). His journey stands as a compelling testament to the potential of strategic academic and entrepreneurial fusion in advancing science-based commercialization.

a)



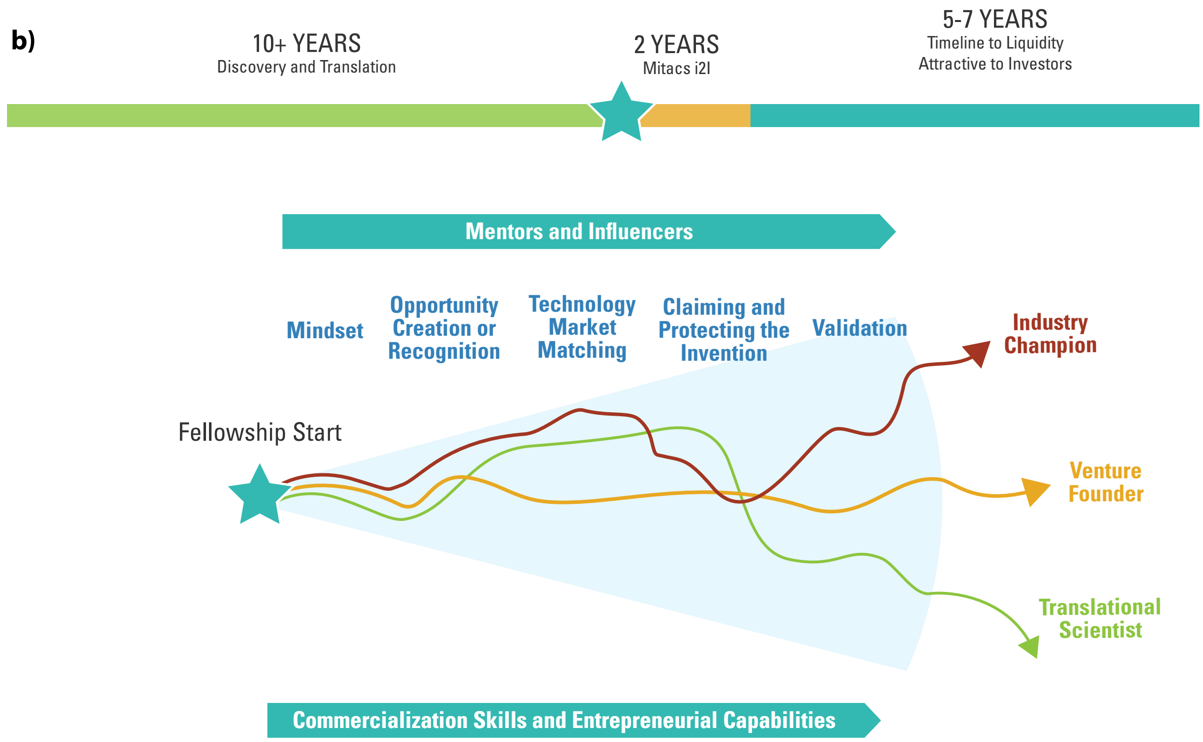


Fig. 10: Developing Commercialization Skills and Entrepreneurial Capabilities in STEM Postdocs

Postdoctoral fellows funded through such fellowships can work on technologies/research that is likely to have an impact on urgent societal challenges. The wider support for the PDFs could include mentorship/networking from potential end-users of the research.

In addition, creating the conditions for entrepreneurs, champions of industry and translational researchers to work together further builds the networks required to translate research into practice and impact. Exemplars 1, 2, and 3 showcase examples of each of the three pathways followed by scientists trained through the SFU and Mitacs i2I training programs. What is evident from these Canadian examples is that the complexity and inherent uncertainties of science commercialization means that a solely venture-focused approach may be underestimating the impact possible through the industry champion pathway and the translational scientist pathway.

i2I Exemplar 1: Evan MacQuarrie – Quantum Computing Industry Champion

As a highly cited and experienced early career researcher, Evan's expertise as a young star within the internationally competitive quantum computing world is broadly admired. After graduating from Cornell and taking up a postdoc with star researcher Mark Eriksson at the University of Wisconsin-Madison, Dr. MacQuarrie was recruited to SFU's i2I program in 2018 through a New Foundations in Research Fund (NFRF) grant aimed at supporting innovation training of quantum experts. The unique grant application, designed to endow skilled quantum researchers with entrepreneurial talent, was co-crafted by Beedie School Professor, Elicia Maine and SFU Physicist and Spin-out founder Professor Stephanie Simmons. Maine and Simmons recognized the need for passionate driven young scientists with entrepreneurial skill within the quantum computing industry. With NFRF support the co-investigators were able to offer an attractive stipend and embedded Evan within the Simmons group, enabling Evan's continued contributions to quantum research while he underwent innovation training.

