The Impacts of Mitacs Internships in Manitoba

Research Manitoba

Mitacs

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List of Acronyms

AC: Alternating Current

DC: Direct Current

HQPs: Highly Qualified Personnel

HVDC: High Voltage Direct Current

IBD: Inflammatory Bowel Disease

Key terms

Alternating current: an electric current that reverses its direction many times a second at regular intervals, typically used in power supplies.

Apiaries: a place where bees are kept; a collection of beehives.

Crohn's disease: an inflammatory bowel disease. It causes inflammation of the digestive tract, which can lead to abdominal pain, severe diarrhea, fatigue, weight loss, and malnutrition.

Direct current: an electric current flowing in one direction only.

Highly qualified personnel: are persons with university degrees at the bachelors level and above.

Inflammatory bowel disease: is a group of inflammatory conditions of the colon and small intestine. Crohn's disease and ulcerative colitis are the principal types of inflammatory bowel disease.

Inputs: The actual research activities, processes, and resources invested towards a project. Examples include the knowledge and expertise of the researcher.

Impacts: The contribution(s) that research makes beyond academia and that directly or indirectly affects all areas within society, the environment, culture, and the economy.

Outcomes: Intended or unintended benefits or effects that derive from the intended results of the research activities. Outcomes can be short or long-term. Examples include licensing agreements, new or revised processes, standard or policy changes, changes in perception or awareness on an issue.

Outputs: The intended results of research activities, including tangible and intangible findings and products of research. Examples include knowledge and discoveries resulting from the research, publications, patents, works of art, partnerships, or enhanced trust that were developed.

Semaphorins: are a class of secreted and membrane proteins that were originally identified as axonal growth cone guidance molecules. They primarily act as short-range inhibitory signals and signal through multimeric receptor complexes.

Executive Summary

The purpose of Research Manitoba's impact narrative is to document the outcomes and impacts of research in the province. The goal of the impact narrative is two-fold: a) to communicate the impacts of research to a wide variety of audiences such as academics, industry, community groups, the public, and other users of research findings, and b) to link outcomes and impacts to the original research.

For the past twenty years, Mitacs a not-for-profit organization has fostered growth and innovation in Canada for business and academia . In Manitoba, Mitacs provides and oversees three programs:
1. Accelerate since 2007, which provides internships to graduate students and postdoctoral fellows.,
2. Elevate since 2013, which provides postdoctoral Fellowships, and
3. Globalink since 2014 which provides both Canadian and international senior undergraduate and graduate students internships to pursue research in a partnered country.

As of 2018 these programs have provided 1,074 internships to students in Manitoba.

The objective of this impact narrative was to investigate what the impacts of research projects implemented with Mitacs funding through their internship program, have been for the interns, academic supervisors, and partner organization.

To advance this line of inquiry, Research Manitoba consulted with Mitacs to identify all internships completed in Manitoba to determine which internship projects would be suitable to participate in a case study methodology. Relevant data (student's name, professor's name, partner organization's name, and description of research) was collected from Mitacs with four research projects being selected based upon their diversity in research areas and different kinds of partner organizations. The following research projects, which were made possible through Mitacs internships, are focused on in this narrative:

- *The semaphorins, a role in Inflammatory Bowel Disease*
- *Investigation of a hybrid cascaded modular multilevel converters*
- *Clay binding of gravel roads*
- *Sensor development of intelligent apiary*

The impacts of the above research projects were examined through the utilization of a case study approach, where the individual cases in the collection were chosen as it was believed that by understanding them, it will lead to a better understanding, and perhaps theorizing of the impacts of Mitacs internships. The development of highly qualified personnel (HQPs) occurred

in all cases and can be theorized as the most common impact of Mitacs internships in Manitoba. The second type of impact identified in half the cases was the advancement of science through innovative discoveries, that were shared in the scientific community through peer-reviewed publications. The third type of impact that was identified in one case, was an increase in profit for the partner organization based upon the research conducted during the Mitacs internships.

Part I: Introduction

A) History of Mitacs

Mitacs is a national, not-for-profit organization that has designed and delivered research and training programs in Canada for 20 years. Working with 70 universities, over 35 colleges, thousands of companies, and both federal and provincial governments, partnerships are built to support industrial and social innovation in Canada. Mitacs was founded in 1999 as a Canadian Network of Centres of Excellence (NCE), dedicated to supporting applied and industrial research in mathematical sciences and associated disciplines.

At the time when Mitacs was established, graduate student enrolment was declining, links between mathematics and industry were non-existent, and talented researchers were leaving Canada[1]. Founded by Don Dawson, Steve Halperin, Luc Vinet and co-founder Nassif Ghoussoub with NCE funding, Mitacs initially promoted mathematics as a tool for industrial development and through this provided opportunities for graduates to gain workplace experience.

In 2003, a research internship program designed to increase the deployment of highly educated graduates into the private sector was launched[2]. Since then, Mitacs has created other programs designed to respond to industrial and university needs, including programs in Research and Development, management, professional skills development and international research training.

- In 2007, the Step program was created to help graduate students acquire professional and business skills
- In 2007 the Accelerate program tripled in size to include all disciplines with a grant of $10 million from the BC government.
- In 2009 Globalink launched with aims to forge international relationships and bring talented international researchers to Canada.
- In 2010, Elevate, a program designed to help keep talented PhDs in Canada was launched. The program provides postdocs with two-year research fellowships, offers professional and business skills training, and connects them with industry[1].

The goal of Mitacs is to provide financially supported internships and serve as a bridge connecting graduate students and Post-Doctorate Fellows to research experience in the employment-sector. This contrasts with the well documented increase in unpaid internships for students in Canada[3]. The media has exposed the negative consequences unpaid internships often have on students' health, finances and academic performance[3,4]. The programs

developed by Mitacs provide some financial security, which grants students in Canada the opportunity to flourish in both their knowledge in and experience in conducting research. An additional goal of Mitacs's is to develop the next generation of researchers and innovators for Canada's knowledge- and innovation-based economy. Mitacs brings together industry, not-for-profit organizations, community groups and post-secondary institutions to develop projects which solve business and societal challenges, while advancing academic research goals. Mitacs funds cutting-edge research across all disciplines, creating job opportunities for graduate students and helping companies reach their business goals.

In 2019, with the support of federal and provincial governments, post-secondary institutions, and industry, Mitacs will invest approximately $140M to support industry-driven applied research projects – in Canada and internationally – primarily through internship programs. Mitacs's programs are enhanced by an extensive Canadian network of over 105 post-secondary institution partners and over 6,000 companies they work with. Over the course of the last 20 years, Mitacs has funded more than 16,000 research projects, resulting in 33,000 students prepared for careers in industry and not-for-profit organizations.

Adding to its strong domestic presence, Mitacs has an extensive international network allowing Canadian researchers and industry to benefit from access to a global knowledge base, and international researchers to bring their expertise to Canada. This two-way knowledge exchange has provided for more than 5,500 international research internships.

B) Why are internships important?

Internships as voluntary, temporary work placements, often undertaken by students, have been welcomed as a win-win situation for both employers and interns[5]. There is evidence that internships feature strongly when it comes to the employability of graduates from higher education[6]. There is some research that has demonstrated that internships are associated with a positive increase in academic achievement[7]. Thus, internships have the potential to be hailed as both an academic outcome booster and a powerful career booster.

The internships offered by Mitacs, are unique as they apply research skills found in higher education to organizations to create or lay the foundation for innovation. Internships offered by Mitacs, financially support graduate students (either pursuing a Master's degree, PhD, or Post-Doctorate Fellowship) or senior undergraduates. Given the suite of programs that Mitacs offers and the potential for students to benefit from the flexible structure of each program to execute their project we provide below a brief description of the time lengths involved in each program:

- An Accelerate internship (for Masters, PhD's and post-docs) can range from 4-6 months with the option of undertaking more than one internship unit.

- The Mitacs Elevate is a two-year research management fellowship designed to support partnerships between postdoctoral fellows and Canadian companies to carry out innovative research projects.
- Mitacs Globalink is a suite of programs designed to engage international and domestic talent in two-way travel-abroad research experiences, which aim to build strong linkages internationally and brand Canada as a destination of choice for international students. An award can range from 3-6 months.

Internships are associated with graduates obtaining a job more quickly, with higher salary levels, as well as increased job satisfaction[6]. Thus, Mitacs provides students the opportunity for increased probability regarding successful employment upon graduation. Mitacs also develops relationships between academic institutions and corporations or non-profits. Through Mitacs, relationships can develop between highly skilled Professors and corporations, which increases innovation in Canada.

Mitacs's cooperative innovation model builds relationships based on shared objectives, supports cutting-edge research that fuels discovery, and delivers work-integrated learning opportunities to innovation leaders.