The culmination of this experience has equipped MacQuarrie with a unique ability to synergize the scientific and business aspects of quantum computing. His accomplishments are evidenced by his highly valued insights into the field, (MacQuarrie 2020), and in 2021 MacQuarrie was appointed to the role of Senior Quantum Architect at Photonic Inc. - a promising and high-profile Canadian Quantum Computing venture co-founded by Stephanie Simmons in 2016.

MacQuarrie's rise to prominence within the industry encapsulates the potential of talent, timely support, and targeted innovation training to foster remarkable contributions within Canadian industry.

i2I Exemplar 2: Entrepreneurial Journey of Benjamin Britton: Venture Founder

As a seminal case study in entrepreneurial academia, Dr. Benjamin Britton's journey underlines the transformation from scientist to venture founder. In 2015, as a senior PhD candidate in SFU Chemistry's Holdcroft Group at the Beedie School, Britton was selected to join the inaugural i2I cohort. Drawing on years of pioneering research into ion exchange polymers, Britton co-founded Ionomr Innovations in 2016, together with his supervisor and two peers. Ionomr has since emerged as an internationally acclaimed cleantech leader, pioneering disruptive economic models in various sectors, including hydrogen, energy storage, carbon utilization, and diverse industrial processes.

Britton's role as Chief Strategy Officer has been instrumental in growing Ionomr into a company that supports more than 40 STEM professionals within Vancouver's local ecosystem, while also maintaining over 100 OEM partnerships worldwide.

Britton attributes the success of his entrepreneurial journey to the i2I program, stating that it succeeded in "lifting the veil between our disciplines and the practice of entrepreneurship, the i2I program is training a new breed of technologists who apply a business lens to the commercialization of their research with the same laser-focus as in the lab".

i2I Exemplar 3: Jasneet Kaur -Science-Based Translational Scientist

Dr. Jasneet Kaur is an Assistant Professor in the Department of Physics, cross-appointed in the Department of Engineering at Brock University, St. Catharines, Ontario. Her research is focused on sustainable nanoengineered materials for clean technologies funded by NSERC and Brock University grants. She specializes in design, fabrication, and engineering of nanostructured materials and nanocomposites by tuning physical, chemical, and electrochemical properties of materials for multidisciplinary applications such as, clean energy storage and conversion technologies, smart coatings, and water treatment technologies.

Prior to Brock, Dr. Kaur was a Mitacs Elevate postdoctoral fellow at Toronto Metropolitan University. As a Mitacs postdoc, she was selected to attend the Mitacs Invention to Innovation (i2I) Skills Training program in 2020. She credits the i2I program as an experience that: *"…facilitated me to think broadly, explore new avenues for my research and enhanced my knowledge on understanding market opportunities, financial literacy and most importantly, it improved my communication style for explaining scientific ventures to the public – which is an important skill for a translational scientist working in academia (as well), from writing successful grants applications to explaining complex concepts to students. I am grateful for this opportunity and would strongly encourage the next postdocs to pursue this program for making a great stride in their entrepreneurial and academic journey*."

Beyond these three exemplars from the i2I program, the full potential of the translational scientist pathway can be further demonstrated through the example of Prof. Robert Langer from MIT who has over a period of over four decades been involved in the co-founding of more than 30 science-based university spin-offs. Prof, Langer has been supported in generating this impact through his work over the decades with a large number of postdoctoral fellows, graduate students, as well as faculty collaborators from MIT and other institutions. The role and support of the MIT technology licensing office (TLO) has also been instrumental in this process.

Exemplar 4: Robert Langer (Translational Star Scientist)

Often under-emphasized, it is important to underscore and illustrate the long-term impact of supporting the translational path. The journey and impact of translational star scientist entrepreneur Robert Langer at MIT demonstrates the long-term outcomes (figure 11).