Through this innovation network, thousands of companies and researchers across the country have worked together to advance new ideas, products, and processes. This proven approach supports the creation of innovation partnerships and facilitates lasting relationships that ultimately result in more aligned and connected research and development. By building a stronger culture of cooperation, Mitacs is contributing to the success of the country's competitiveness and the creation of a vibrant and dynamic innovation ecosystem.

C) What is the role of Mitacs in their internships?

The role of Mitacs in facilitating research and innovation through internships is multidimensional. Mitacs receives both Federal and Provincial funding for the internships and provides developmental and logistic support throughout the internship process. In Manitoba, the provincial source of funds is Research Manitoba. The partner organization contributes 50 percent of the finances for the internship.

In Manitoba, the most common internship utilized by graduate students is the Mitacs Accelerate Program, and the key person in developing these internships is the Mitacs Business Development Officer The business development specialists – there are 80 of them embedded within past-secondary institutions across Canada – connect and foster the relationship between academic supervisors and the partner organization; their ties with post-secondary institutions, industry and not-for-profit organizations enable them to match the right researcher and student/postdoc with the best opportunity. The Business Development Officer remains

involved in the project from the development stage, through the application process and is available throughout the course of the project.

D) Impact narrative approach and methodology

Research Manitoba develops impact narratives to document the outcomes and impacts of research in the province. The goal of the impact narrative is to: a) link outcomes and impacts to the original research, and b) communicate the impacts of research to a wide variety of audiences such as academics, industry, community groups, the public and other users of research findings. Specific goals of the Research Manitoba impact report are to:

- Determine the return on investment on funded programs and projects;
- Record accountability and transparency (a reporting tool to the Government of Manitoba);
- Encourage a proactive and prospective measurement and monitoring of research impacts among researchers, funders and users of knowledge; and,
- Contribute to the growing practice of research impact assessment in Canada and globally.

Outputs, outcomes, and impacts in this narrative are examined through the lens of the Research Manitoba impact framework, which is divided into five categories:

a. **Advancing knowledge** involves creation/co-creation of knowledge, new discoveries and breakthroughs arising from research, and contributions to the knowledge pool.

b. **Building capacity** refers to the development and enhancement of the ability of individuals and teams to conduct and sustain research.

c. **Influence on perceptions, thinking, awareness, and decision making** because research activities/findings can take numerous forms, but this largely refers to the influence and effects on government; industry; the research enterprise; not for profit organizations; individuals, groups and communities; educational institutions; and the public.

d. **Applications and changes** are the outcomes and impacts that result from research in natural sciences and engineering disciplines.

e. **Broad benefits** include economic, technological, environmental, social/societal, and cultural impacts such as wellbeing and prosperity**.**

To identify and understand the extent of the impacts as well as the work of Mitacs, this impact narrative poses two evaluation questions:

1) What have the impacts of the research projects involved in Mitacs been for the interns, professors, and partner organization?

2) To what extent has Mitacs's role contributed to the identified impacts?

To answer the first evaluation question, Research Manitoba consulted with Mitacs to identify all internships completed in Manitoba and their relevant data (student's name, professor's name, partner organization's name and description of research). From this data four research projects were selected to participate in a case study methodology. The case studies were selected based upon their diversity in research areas and different kinds of partner organizations. The descriptive case study approach was carefully chosen in order to a develop, a complete detailed portrayal of some of the Mitacs internships so that their narratives, could be shared with policy makers and scholars.

Research Manitoba discussed with Mitacs an impacts-and-research diagram (Appendix 1) and the approach of the impact narrative. The diagram illustrates, in broad strokes, the scope of the impact narrative including:

- Determining the impacts that will be highlighted,
- Identifying the evidence that connects the impacts with the original research activities,
- Linking the appropriate research activities and inputs to the identified impacts.

For the second question, contribution analysis or a theory of change model is used to show how funded research, which Mitacs orchestrated have led to the identified impacts. Contribution analysis is a causal model that shows the links between activities, outputs, outcomes, and impacts[8].

To collect data for the impact narrative, 12 semi-structured interviews (Appendix 2), where participants were: academic supervisors, interns, and partner organizations, were conducted. Twelve surveys were also completed, and each survey was customized to whether the recipient was an academic supervisor, intern, or partner organization (Appendix 3). The breakdown of the participants' roles in the internship is as follows:

- 4 University Professors (Academic Supervisors)
- 1 intern who was a Post Doctorate Fellow at the time of the Mitacs internship
- 2 Interns who were PhD Students at the time of the Mitacs internship
- 3 Interns who were M.Sc. Students at the time of the Mitacs internship
- 2 Presidents of partner organizations

The remaining two partner organizations provided statements regarding their experiences with Mitacs. Due to geographical constraints, a full semi-structured interview could not be

conducted, but the partner organizations' perspective was still incorporated into the impact narrative.

E) Limitations

Some Mitacs internships that were selected for the case study analysis had multiple partner organizations; when this occurred, we were only able to receive one partner organization's experience with the Mitacs internship. In addition, not all partner organizations were from Winnipeg which prevented an interview occurring. In this instance the partner organization provided a quote describing whether they valued the internship and the reasoning behind their sentiment.

The overarching limitation in any study utilizing a case study methodology is the possibility that the findings presented here are unique and not representative of most Mitacs internships. This limitation has been reduced by having the Mitacs Manitoba Business Specialist who is familiar with the outcomes of all Manitoba internships, perform a peer review of our outcomes to ensure they do not consist of a few outliers.

Part II: Findings

A) Financial Inputs into Internships

There are three contributors who provide necessary funding towards Mitacs internships: 1) Government of Canada, 2) Government of Manitoba/Research Manitoba, 3) Partner organizations.

<u>Accelerate:</u>

Accelerate Program in Manitoba began in the 2007-2008 fiscal year. During that year the total funding received was $327,500. Eleven years later in 2018 the total funding for Mitacs Accelerate Program grew to $1.78 million. (Figure 1.). In the first few years of Mitacs in Manitoba, often the Government of Manitoba provided the largest proportion of funds, but from 2009 onwards often either the Government of Canada or partner organizations has provided most of the funding (Table 1.).

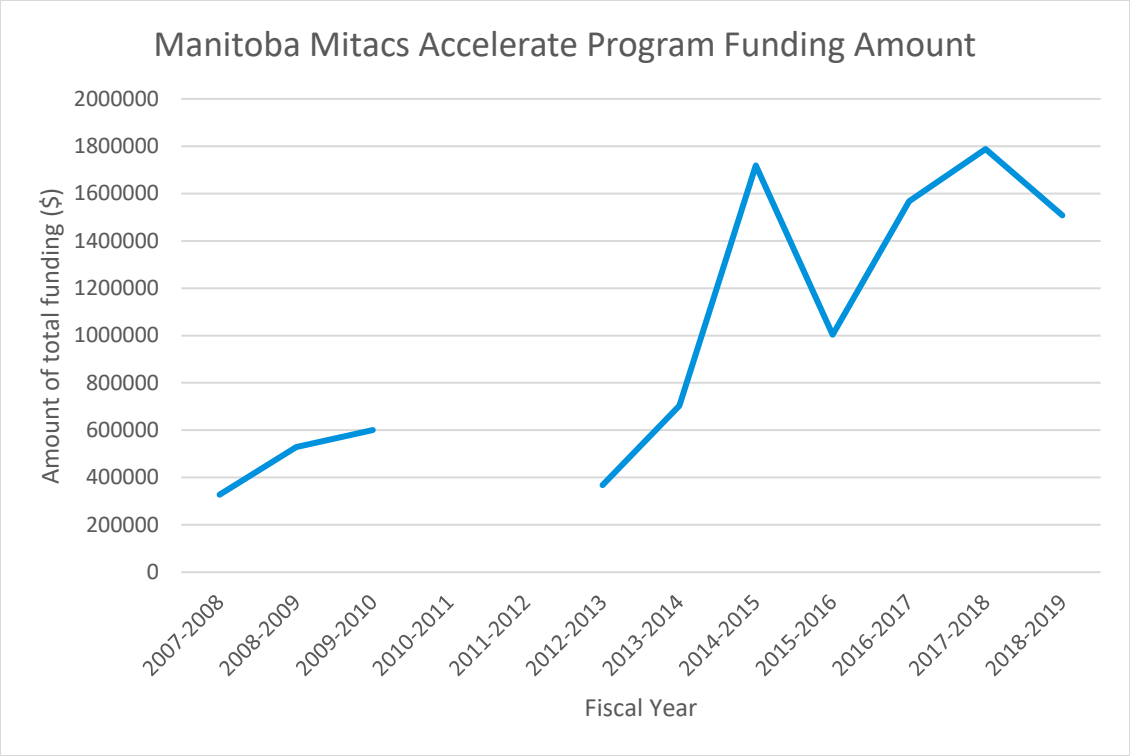


Figure 1. Total funding received by the Manitoba Mitacs Accelerate Internship Program from 2007 to 2019. *Mitacs was not available in the province of Manitoba between 2010-2012.

Table. 1. Detailed funding breakdown for the Accelerate Internship Program.

Fiscal year	**Total funding**	**Funding received from the Government of Canada**	**Funding received from the Government of Manitoba or Research Manitoba***	**Total funding received from the partner organizations contribution**
2007-2008	$327,500	$75,000	$140,000	$112,500
2008-2009	$529,500	$169,500	$202,500	$157,500
2009-2010	$599,900	$233,650	$170,000	$196,250
Mitacs not in Manitoba between 2010-2012	N/A	N/A	N/A	N/A
2012-2013	$328,146	$154,010	$120,000	$94,136
2013-2014	$702,728	$256,358	$210,000	$236,370
2014-2015	$1,719436	$568,436	$510,000	$641,000

2015-2016	$1,003608	$371,450	$300,000	$332,158
2016-2017	$1,566817	$452,400	$439,667	$674,750
2017-2018	$1,788003	$620,167	$413,444	$754,392
2018-2019	$3,393,228	$1,176,000	$736,730	$1,480,498

Data provided by Mitacs. *Research Manitoba took over the Government of Manitoba funding in 2015.

Globalink:

In 2015, the Globalink internship program was implemented in Manitoba and provided graduate students the opportunity to partake in research outside Canada, as well as the opportunity for international undergraduate students to come to Manitoba to collaborate on research.

Table 2. Detailed funding breakdown for the Globalink Internship Program.

Fiscal Year	**Total funding**	**Funding received from the Government of Canada**	**Funding received from Research Manitoba**	**Total Direct funding received from the partner organizations contribution**	**Total Indirect funding from the partner orgs**
2015-2016	$240,071	$80,071	$100,000	$0	$60,000
2016-2017	$167,386	$71,386	$60,000	$0	$36,000
2017-2018	$341,653	$157,653	$60,000	$31,000	$93,000
2018-2019	$381,147	$237,647	$90,000	$53,500	$0

Research Manitoba was appointed in 2015, by the province to distribute funding to Mitacs on behalf of the Government of Manitoba. From 2015 to 2019, Research Manitoba has awarded Mitacs a total of $2.25 million that was distributed to the multiple types of internship programs that Mitacs orchestrates in the Manitoba.

Table 3. Research Manitoba's contribution of funding for all Mitacs program types in Manitoba.

Fiscal Year	**Amount of funding***
2015-2016	$400,000
2016-2017	$700,000
2017-2018	$500,000

2018-2019	$650,000
Total Funding through all years	$2,250,000

* *The financial tables provide leveraging based on all projects approved in a fiscal period. These approved projects can be funded by both the grant awarded in the fiscal year and also from funding that has derived from prior year cancellations.*

B) Mitac's Programs in Manitoba

In Manitoba the three programs that operate have had multiple approved projects. The data we received from Mitacs began in the year 2011 and is presented in the figures below.

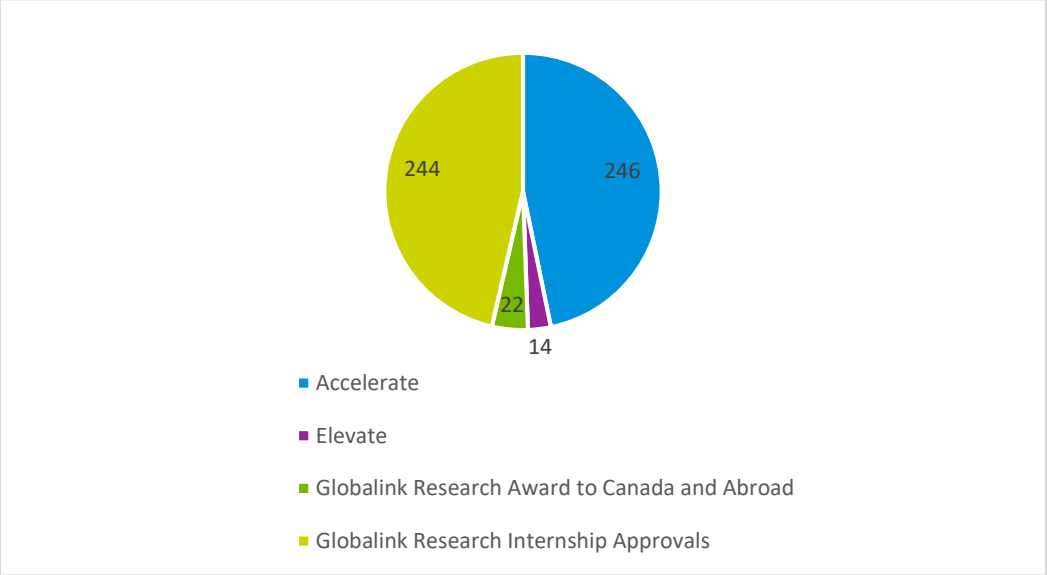


Figure 2. Number of approved projects in each program from 2011-2019.

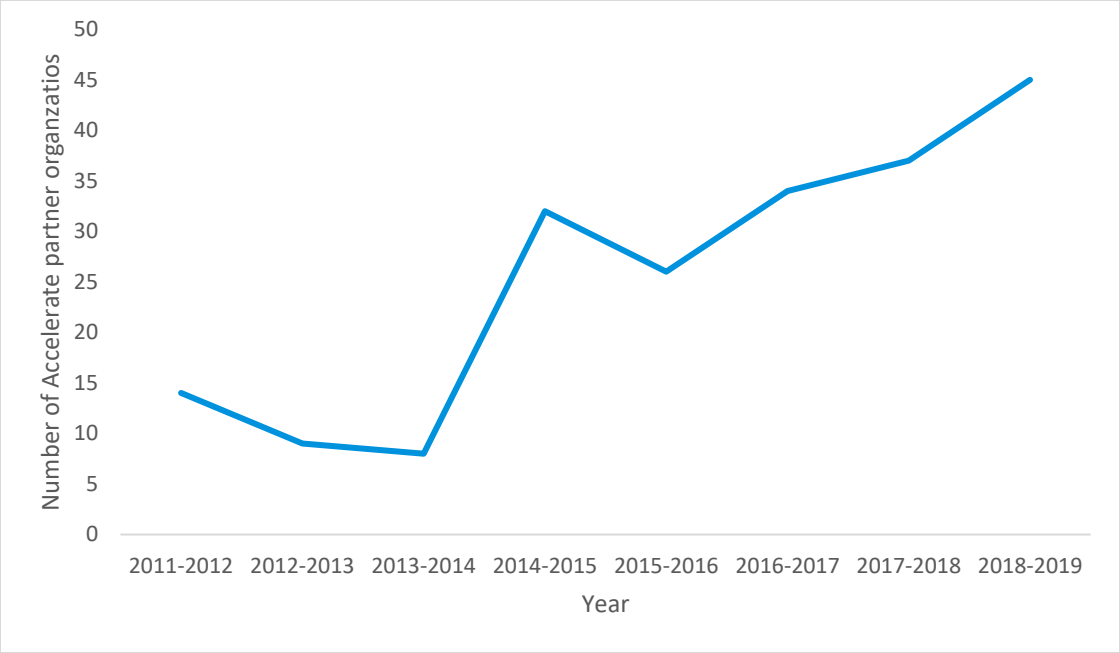


Figure 3. Number of Accelerate partner organizations participating in Manitoba internships from 2011 to 2019.

C) Introduction of case studies

Four cases were selected to provide a collective case study approach. Individual cases in the collection were chosen for we believed that investigating them will lead to better understanding, and perhaps better theorizing, of the impacts of Mitacs internships. The four cases are as follows:

Table 4. Mitacs internship projects selected for collective case study analysis.

Title of research project and partner organization type	**Research area**	**Number of students and their level of study**	**Years active**	**Total funding received**	**Partner organization type**
The Semaphorins, a role Inflammatory Bowel Diseases (IBD)	Potential therapeutic strategies for IBD	1 postdoc 1 PhD student 1 M.Sc. student	October 1, 2016 to Apr 30, 2020	Total award = $255,000 Total released to the university = $240,000	Non-profit, charitable foundation

				Total pending release = $15,000	
Clay binding of gravel roads,	Rural and haul road stabilization technologies	1 M.Sc. student	June 19, 2018 to Dec 17, 2018	$15,000	Private business
Investigation of Hybrid Cascaded Modular Multilevel Converters	Electrical Engineering	1 PhD Student	Feb 1, 2018 to November 30, 2018	$30,000	Two crown corporations and one private business
Sensor development for intelligent apiary	Sensor development	1PhD and 3 M.Sc. students	Mar 1, 2015 to Aug 31, 2017	$80,000	Function Four Ltd. and Durston Honey Farms

Diverse research areas were chosen as Mitacs is one of the few funding programs that allows research in various academic subject areas an opportunity for funding, if a partner organization is both identified and can provide funding.