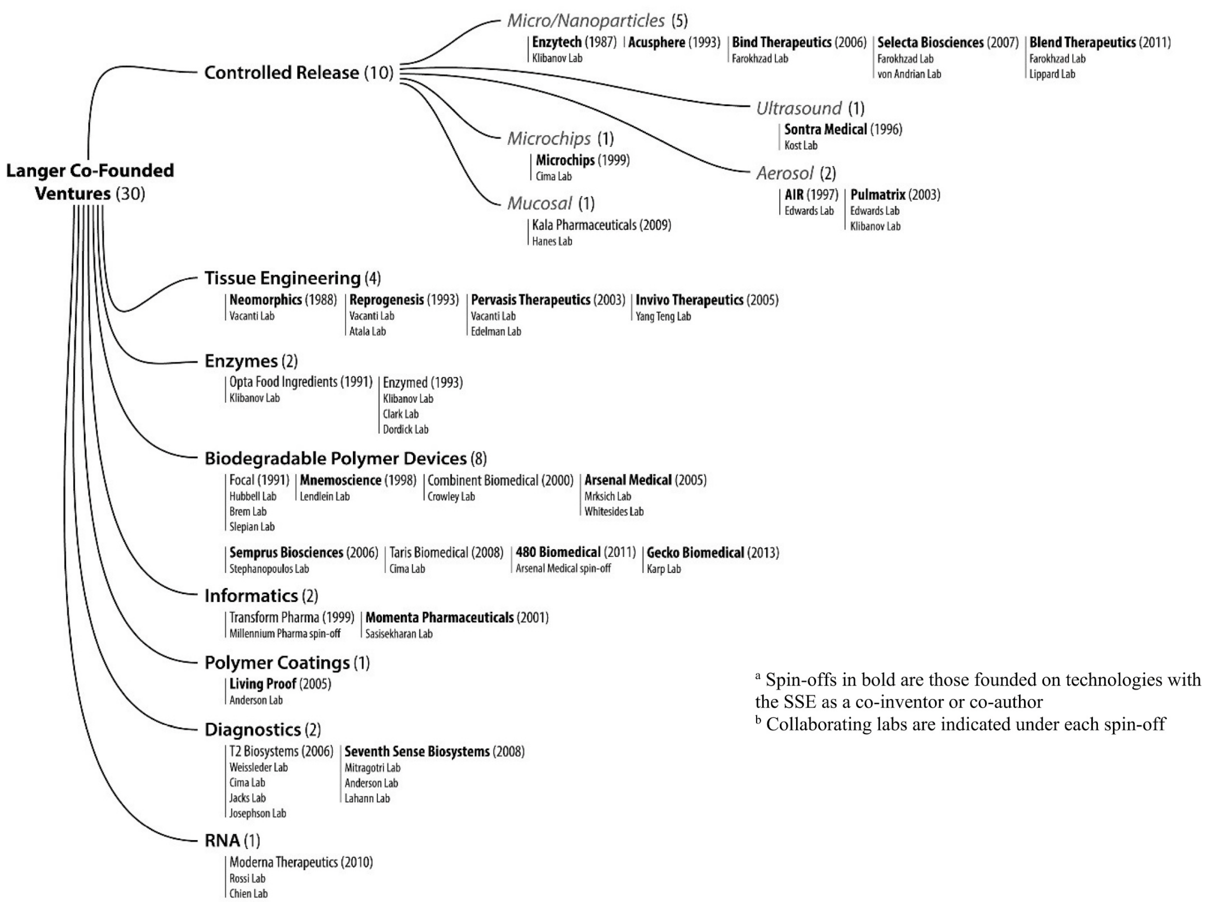


Fig. 11: Translational Scientist Robert Langer and the long-term impact from his lab (Source: Thomas et al, 2020)

From initial research on controlled release polymers platform technology in 1976, Bob Langer co-founded 10 science-based university spin-offs over the next 30 years. He and his colleagues, students, and postdocs have developed multiple platform technologies, co-founded over 30 science-based university spin-offs which have gone on to raise significant amounts of venture funding (Thomas et al, 2020). Several of these technologies are on the market. Beyond the ventures co-founded by Bob Langer, many graduate students and postdocs from his lab continue their commercialization journey as translational researchers and/or co-found their own science-based ventures from their own academic labs. Thus, his broader impact is not only from his own co-founded ventures but also the impact generated through the ventures co-founded by his mentored lab alumni several years later and the HQP trained and employed in industry.