D) The Semaphorins, a role in Inflammatory Bowel Diseases (IBD)

Why is this research important?

Canada has the highest prevalence of IBD world-wide with 0.7% of the population affected[9]. IBD is a term encompassing two distinct, but related diseases with overlapping genetic susceptibility: ulcerative colitis and Crohn's disease. The cardinal symptom of ulcerative colitis is bloody diarrhea while in Crohn's disease abdominal pain is a more prominent symptom. IBD is a chronic disorder and dramatically impacts quality of life and often surgery is needed due to failed medical interventions[10]. By 2030 approximately 1% of Canadians are expected to develop IBD with direct health care costing over $2.3 billion annually[11]. The etiologies of IBD are unknown, resulting in imperfect efficacy of therapies for these conditions, which leads to increased costs and lower positive effects. Emerging evidence suggests that there is evidence of a mild inflammatory process within the gastrointestinal tract, but the underlying cause of this inflammation remains unclear. Thus, advancements in developing novel therapeutic strategies and a better understanding of immune cell regulation in the human intestines are needed.

Academic supervisor, Dr. Jean-Eric Ghia, Associate Professor in Immunology and Internal Medicine at the University of Manitoba, took on this challenge by partnering with Crohn's and Colitis Canada for multiple Mitacs internships, to investigate the role of semaphorins in IBD. Specifically, Dr. Ghia and his Post-Doctorate Fellow, PhD student, and M.Sc. student looked at semaphorin -3E, which is a membrane bound protein that regulates cell trafficking and immune cell-to cell interactions. It is known that semaphorin -3E is involved in the pathogenesis of chronic inflammatory diseases, including rheumatoid arthritis, asthma, atherosclerosis, adipose tissue inflammation, and insulin resistance. The research project initiated by Dr. Ghia is the first to investigate the immune-modulatory role of semaphorin -3E during the development of intestinal inflammation.

Process to develop the internship

Dr. Ghia shared during his interview that a Mitacs Business Specialist (Dr. Forough Khadem) who completed her PhD in Immunology at the University of Manitoba, gave him information about the Mitacs internships. Dr. Ghia explained, *''But at that time I was a little bit suspicious, because most of the time from Mitacs it's industry partnerships, they're looking for industry partnerships''*. Dr. Khadem assured Dr. Ghia that partner organizations can be non-profits as well.

Dr. Ghia and Crohn's and Colitis Canada had a previous working relationship history before he reached out to them about the possible Mitacs internship collaboration. In 2004, Dr. Ghia was first introduced to Crohn's and Colitis Canada by his Post Doctorate supervisor, the distinguished gastroenterologist Dr. Stephen Collins at McMaster University. Following Dr. Ghia's appointment to the University of Manitoba, he secured funds for IBD research from Crohn's and Colitis Canada which began an established track record of utilizing research funding from Crohn'ss and Colitis Canada to advance the knowledge of the etiologies of IBD.

An outcome of the internship through Mitacs was not only to advance research but also provide an outreach event of the latest research to persons with IBD and their family members. Dr. Ghia explains:

''we are trying to develop something that actually would touch the patient, would touch the family of the patient, to have a better understanding about the disease, and also to have a better understanding of what the researchers are doing''.

As the funds received from Crohn's and Colitis Canada are from fundraising activities, creating and hosting events that involve persons who have Crohn's or colitis is vital. Dr. Ghia shares, *''fundraising activities that are mainly done by the patients, by the family, the communities surrounding the patient, and also the donor''.* He went on to say, *''patients should know how their donations are being utilized to advance research''.* Dr. Ghia incorporates this humanism into his research and outreach events, while modelling for his trainees to do the same.

Impacts from the Internships

While Dr. Ghia and his team of Mitacs interns were investigating semaphorin -3E, they came across the possibility of Chromogranin-A, involvement in ulcerative colitis. Before this no one had examined the role Chromogranin-A has in ulcerative colitis.

The following discoveries were made on the role of Chromogranin-A in ulcerative colitis:

- Chromogranin-A plays a critical role during colitis through the modulation of macrophage functions via the caspase-3/p53 pathway.
- Chromofungin and Catestatin, Chromogranin-derived peptides, regulates intestinal inflammation by remodelling the functions of macrophages and the dynamics of epithelial cells via Nf-kB and STAT3 dependent mechanisms.

To share these discoveries with the scientific community, the following peer reviewed papers were published:

1. Eissa N, Hussein H, Kermarrec L, Ali AY, Marshall A, Metz-Boutigue MH, Hendy GN, Bernstein CN, Ghia JE. Chromogranin-A regulates macrophage function and the apoptotic pathway in murine DSS colitis. Journal of Molecular Medicine. 2018 Feb 1;96(2):183-98.
2. Eissa N, Hussein H, Hendy GN, Bernstein CN, Ghia JE. Chromogranin-A and its derived peptides and their pharmacological effects during intestinal inflammation. Biochemical pharmacology. 2018 Jun 1;152:315-26.
3. Eissa N, Hussein H, Kermarrec L, Grover J, Metz-Boutigue MH, Bernstein CN, Ghia JE. Chromofungin ameliorates the progression of colitis by regulating alternatively activated macrophages. Frontiers in immunology. 2017 Sep 15;8:1131.
4. Eissa N, Hussein H, Mesgna R, Bonin S, Hendy G, Metz-Boutigue MH, Bernstein C, Ghia JE. Catestatin Regulates Epithelial Cell Dynamics to Improve Intestinal Inflammation. Vaccines. 2018 Sep 20;6(4):67.
5. Eissa N, Hussein H, Kermarrec L, Elgazzar O, Metz-Boutigue MH, Bernstein CN, Ghia JE. Chromofungin (CHR: CHGA47-66) is downregulated in persons with active ulcerative colitis and suppresses pro-inflammatory macrophage function through the inhibition of NF-κB signaling. Biochemical pharmacology. 2017 Dec 1;145:102-13.

The research team with Mitacs interns also made discoveries regarding semaphorin-3E:

- Semapphorin-3E is expressed in the colonic mucosa and is reduced in patients with ulcerative colitis and in experimentally-induced colitis.
- Pharmacological manipulations or deletion of semaphorin-3E can regulate experimental colitis.

These semaphorin -3E discoveries led to the following publication:

1. Kermarrec L, Eissa N, Wang H, Kapoor K, Diarra A, Gounni AS, Bernstein CN, Ghia JE. Semaphorin 3E attenuates intestinal inflammation through the regulation of the

communication between splenic CD11C+ and CD4+ CD25-T cells. British journal of pharmacology. 2019 Feb 8.

Spotlight on interns

The Semaphorins, a role in IBD, have had multiple internships from Mitacs through the Accelerate program. The first Mitacs internship started in October 2016 for the project and the research has secured additional Mitacs internships until April 30, 2020. There have been multiple interns involved in the project: 1 Post-Doctorate Fellow: Dr. Laetita Kermarrec; 1 PhD student: Dr. Nour Eissa (undertaking his second PhD); and a M.Sc. student: Kunal Kapoor.

In this section we will highlight two of the interns with whom we conducted in depth interviews.

Spotlight: Dr. Laetita Kermarrec

Dr. Kermarrec received her PhD from the University of Nantes in France in the innovative field of Neurogastroenterology. She then came to the University of Manitoba for her Post Doctorate Fellowship under the supervision of Dr. Ghia to investigate the role of semaphorins in IBD.

The internship with Mitacs provided Dr. Kermarrec the opportunity to further her research and to organize an event showcasing the latest research for IBD as an evening for persons with IBD and their families. Through the partner organization Crohn's and Colitis Canada an educational evening was created. Dr. Kermarrec shared, *"it was really interesting for our partner to get young researchers with basic scientific background involved".* The event was also meaningful to Dr. Kermarrec as she explained:

> *"direct contact with patients and their relatives boosted my motivation for moving forward in the research project. It also kept me on track toward the final aim of this research which is improving the quality of life of the patients [with IBD]"*

Through the partner organization Crohn's and Colitis Canada, Dr. Kermarrec shared that she, *"learned how to present a highly specific subject in lay language".* Developing communication skills and event planning was also valued by the other intern Dr. Eissa.

Currently, Dr. Kermarrec is pursing a second Post-Doctorate Fellowship at CancerCare Manitoba and is investigating personalized-medicine in brain cancer by targeting DNA repair in glioblastoma multiforme. In addition to preforming research, she enjoys teaching the next generation of students.

Spotlight: Dr. Nour Eissa

Dr. Eissa came to the University of Manitoba to pursue his second PhD under the supervision of Dr. Ghia. Dr. Eissa's first PhD was in Veterinary Medical Sciences through a joint program between The University of Ohio and Benha University in Egypt. He chose to pursue his second

PhD in Manitoba because of, "*Dr. Ghia, I was selective in finding a supervisor, Dr. Ghia has similar research interests and a dedication to mentoring".* Dr. Eissa's PhD dissertation focused on the role of Chromogranin-A in IBD that was discovered during the Mitacs internships.

Outputs:

7 Peer-reviewed publications

17 Conference presentations

26 Posters

1 PhD dissertation and 1 Post-Doctorate Fellowship, and 1 M.Sc. thesis

1 Dean of Medicine Award for Public Research Excellence

The funding from Mitacs provided Dr. Eissa and the research team the opportunity to explore the role of Chromogranin-A in IBD. Dr Eissa shared, *"the funding from Mitacs helped me to later receive a CIHR [Canadian Institute of Health Research] Post-Doctorate Fellowship".* Holding a highly regarded Mitacs internship helped this student by strengthening their applications for a national funding award.

Dr. Eissa developed his leadership and communication skills through the partner organization Crohn's and Colitis Canada. The public educational event the interns organized with Crohn's and Colitis Canada provided the opportunity for Dr. Eissa to:

> *"…organize with the Manitoba contacts from Crohn's and Colitis Canada and plan the event. The presentation had to be done in a way that patients and their families could understand. I went from being quiet to getting the Emerging Leadership Award [from the University of Manitoba] and these leadership skills are from Mitacs".*

Currently, Dr. Eissa is a CIHR Post-Doctorate Fellow in gastrointestinal basic biology research in the Departments of Internal Medicine and Immunology at the University of Manitoba.

<u>Overview of impacts</u>

The research findings that resulted from the Mitacs internships investigating Semaphorins in IBD lead to new discoveries that may expedite the development of therapeutic strategies for persons with IBD. As a result of the discoveries, the publications have continued to make the University of Manitoba well known for its basic biology research in IBD. Mitacs and the partner organization also aided in developing the interns into highly qualified personnel through educational and leadership development opportunities.

E) Investigation of a Hybrid Cascaded Modular Multilevel Converter

Why is this research important?

Electricity is an integral part of our everyday lives. Over ninety-five percent of electricity in Manitoba is generated by using the power of falling water. These generating stations are located hundreds of kilometers away from where most Manitobans live[12]. For the electricity to travel from northern Manitoba to the highly populated southern area transmission lines and stations exist along the way. As a result of the long distances that electricity must travel, direct current (DC) is used in Manitoba to prevent the high loss of power when compared to alternating current (AC)[12]. Yet, at the generating station turbine generators produce AC electricity, which then must be converted to DC electricity. In order to be usable electricity for Manitobans, the DC electricity must be converted back into AC electricity through an inversion process. Research looking at improving this conversion process and developing control systems for the conversion are vital to power loss.

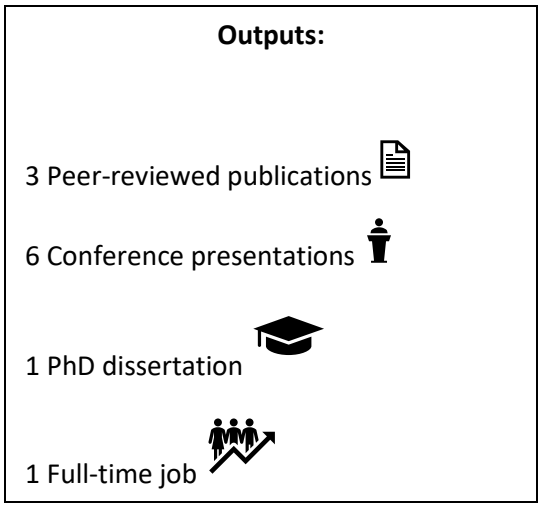
Professor Shaahin Filizadeh partnered with the Manitoba High Voltage Direct Current (HVDC) Research Centre (Crown corporation) and Manitoba Hydro to study a new generation of power electronic converters that are used in HVDC transmission systems. Professor Filizadeh's PhD candidate Xianghua (Sherry) Shi was an ideal intern to move this research forward. Professor Filizadeh shared:

''She [Sherry] presents a very unique skillset; she's very good at mathematical modelling and excellent in experimental work. Once I saw the potential I thought, why don't we do something that's greater than what we have done in the past''.

The project grew more ambitious due to Sherry's diversity of knowledge. Professor Filizadeh shared, *''Well, at the initial stages I was still thinking of simulation, but then she [Sherry] said that she has built these things in the past, similar power electronic circuits; and so I said, why don't you build this particular converter?''.* The initial research project consisted of understanding a new generation of power electronic converters that are used in HVDC transmission systems. Sherry's knowledge accelerated the project to move beyond simulation to developing the hardware control systems, experimental verification, and to examining how the power electronic converters interact with the rest of the network components they need to engage with in the real-world setting.

Process to develop the internship

Professor Filizadeh has held Mitacs internships for his graduate students since 2006. Throughout that time period he has partnered with: RTDS Technologies Inc., Manitoba Hydro, and Manitoba HVDC Research Centre (Manitoba Hydro International). Professor Filizadeh shared, *''these are partners that I had worked with throughout the years prior to this project, so*



I was well aware of their interests and their expertise''. A well-connected academic supervisor as demonstrated by Professor Filizadeh provides the opportunity for a mutually beneficial research project to flourish, by utilizing existing established partnerships.

This research project consisted of three partner organizations, which provided the opportunity for each to bring their facilities and expertise to one specific aspect of the research. In total four internship units were used, which provided Sherry the time to work at each of three partner organizations. Two internship units were spent at RTDS Technologies Inc. where the focus was on hardware development because RTDS's real-time digital simulator was used. The simulator was developed by RTDS and Professor Filizadeh shared, *''[simulator] is an impressive piece of equipment, it's unique in its capabilities''.* The simulator has its own software, which allows all components to run in real-time and model the rest of the network and the control system.

At Manitoba Hydro the very efficient energy processing hardware developed was tested to examine how it interacts with the system. Manitoba Hydro has expertise in this area*, ''our internship supervisor at Manitoba Hydro is an HVDC expert so we thought that this is fantastic, she [Sherry] can learn from him and see how this fits in the context of the power system''* (Professor Filizadeh).

At the Manitoba Hydro's HVDC Centre the focus was on modeling and loss analysis to calculate and improve efficiency. This line of inquiry is vital as Professor Filizadeh:

> *''you're processing massive amounts of energy, and even a half percent extra loss could be a deal breaker, as a large amount of energy will be lost…Converters have to be very, very efficient''.*

Bringing together the three partner organizations for the Mitacs internship provided the opportunity for multiple areas of expertise to be combined.

<u>Overview of impacts</u>

The outcomes for the Mitacs internship, *Investigation of a hybrid cascaded modular multilevel converter*, are numerous. Professor Filizadeh emphasized the following, *''the best outcome is the actual student gaining expertise and new skills, so I think the best outcome for Sherry is the knowledge that she acquired''.* In addition to building highly qualified personnel during this research project there were also other outcomes.

The following discoveries were made regarding electromagnetic transit simulator estimating the semiconductor losses in a hybrid cascaded modular multilevel converter:

- The novel voltage-regulation method invented in this research results in lower semiconductor switching losses than other methods already existing;
- The new modifications to the converter topology proposed in this research and verified using simulations and experiments lower the converter's losses for the majority of its conceivable operating points;
- The hybrid cascaded modular multilevel converter and its newly developed variants have noticeably lower switching losses than conventional full-bridge modular multilevel converters.

Voltage source converters are used in AC grids and HVDC transmission; the protection system can block the converter and it can take a long-time to restart the system. There is a great deal of attention on AC-fault ride through capabilities, and the Mitacs research project made the following developments:

- Created a generalized independent-phase control scheme for various voltage-source converters.
- Created special algorithms to enable fast recovery from faults.