The proposed Mitacs i2I commercialization postdoc also begins to relieve some of the tensions and misalignment identified in Section 3.1, including:

- The importance of aligning the incentives of the HQP, their supervisors, the University, and the Canadian science innovation system by setting up a postdoc meant to advance research and science translation efforts together, including journal articles or chapters on commercialization or translational grants.
- To increase the legitimacy of post-doctoral fellows and faculty pursuing translation and commercialization of their deep tech research, or who want to spin out a company with their own deep tech invention, by linking it to existing, accepted, and award-winning training programs based on commercialization research.
- To address the gap after basic research but before incorporation, where significant Canadian research fails to cross into application or commercialization, by providing a funding source and support structure specific to that gap, empowering breakthroughs from labs previously less or not focused on commercialization and translation activities.

5.2 Proposed STEM commercialization postdoc fellowship model components

The Mitacs i2I commercialization postdoc aims to develop future global scientist-innovators with an entrepreneurial mindset, entrepreneurial capabilities, and innovation skills while simultaneously shaping science innovation opportunities from Canadian university labs which have the potential to create new industries or transform existing ones. Incorporating the Mitacs i2I innovation skills training program as the national backbone for training, supervision, and outcome measurement, this postdoctoral program will support and translate complex, high potential science that could create and support thriving Canadian science-based businesses and sectors. The proposed Commercialization postdoc aims to de-risk university (or Government) laboratory early-stage inventions and innovation ideas over a 2-year period. A postdoc fellowship aimed at advancing science and commercialization without the goal of the venture, but instead identifying and supporting each of the three pathways would look as follows. Table 3 summarizes the key elements of the proposed commercialization postdoc.

Table 3 – Proposed Mitacs i2I Commercialization Postdoctoral Fellowship Model

Program Element	Recommendation
Full-Time	Y
Duration	24 months
Science-focussed	Y
Model	Modified Fellowship
Supervision	Co-supervised by PI & CI
Training	Intensive cohort I&E learning bespoke to focal research idea
Mentoring	Industry and academic leaders from same sector, administrative concierge for further connections
Stipend	Matching funding not required
Facilities Access, patent costs, vouchers	In-kind from, and negotiated with, host institution and other ecosystem partners
Intellectual Property	Dependent on Host Institution

We propose looking for candidates with potential across all three paths (innovation champion, translational scientist, scientist entrepreneur) noting that potential pathways will shift, but attempting to avoid bias toward a single path.

Salary/Stipend: Each of the existing programs pays above the average postdoc salary. As the interviewed PIs underscored the importance of a competitive salary to ensure postdocs would not move on to industry or other opportunities. An amount equal to or exceeding the previous Mitacs deep-tech post-doc pilot would be appropriate for a such an important role in the Canadian Innovation Ecosystem.

Resources Provided: Access to facilities, given the requirement of a PI and CI should be accessed through the funding to access the facilities they need to advance the technology readiness level of their deep tech research, de-risking both scale up and commercialization strategy. Additional funding would ideally be provided for additional required experiments and support aligned with the translational side of the participants' journey.

As this proposed postdoc fellowship is positioned at the pre-incorporation stage, the IP would have to follow the policies of the host university, and mentorship would be used to clarify and help plan an ongoing IP strategy for both the host lab and the postdoc, ensuring clarity through the development process.

5.3 Comparison of the Proposed Model with Existing Models

The advent of commercialization postdoctoral fellowships aimed at researcher-led science-based commercialization appears to be a phenomenon that arose independently in multiple jurisdictions. In particular, the Cyclotron Road, Runway Startup, and the Innovation Catalyst grant programs, which share the most similarities in program components, were all driven by innovative founders that spearheaded adoption within friendly host institutions. These programs have undergone further refinement to converge on broadly similar models informed by outcomes over time (Table 4). As examples of modified fellowships, these three programs share similarities to the proposed Mitacs i2I Commercialization Postdoctoral Fellowship model, with a strong focus on comprehensive support of a small number of highly curated participants. In contrast, the ICURe and Mitacs' Accelerate Entrepreneur programs take a more staged approach, offering a lesser quantum of individual supports to a much larger cohort of participants.

The proposed two-year Mitacs i2I commercialization postdoc fellowship aligns with the complexities inherent in the timeline for science-based translation. It facilitates participants' exploration of three distinct innovation pathways, namely as industry champions, venture founders, or translational scientists.

A generous stipend grants participants the financial freedom necessary to focus on their innovative pursuits and attracts high-calibre candidates, much like other large awards such as the Banting fellowship and the NRCAN fellowships in Canada. The prestige associated with fellowships such as the Cyclotron Road program, offered via the NSF Activate initiative, draws hundreds of annual applications, bolstering the validation of academic-led, science-based innovation amongst both academia and investment communities.

The successful translation of science-based ideas hinges largely on comprehensive supports that extend beyond financial provisions. These supports should enable early-stage developmental activities such as market discovery, prototype creation, technology de-risking, IP strategy formulation, and patent applications. Flexible funding, a viable alternative to early-stage private investments, caters to the intricacies of complex innovations characterized by lengthier development timelines. Most existing programs emphasize venture formation, facilitated by institutional or venture capital SAFE equity agreements. For instance, the Innovation Catalyst Grant provides flexible funding of $70,000 per year with no equity limitations, with an expectation of venture formation and leveraging support through other grant mechanisms. The envisaged Mitacs i2i commercialization postdoc model aims to support a broader spectrum of innovators, including Translational Scientists, Industry Champions, and Venture Founders.

Access to specialized equipment situated within institutional facilities and academic labs is crucial to overcoming the hurdles associated with transforming laboratory inventions into impactful innovations. Localized fellowships, such as Cyclotron Road, the Runway Startup Program, and the Scientific Ventures Program, negotiate access to such facilities through overarching agreements with their host institutions. Conversely, a national approach necessitates a more comprehensive strategy whereby equipment access is negotiated individually with each institution hosting a fellow. This methodology, refined through ongoing partnerships, will pave the way for a sustainable model that streamlines program delivery over time.

Central to the modified fellowship model is an extensive innovation training component. This feature is evident in the models we have examined, models which largely evolved organically and were advocated by individuals as opposed to established funding and training organizations. A shared trajectory in these models highlights a progressive emphasis on innovation training as an integral part of their evolving programs, highlighting the convergence of their empirical approach to program development with the innovation pedagogy research-based approach examined in Section 4.3. The proposed Mitacs Postdoctoral Fellowship stands to gain significantly from the established i2I training curriculum that has already succeeded in building a robust national delivery platform.

Intense investment of both time and resources into a small cohort of top performing, entrepreneurially minded postdocs enables mentoring support that is both greater and more flexible than for the staged model programs. Furthermore, distinguished mentors and investors are more inclined to share their networks and engage deeply with fellows who, via a careful selection process, have strong future potential throughout the Canadian innovation ecosystem.

The issues of program funding and intellectual property are at the heart of fellowships centered on innovation. A degree of flexibility, mirroring the Innovation Catalyst Grant's approach, both in the disbursement and utilization of funds as well as in the negotiation of IP ownership, without the requirement for matched funding, or SAFE equity agreements, and under favourable institutional IP arrangements, will grant the Mitacs i2I commercialization postdocs the unfettered capacity needed to follow the most suitable innovation pathway as they navigate critical early-stage commercialization challenges.

Table 4: Comparison of proposed model with existing models

Characteristics	Innovation Catalyst Grant (2004)	ICURe (2013)	Cornell Runway Startups Program (2014)	Cyclotron Road (2015)	SVP Concordia (2021)	Mitacs Accelerate Entrepreneur (2019)	Mitacs i2I Commercialization Postdoc Fellowship
Science-focused	Y	N	N	Y	Y	N	Y
Duration (months)	24	3+	24	24	24	4-24	24
Salary p.a.	CAD 60K	GBP 35K	USD 100K	USD 90K	CAD 45K	CAD 15K	Meeting/ Exceeding Canadian norms
No. of positions	8	10-15/3mo	Up to 6	10	2-4/6mo	100s	Selective
Total Flex funds for commercialization	CAD 130K	GBP 300K~	USD 325K	USD 100K + 300K*	CAD 52K	CAD 5K^	To be provided.
Pathway Focus	Venture	Venture	Venture	Venture	Venture	Venture	Multi-path – Venture, Industry, Translational Scientist
Stage	Early Stage	2-6	Early Stage	Early Stage	Early Stage	Incorporated◊	Early TRL
Facilities Access	6 months/ Negotiated	University specific/ Self -directed	USD 50K/p.a.	USD 100K	Case-by-case Basis	Self-directed	Case-by-case basis
Training	1 to 1	5-day bootcamp + market validation	3 Months half-day intensive	90 mins weekly	Workshops + partner programs	Mitacs offerings optional	Mitacs i2I 11 months, followed by i2I graduate certificate.
Mentoring	Leverages local accelerators/ incubators	Embedded mentor in team	Weekly office hours	Quarterly events, weekly invitees	Bi-weekly 1 on 1, + advisory council	Self-Directed	Co-supervision by PIs and commercialization investigators (CI). Additional monthly sector-specific mentoring.
Model	Modified Fellowship	Staged	Modified Fellowship	Modified Fellowship	Modified Fellowship	Staged (Renewable)	Modified Fellowship with pathways for later applicants
SAFE Agreement	No	No	Yes	Optional	Yes	No	No
Matched funding requirement	No	Yes	No	No	No	Yes	No
Intellectual Property	Pre-Negotiated with host TTO	According to host institution TTO	Blanket license from TTO, IP for equity, SAFE	None/ pre-existing	SAFE/ According to host institution TTO	Pre- Negotiated with host TTO	According to host institution TTO
Initial funder	Provincial government	UK research and innovation	Jacobs Institute (endowment)	Philanthropy/ DOE	Canada Economic Dev. for QC.	Mitacs Canada	Mitacs Canada, Provincial, Private.