The following publications were produced:

1. X. Shi, S. Filizadeh and D. A. Jacobson, "Loss evaluation for the hybrid cascaded MMC under different voltage-regulation methods," IEEE Transactions on Energy Conversion, 2018.
2. X. Shi, S. Howell, C. Shumski, et al., "Capacitor-voltage regulation and linear-range extension of a hybrid cascaded modular multilevel converter," IEEE Generation, Transmission & Distribution, 2017.
3. X. Shi and S. Filizadeh, "Independent-Phase Current Control of a Three-Phase Voltage-Source Converter under Unbalanced Operating Conditions," The Journal of Engineering, 2019.

Sherry the PhD student intern also presented the findings from the Mitacs internship at multiple conferences:

1. X. Shi and S. Filizadeh, "Pole-to-pole DC-fault Behavior Analysis of a Hybrid Cascaded Modular Multilevel Converter in HVDC Applications," in CIGRE Canada Conference, Calgary, Canada, Oct. 15-18, 2018.
2. X. Shi and S. Filizadeh, "Design Considerations of a Hybrid Cascaded Modular Multilevel Converter," in CIGRE Canada Conference, Vancouver, Canada, Sept. 18-21, 2017.
3. X. Shi and S. Filizadeh, " Laboratory Setup of Modular Multilevel Converters with RTDS as controller," in RTDS Technologies North American Appl. + Tech. Conf., Denver, USA, May 14-16, 2019.

Spotlight on intern: Xianghua (Sherry) Shi:

Sherry received her Bachelor and Master's degrees of electrical Engineering at the Nanjing University of Aeronautics and Astronautics in China. In 2016, Sherry began her PhD studies in Electrical Engineering at the University of Manitoba. Sherry's first experience with industry partners occurred in 2017 when she participated in the training program at RTDS where, *''comprehensive information about the operation of the device and the interface between software and hardware''* was provided. This training provided Sherry the opportunity to further refine the Mitacs research project with Professor Filizadeh.

Sherry explained the value of the Mitacs internship*, ''it provides students the opportunity to connect directly with the industrial partners and develop professional connections with practicing engineers''.*

When the interviewer asked Sherry, "What do you think the top three benefits were for the Mitacs internship was?", she shared:

> *''The first is related to networking skills such as communication and team work. It [internships] helped me to get familiar with the working style in Canada. And the second benefit is that I could make the proper devices and products there [partner organizations] to support my PhD [research]. The third one is regarding business skills. As a student, I don't know too much about the management of projects. At these companies I can interact with engineers to talk about product management and the ways to develop a proper plan. Of course, there are other benefits, it really helped me to alleviate my financial pressure in my life''.*

Overview of impacts:

Lastly, Sherry explained the overall impact of the internship program for the students fortunate enough to secure internships, *''I think the Mitacs program has done a lot for students. With this working experience, we can have a better chance to apply to a dream job''.*

The outcomes of the Mitacs internship for the project, *Investigation of a hybrid cascaded modular multilevel converter*, demonstrates the value of collaborating with multiple partner organizations that each brings unique expertise and facilities. One of the partner organizations RTDS Technologies shared the following:

> *''RTDS Technologies has definitely profited from participating in Mitacs-supported R&D projects. We have participated in a number of interesting and challenging projects ranging from novel protection scheme development to investigation of high power HVDC valve design. The biggest single benefit of the Mitacs program has been the relationships we have developed with the Masters and PhD students, several of whom have later become employees of our firm.".*-Paul Forsyth VP Marketing and Sales

For research in electrical engineering to advance and benefit Manitoba Hydro, collaboration as Professor Filizadeh and Sherry formed is ideal.

F) Clay Binding of Gravel Roads

Why is this research important?

Much of the road network across Canada is comprised of gravel roads, including 80% of roads in Manitoba, some 67,000 kilometers. Many rural communities, residents, and industry depend on them for their livelihood. These roads are transient and quickly become loose, rough, dusty and lose strength, all of which can lead to dangerous driving conditions. Current ways to mitigate the degradation of gravel roads is through regular and expensive maintenance, often requiring the application of chloride salts[13] or other toxic materials. Consequently, there is a great need for an environmentally safe and low-cost product and construction techniques for their stabilization. The research project, Clay binding of gravel roads, is working to solve this problem.

Process to develop the internship:

A chance meeting at the Mining and Minerals Convention in Winnipeg, between Professor Mumin, Chair of the Geology Department at the University of Brandon and President of Cypher Environmental, Todd Burns, spurred a dialogue about research regarding the possible stabilization of unpaved gravel roads in Canada. Professor Mumin's initial curiosity about the road material sample at the Cypher Environmental booth caused him to ask whether, *''this has ever been used on municipal roads in Canada?''.* Todd shared that it had not. Professor Mumin knew that the roads around the Brandon area could possibly be an ideal candidate to investigate if the process could be adapted to solving local road problems using local materials and Cypher stabilization products.

Professor Mumin did not want to solely examine the laboratory aspect of the subject, but also desired a field component for the research to ensure maximum knowledge development. Professor Mumin contacted the Rural Municipality of Cornwallis east of Brandon to partner with Brandon University and Cypher Environmental in the development of test roads. This possibility of test roads in Cornwallis combined with laboratory work on clay binding led to the Mitacs internship.

It was President of Cypher Environmental, Todd Burns who had heard of Mitacs through the Natural Sciences and Engineering Research Council of Canada (NSERC) and suggested that an application be created for the Accelerate internship program.

Impacts from Internship

The laboratory and field research during the Mitacs internship moved quickly into innovative territories within geotechnical engineering. For example, assessing the clay-rich stabilized roads did not align with many of the standard geotechnical engineering testing procedures. Professor Mumin and his team had to develop their own methods and standards for testing, which makes up a large component of intern Riley Cram's M.Sc. thesis. The research team tested the following:

- Binding and bearing strength of local materials with different clay-aggregate mixes, catalysts, and polymer applications
- Unconfined compressive strength (binding energy) of different clays under various parameters
- Compaction energies and densification
- Curing times
- Moisture content and reabsorption
- Dust reduction and environmental mitigation
- Road durability

Local clay-rich materials are being used to develop a made in Manitoba solution for gravel road stabilization. The right type of cohesive (reactive) clay is ideal, because with the addition of catalysts and polymeric agents the natural properties of these clays can be manipulated to act like a cementing agent. Cypher Environmental has previously used their product EarthZyme on mine haul roads outside Manitoba, applying it to in situ materials. Professor Mumin's research is focusing on adapting and improving this process for rural roads in Manitoba and across Canada. Mumin states, "Because we do not have cohesive clays on our roads, this presents both a challenge and a great opportunity to engineer the entire process from initial selection and preparation of materials, through to the actual construction protocol".

As the partner organization, Cypher Environmental, a Winnipeg business, greatly benefited from the Mitacs internship. President Todd Burns shared the following:

"We were able to get some phenomenal research done. Its added significant value to the company in terms of strengthening our value proposition through accredited third-party research, but also through the internship program we were able to actually develop talent for the company, Riley Cram [intern], we have created a job for him. The fact that we've actually created jobs over the internship speaks for itself".

Cypher Environmental also increased its revenue through the Mitacs internship. Todd Burns shared*, "I don't have the actual number value of how much more revenue we've generated, but it certainly is opening up a new market for us".* Currently, the cost for creating a road with this specialized technology is about $75,000 - $100,000 per mile, which includes: material costs, laboratory material testing, material transportation, construction equipment costs, labour, supervision, and product, versus paving costs of $ 1 million per mile. Using the ideal ratio of clay, aggregate, and EarthZyme, the prepared product is laid down six-eight inches thick on

existing gravel roadbeds. The clay acts as a strong binding agent that retains some plasticity so that it does not crack or break like cement and asphalt.

The Mitacs Accelerate internship provided the opportunity for the partner organization to leverage research expertise to create innovative developments and talent to move the company forward. The internship also provided the opportunity for the research of Brandon University to reach an international audience.

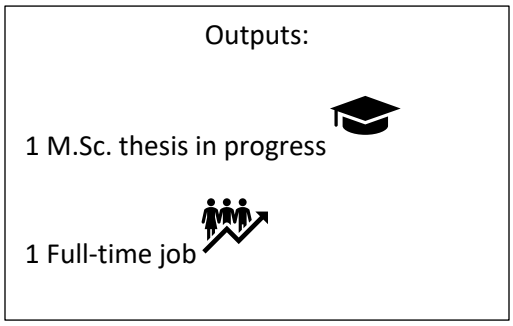
Spotlight on intern: Riley Cram

Riley received his Bachelors of Science Honours degree from Brandon University. He then started his Master of Science research under the supervision Professor Mumin on the subject of gravel road stabilization. Riley undertook two Mitacs Accelerate internships, one during the summer field season of 2017 and one during the summer of 2018. The major benefits Riley shared was:

''I was able to pursue what I wanted to research with a lot less stress because you don't have to work part-time jobs, you don't have to go into debt through student loans. You can do your research and your internship together''.