5.4 Discussion: Why this model fills a critical gap for Canada

One of the most significant aspects of this proposal draws on the understanding that science-based university spin-offs require significantly longer timelines and need additional funding for de-risking and scaling up breakthrough technologies with societal impact (Maine and Seegopaul, 2016; Maine and Thomas, 2017; Thomas et al, 2020; Park et al, 2022). Even with high levels of commercialization training and support, not every science-based innovation idea may be ready for commercialization via translation to industry or venture formation, and additional external fundraising, within a period of 24 months, particularly within Canada. Between research and these types of programs lies a clear gap in support that, if addressed, would create a greater supply of high potential research to take forward and the talent to do it, complementary to existing models. Another related point to note is that venture formation is not the only or best path for every research project or researcher, however funding approaches, like SAFEs, constrain participants to venture outcomes and timelines. Acknowledging these challenges, the proposed commercialization-focused STEM postdoctoral fellowship offers three pathways to facilitate societal impact through science-commercialization.

For ideas closest to commercialization, an industry pathway is offered for postdoctoral fellows to connect with and translate scientific research within established companies. This pathway recognizes that Canadian ventures have typically been slower to adopt new technologies emerging from university settings and supports postdoctoral fellows who elect to work in these established companies.

For ideas with a somewhat longer timeline involving further de-risking and fund raising, this postdoctoral fellowship follows the standard approach in advocating for science-based university spin-off formation through the venture pathway, supporting postdoctoral fellows undertaking the significant task of de-risking and scaling up breakthrough technologies.

The third pathway recognizes that even with bespoke training, there may be some breakthrough ideas which may be very early for the market. In such instances, further awareness of the potential of the technology among industry and policy stakeholders is needed. An example of such a situation is the case of green hydrogen which is now gaining increasing traction in the marketplace though some of the foundational technology has been in development for more than two decades. In such cases, it may be advisable for the postdoctoral fellow to follow the translational scientist pathway, which has a longer timeframe, and the additional advantage that the scientist-entrepreneur becomes an academic PI. A translational scientist that establishes their own academic research group can train additional graduate students and postdoctoral fellows to support the longer-term commercialization of their technology. The value of such an approach has been observed in some recent studies (Thomas et al, 2020; Park et al, 2022).

By focusing on this early-stage of commercialization without presupposing the appropriate path, and instead incorporating a process to ensure rigorous decision-making, validation and strategic choices, stronger foundations can be set for high impact, science-based research translation. Postdoctoral fellows have been clearly shown substantial potential to be key agents of unlocking value and impact at this stage, when enabled by the support of PIs and host universities, better aligned with existing incentives, and incentivized through the competitive funding, training, and mentoring supports. Thus, this approach aligns the potential of these HQP with this important gap in the Canadian innovation ecosystem, while complementing existing solutions.

6. Proposed Fellowship Model – Potential Implementation Challenges, Risk Mitigation, and Impact Measurement

Through entrepreneurial talent development, Mitacs, SFU, and their partners across Canada already provide a continuum of training, financial support, and mentorship for science and engineering graduate students, post-docs, and research faculty to support science-based innovations with potential global impact. This commercialization postdoc would be a crucial addition to that high impact continuum, allowing Canada's most promising researchers the opportunity to focus on world-changing research at a critical and under-supported stage.

It is suggested that the postdoc stipend be set at an amount that would be attractive and keep high potential candidates from moving to more lucrative positions outside Canada. Training can be largely done through the existing i2I infrastructure and with additional staff to support the program participants and support team. While unmatched internships are currently not within Mitacs' mandate, exploring this approach would be ideal given the overwhelming evidence that other nations have already moved away from matching models and current Canadian policy discussions are also moving in that direction.

It is suggested that this commercialization postdoc include funding for facilities' access, patenting, and other vouchers, and that these be required as in-kind contributions by the host institution. Given that this selected commercialization postdoctoral fellow would be an active member of their lab, the IP policy of the host institution would apply, and how to work within it would be part of the deliverables and coaching.

6.1 Potential Implementation Challenges & Risk Mitigation

Through our interviews and the final workshop in Kingston, we were not only able to understand the gap in support but were also able to hear from stakeholders about challenges and opportunities for risk mitigation. These include the following challenges and how they have or will been addressed (Table 5).

Table 5: Implementation Challenges and their Mitigation

Potential Implementation Challenge	Mitigation
Coordinating players and funders	By using existing models, working with faculty, existing Mitacs systems this risk is minimized.
Building buy-in with PIs	Support commercialization of research involving PI, team with CI, builds commercialization capacity in the lab of the PI.

Potential Implementation Challenge	Mitigation
University Process	While there was concern that existing university processes would not support this program, by linking two established programs which have already been vetted and implemented nationally, this risk is minimized.
Postdocs won't have time to participate in entrepreneurial training	Ensuring that part of their funding is tied to their translational deliverables, each participant will have to manage their time and priorities. Moreover, making the PI part of a team supporting the student furthers buy-in and accountability.
Will this be valued given the current, culture, existing mindsets, institutional narratives on innovation?	Feedback on i2I shows that faculty increasingly feel the need to help their students build skills, and that they would like to see their research have impact, but often do not know how. Having a program that advances innovation and research starts resolving this tension and will have benefits in terms of marketing and recruitment.
Accessibility	The requirement of matching funding for such initiatives often limits access to a few institutions that can provide for or arrange additional funds. Therefore, given the scarce resources of most universities, a non-match commercialization postdoc with in-kind and centralized supports would allow for much wider participation leveraging existing systems from across Canada.

The difficulty in measuring the impact of such a program was also noted as a challenge. The potential impacts of the proposed commercialization postdoc, the time lag of impacts, and how it could be measured is discussed below.

6.2 Impact Measurement

The proposed program will have substantial direct and indirect impact on researchers and labs and will provide opportunities for innovation and economic growth. In our interview data, the need for models that would support the type of research translation that could solve global challenges was repeatedly underscored. As has been noted in earlier sections, this focus requires a long-term approach.

Through three translational pathways, the i2I program enables the development of innovation leaders in industry who can be a bridge back to university research labs. It fosters the founding of well-endowed spin-off companies that will not only create jobs but reach back into the lab to continue advancing research and training, and incentivises broader, more impactful research, and deeper interdisciplinary collaboration for translational scientists in universities.

The current i2I programming has already shown substantial impact, with alumni co-founding and scaling ventures from labs where no spin-offs had been co-founded before; alumni transitioning into key leadership roles in science-based firms; or changing how they run their academic labs and pursue opportunities as translational scientists. Using and augmenting the existing program metrics, short-term impact can be measured. It is also recommended that mid-term and longer-term impact measures be gathered, which will help to drive further program refinement, as well as create much needed evidence to inform academic and government policies. Typical medium-term impacts could be an increase in strategic patenting activities, changes in publishing patterns in research labs, increase in submission and granting of translational and commercialization funding, attraction of industry or other partners, as well as observable changes in attitudes and culture which can be measured through surveys and interviews.

After strengthening and catalyzing the early-stage research and researchers still in the lab, each pathway will create substantial long-term impact.

In the industry champion path, it is expected that program participants would move into leadership positions in existing ventures to guide the translation of academic science into industry settings. They can also hire and lead other researchers and build better connections to academic labs.

For those ideas where venture co-founding is appropriate, existing programs show the potential to generate large economic benefits. For example, the Innovation Catalyst Grant (as GreenSTEM) embedded 9 fellows over 3 years at the University of Calgary from 2018 to 2021 leading to C$80 million of follow-on funding and investment in venture formation, an approximately 40:1 return on the provincial government's investment.