The business and technical knowledge the Mitacs internship provided to Riley made him the ideal new employee for Cypher. Riley started working full-time for Cypher Environmental in February of 2019 and will graduate with his Master's of Science in May 2020.

Overview of impacts:



Industries and government delegations from Alberta, Ontario, China, Japan, Russia, Ukraine, Honduras, India and 4 other countries (with more arriving each year) have travelled to examine the test roads created in the Brandon area that were developed during the Mitacs internship. These delegations are learning the technology in Manitoba and then applying it to their own situations. The international interest and global benefit of the installation of stabilized gravel roads with application of a tailored EarthZyme product, has great potential for the economy of Manitoba.

G) Sensor Development for Intelligent Apiary

Why is this research important?

There is high value in honeybees; as a primary pollinator for Canada's crops and through sales of honey being exported. In 2016, Canada's total honey exports grew to $72 million[14]. In commercial beekeeping, monitoring the apiaries (beehives) is difficult as they are spread over large distances in rural areas. It is advised that apiaries are as far away from one another as possible and in areas with harsh winters such as Manitoba, bees often winter in warmer climates such as British Columbia. Currently, in order to monitor the apiaries to ensure the health of the colony, a person must physically visit the apiary. Travelling these distances is an added monetary expense and a large time commitment. With these large geographical distances in mind, there has been interest in developing a remote monitoring system.

Function Four, a Winnipeg company, and Durston Honey Farms partnered with Mitacs to develop a potential remote monitoring system for apiaries. Three different graduate students have held internships for the ongoing research project investigating sensor development for intelligent apiary. Each intern has worked on a different aspect of the sensor development, which has created diversity in the potential value of the research. The first intern focused on image-based monitoring by creating three deep learning-based object detection models to detect bees and predators. The second intern's research centered around the creation of printed circuit board that was tested in apiaries to control temperature and measure both honey levels as well as the locations of the bees in the apiary. The third intern whose research is currently ongoing is creating a distributed monitoring platform system, to store, visualize, and create real time alerts for the sensors created in the previous internship.

Process to develop the internship

The CEO of the Function Four, Bruce Hardy, reached out to a Mitacs Business Development Specialist Iman Yahyaie who then contacted Professor Cyrus Shafai who has a research speciality in sensors. Bruce shared, *''Iman connected me with Cyrus…and then [Iman] spent time fostering the relationship between us and with the university''.* The relationship started by sharing the designs of integrated sensors that Function Four had already created with Professor Shafai. Professor Shafai and the interns expanded on some of the designs and implemented the ideas.

Impacts from the internship

The research led to two Master of Sciences theses in the Department of Electrical Engineering being produced. A third thesis in the same department is currently in progress.

In terms of research outcomes, the following has been developed:

- Three deep learning-based object detection models to detect bees and predators
- A printed circuit board that can regulate temperature and interdigitated capacitor that can measure the location of the bees and honey levels
- Distributed monitoring platform system (big data collection and storage, visualization, and real time alerts based on thresholds set for certain values.

The research was also presented as proceedings at the following conferences:

1. Colin Gaudreau, Cyrus Shafai, and Miroslaw Pawlak, "Implementation of Computer Vision Algorithms to Monitor Bees & Predators Surrounding the Apiary," Canadian Society of Bioengineering Conference, Winnipeg, Canada, 6-10 August 2017.
2. Valerie Beynon and Cyrus Shafai, "Interdigitated Capacitor Sensor for Honey Cell Content Monitoring in a Smart Hive," Canadian Society of Bioengineering Conference, Winnipeg, Canada, 6-10 August 2017.

The CEO of Function Four, Bruch Hardy, shared the following when asked about the value of academic research for his company, *''as we grow, we are seeing and trying to engage key investors, so having a third-party entity collaborate with us increases our creditability''.* The impact of the Mitacs Accelerate internships for research in sensor development for intelligent apiary, spans from innovative developments, creating high-qualified personnel, and providing support for increased investments for a company in the early-stages of development.

Spotlight on interns

In-depth interviews were conducted with two of three interns that worked on their sensory development research for the intelligent apiary project through Mitacs Accelerate Program. They shared how meaningful the opportunity be financially supported while working on research that has potential use in industry was for them.

Intern: Valerie Beynon

Valerie received her Bachelor of Engineering in Electrical Engineering at the University of Manitoba. During one of her final year courses she heard Professor Shafai announce a possibility opportunity for graduate research. She followed up on this interest and in 2018, completed her Master of Engineering degree. Her thesis research was part of what was created during the Mitacs internship research. The research developed a printed circuit board that can regulate temperature and interdigitated capacitor that can measure the location of the bees and honey levels. These innovations were then field tested in an apiary with bees. Valerie shared the following, *''I came from a background of electrical engineering and computer programming and I was learning and making technology for outside my field, for entomology with Dr. Currie [head of Entomology at the University of Manitoba]''.* The ability for an intern to use their skills outside their field to develop innovations for industry is a unique opportunity that would likely not be possible without a Mitacs internship. The Mitacs internship also facilitated the collaboration with honeybee research expert Dr. Rob Currie. As a result of the internship, Valerie has a full-time position working for one of the companies that is owned by the Mitacs internship partnership organization's CEO, Myera Group.

Intern: William Robinson

William received his Bachelor of Science in Mathematics and Physics. He shared, *''before I was already working in computer programming in industry and in order for me to decide to purse a Masters Degree it needed to be affiliated with industry''.* The collaboration between CEO Bruce Hardy and Professor Shafai that was developed and refined through the first and second Mitacs internship provided the opportunity for William to continue advancing the work previously completed for the sensor development for intelligent apiary project in industry. William undertook an eight-month long internship that aided in developing an application program interface and fully developed a pilot distributed monitoring platform system that consists of big data collection and storage, data visualization, and real time alerts based upon thresholds set for certain values.

Outputs:

2 Conference presentations

2 M.Sc. theses and 1 thesis in progress

<u>Overview from impacts</u>

CEO Bruce Hardy explained the value of Mitacs for industry, *''it begins with the fact that in order for research to be successful there needs to be a champion for industry and that is part of Mitacs does''.* The work conducted by the three graduate students who held Mitacs internships for the project, sensor development for intelligent apiary, advanced the remote monitoring system forward. Two of the graduate students are now working at start-up company Bruce Hardy developed called, Myera Group. Mr. Bruce Hardy also shared, "*The Mitacs internships are an important ingredient for the advancement of high caliber research that continues to spur our growth*".

Professor Shafai explained the value of the Mitacs internship:

''it's actually really good for the students…they are applying engineering knowledge to a completely different discipline, they're working with a different department, and the companies they're working with do not have this background. So it becomes a team effort and the student learns how to operate in industry''.

As demonstrated by the above cases studies The Mitacs internship provides the opportunity to create highly-qualified personnel and further developments in industry.

Part III: Discussion

A) Impact of Mitacs internships on students

Each intern who was interviewed for the in-depth case study analysis also filled out a survey (Appendix 3). We investigated whether the Mitacs internship provided students experience and training in workplace skills. The results from the survey demonstrated the following:

Table 5. Percent of interns interviewed in the case studies who developed skills during the Mitacs internships.

Skill	Percent of interns who identified developing this skill
Communication	100
Team work	100
Ability to problem solve	100
Business knowledge and skills	83

Academic supervisors who were interviewed completed surveys as well. Across all case studies the $5,000 to support research costs was used to purchase lab equipment and materials for the research. The equipment that was purchased was used the Mitacs internship and in all cases will also be utilized by other students for future research. The benefits of the Mitacs internship indirectly increases the research capacity of the universities and future students' research opportunities. All academic supervisors were also in the process with Mitacs to negotiate further internships.

B) Far reaching impacts

Establishing the linkages between business growth and research helps to highlight the value of the research to the public, funders, stakeholders, and the researchers themselves. It also helps to understand the uptake and the effects of the research findings.

Contribution analysis is an approach that helps assesses cause and effect in program evaluations, and helps those involved (e.g., researchers, policy makers, managers), see what outcomes the contributions of their programs have made. The strength of this analysis approach is that by understanding why the results occurred, it helps pinpoint how the intervention(s) have contributed to the observed outcomes or results. It addresses the difference (e.g., the growth of industry), that the research has made, and how much of that growth can be attributed to the research. Here, contribution analysis is used to answer the following questions:

1) What have the impacts of the research projects involved in Mitacs been for the interns, professors, and partner organization?

2)To what extent has Mitacs' role contributed to the identified impacts?

The theory of change (Appendix 4) diagrammatically addresses these questions and shows the connection between the Mitacs internships and impacts.