Secondary analysis of Cyclotron Road's cohort of approximately 70 Fellows since 2015 conducted through this project identified 37 ventures that have progressed from an early stage to investor funded enterprises. Total investment in these maturing ventures totals more than US$ 800 million, a 10:1 economic return on program costs. We note that this is from the more munificent US ecosystem.

For those who pursue the translation path, this has the potential for perhaps the greatest impact over time. Looking at the example of the Langer lab (refer to section 5.1), when given the proper foundations, these labs can train the next generation of commercialization-oriented scientists, changing culture and capacity, as well as building the industry connections that can lead more students down the industry champion, venture founder, or translational scientist path. Moreover, they can become co-founders of high impact science-based ventures from their own independent labs. As noted, over a 40-year period the Langer lab spun-out over 30 ventures and trained many graduate students and postdocs, many of whom went on to co-found other impactful science-based ventures, while continuing to be highly productive in publications that influenced the evolution of their respective field.

6.2.1 Other indirect impacts

Based on the above research, as well as workshop input from stakeholders such as professors, university administrators, Mitacs representatives, i2I Alumni and current grad students and post docs, other indirect change that could be created by such a program includes:

Attitude and Culture Change: A postdoc program like this, which advances research and advances translation while the participant is still based in the lab, can increase the acceptance and attractiveness of pathways beyond the typical academic route. It can better align traditional university outcomes and incentives, such as papers and grants, while re-orienting them to be more translational. As current i2I feedback suggests, having students advance their entrepreneurial mindset also has a positive impact on lab mates and PIs who begin to see additional value.

Relieving pressure and dependence on entrepreneurial Pis: Our research suggests that several Pis are building in their own entrepreneurial supports for their labs. While of great benefit to their students, it means this type of support is not being built into the university structure. By building a system that can support (and create) entrepreneurial Pis, additional capacity can be built across Canada. The creation of a commercialization CI role also allows such entrepreneurial Pis to support multiple students, creates interdisciplinary connections, and can provide access to a larger national and international network of industry mentors and commercialization researchers.

Equity, Diversity, and Inclusion: By requiring a match, many programs create barriers that limit the types of researchers who can participate, making participation easier for those with greater resources and/or from well-resourced labs and universities. Removing those barriers will have an impact on who can and does participate.

Signalling: Having a high-profile program that can focus on the type of high impact research with long time frames has the additional bonus of being able to help attract global talent to Canadian labs, as well as retain talented researchers trained in Canada.

The continuum of impacts unlocked through this commercialization postdoc suggests that existing Mitacs i2I programming can be further leveraged to generate significant value for Canada while addressing global societal challenges.

7. Conclusions

This study is motivated by the increasing recognition that science and science commercialization can play an important role in addressing significant societal challenges such as climate change and pandemics. We uncover and highlight the role of postdoctoral fellows in the early translation of scientific research from academic labs into breakthrough products and services. We conduct an in-depth literature review on science commercialization and the under-recognized role of postdoctoral fellows in this process, and a comparative analysis of leading STEM commercialization postdoctoral programs in the US, the UK, and Canada. This analysis is further complemented by 50 in-depth interviews and a focus group workshop with stakeholders.

Drawing on the results of this exercise, as well as the experience of running the SFU and Mitacs i2I innovation skills training program since 2015, we identify areas of improvement in existing commercialization postdoctoral training and funding models. Based on our research and i2I delivery insights, the key considerations most relevant to the Canadian Science Innovation ecosystem are:

1) To broaden the focus of commercialization training from a sole venture formation focus, to include an industry champion focus and a translational scientist in academia focus essential for the medium term and long-term value creation from breakthrough scientific inventions in Canadian universities.

2) To not require matching funding for the proposed commercialization postdoc as it can disadvantage underrepresented groups as well as hold back commercialization of some of the most impactful science. In-kind matching in terms of access to research facilities and space would be appropriate for this proposed model.

3) To provide a level of postdoctoral compensation and flexible commercialization support funding that attracts the brightest postdocs to Canada while accounting for inflation and taxation.

We note that our proposed model is complementary to existing commercialization postdoctoral fellowship models and leverages the training currently being provided through the Mitacs i2I skills training program across Canada.

We anticipate that the acceptance and roll-out of this strategic pilot program can unlock and leverage the significant latent potential of STEM postdocs in Canada through bespoke commercialization training designed specifically for the Canadian science innovation ecosystem. In doing so, Canadian science researchers can be mobilized to address some of the significant societal challenges of our time.

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