The impact most often linked to workplace internships is the creation of highly qualified personnel (HQPs). This is also true for Mitacs internships, as graduate students and Post-Doctorate Fellows often learn the skills of conducting research in an industry setting. Of the interns that were involved in our selected case studies with a for-profit partner organization, three out of four became full-time employees. The creation of full-time positions within the partner organization demonstrates that the HQPs that are created through the Mitacs internship program are highly valued for their knowledge in specific research.

Amongst the four case studies, the research project *The semaphorins, a role in Inflammatory Bowel Disease (IBD)* has had the largest impact in terms of scientific discoveries. This is interesting as the partner organization was a non-profit foundation and this demonstrates the value a non-profit can bring to scientific discoveries. Developments and profits in scientific discoveries often occur much later in the scientific process[15] as the initial research that is required is often financially out of the scope for a small to medium sized business, as there are little to no initial returns.

The research project with the most potential to impact Provincial revenue was *The Investigation of a hybrid cascaded modular multilevel converter*. This research looked at improving the conversion process of electricity in the form of DC back to AC to prevent power loss for Manitoba Hydro. The reduction in power loss correlates to an increase amount of electricity that can be sold. As Manitoba Hydro exports electricity to the United States, Saskatchewan, and Ontario; the less electricity that is lost during the conversion process the greater amount of electricity that is available for opportunity sales. The research project, *The Investigation of a hybrid cascaded modular multilevel converter* also produced an innovative discovery that was shared in a peer-reviewed publication.

From an environmental sustainability perspective, the research project *Clay binding for gravel roads* has high potential to positively impact rural communities and the natural resource industry.

The research project investigating, *Sensor Development for Intelligent Apiary*, explores opportunities for Smart Agriculture to improve efficiency for honey producers. Additionally, there is potential for the remote monitoring system to help determine the causes of honeybee population decline. The research in this project is in preliminary stages.

C) The Future of Mitacs

Mitacs business development professionals have actively been participating in regional development activities to build networks and outreach in northern Manitoba (the Pas), Brandon, Pinawa, and others. In the past year, three new Manitoba institutions have signed on

as Mitacs network partners (Red River College, Assiniboine College, and Canadian Mennonite University). In addition to this, Mitacs is engaged in ongoing discussions with other institutions including University College of the North (UCN). UCN is especially relevant with Mitacs' increasing strategic focus on indigenous research engagement.

This personal and intrinsic connectivity into the Province's institutions uniquely positions Mitacs representatives to develop strategic engagements between institutions, especially universities and colleges where increased collaborations offer substantive benefits to companies looking for a full spectrum of research, from fundamental to the applied.

Mitacs has already developed what may be the most significant university-college research collaboration in Canada's history between the University of Ottawa and Algonquin College (valued at ~$2.2 million). In Manitoba, the University of Winnipeg recently received it's largest Mitacs grant ($435,000) to date with Weston (via their Seeding Food Innovation grant) focused on cutting-edge agricultural technology (machine learning and artificial intelligence) and Red River College staff and students are also supporting the project.

Mitacs is also in its second year of a pilot program, Mitacs Accelerate Entrepreneur, that allows graduate students to co-fund research (they worked on or published) to support the development of their own Startup businesses. This program is offered nationally with university connected incubators.

Mitacs has partnered with North Forge in Manitoba, who is a key player in the Province's innovation strategy. Four graduate student-led start-ups are currently receiving business mentorship and participating in North Forge's Startup acceleration programming; several more such opportunities are under review or in development.

This program addresses a key challenge for Startup communities/leaders, which is attracting technically talented and knowledgeable individuals to develop start-ups and engage in the community. Mitacs is committed to increasing activity and growth in Manitoba's economy.

Part V: Conclusion

The impacts of Mitacs internships were examined through the utilization of a case study approach, where the individual cases in the collection were chosen as it was believed that by investigating them, it will lead to a better understanding, and perhaps theorizing of the impacts of Mitacs internships. The Mitacs's internships aided in the development of HQPs and can be theorized as the most common impact of Mitacs internships in Manitoba. The second type of impact identified in half the cases was the advancement of science through innovative discoveries, that were shared in the scientific community through peer-reviewed publications. The third type of impact that was identified in one case, was an increase in profit for the

partner organization based upon the research conducted during the Mitacs internships. These impacts demonstrate the capability of Mitacs internships in: developing HQPs, advancing scientific discoveries, and helping to grow the economy of Manitoba.

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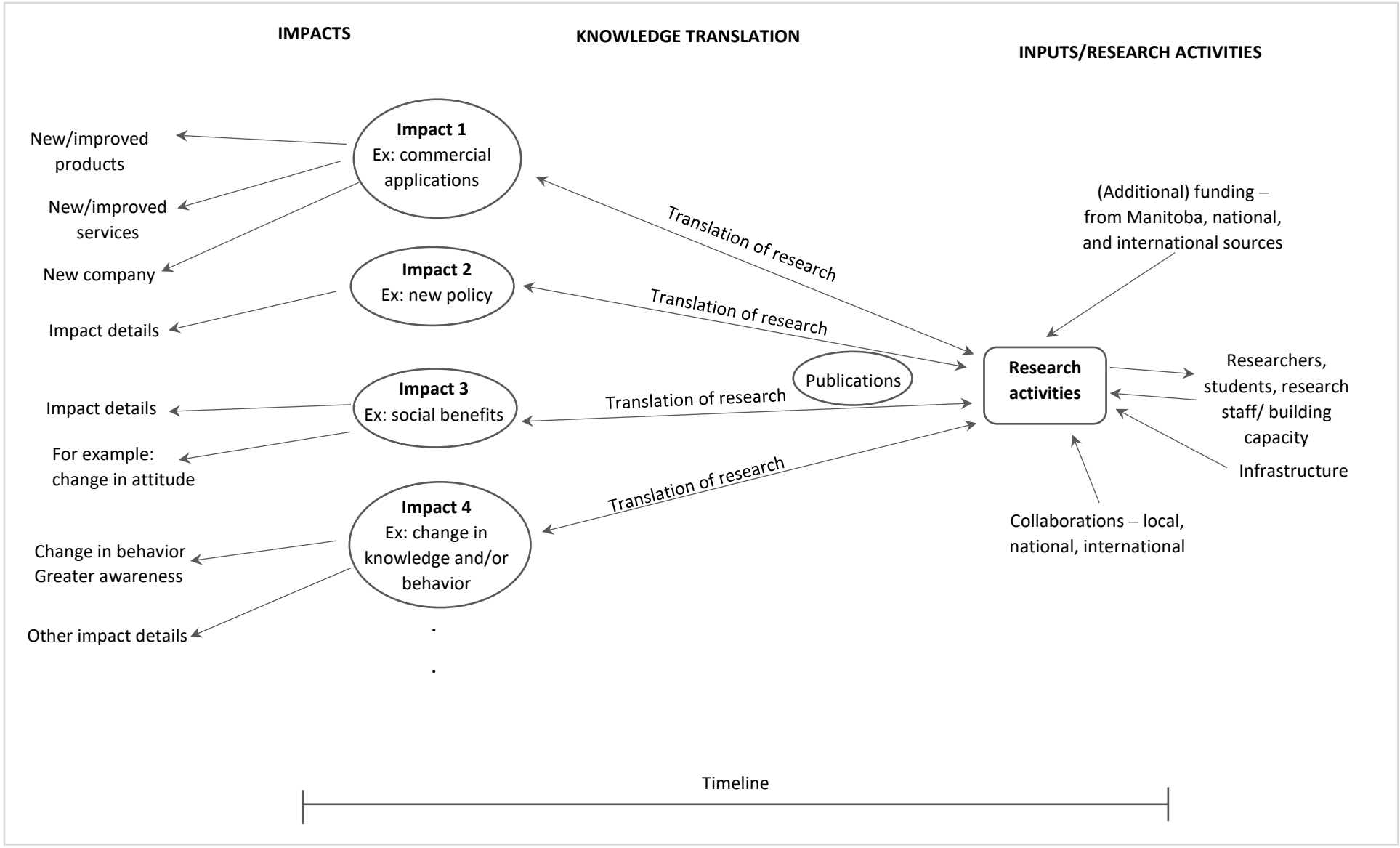
Appendix 1. Linking impacts and research



Appendix 2. Interview Guides

Draft Mitacs Internship Interview Guide

Academic Supervisors (Professors)

1) How did you first hear about the funding Mitacs internships has for students or post-doctoral fellows?
2) How did you find a partner organization to match the funds from Mitacs? *Prompts: was this easy or difficult*
3) How did you select your student internship? How many internships have you had?
4) How much funding did you receive?
5) How did you use the extra $5,000 provided by Mitacs?

About your research project:

6) What was your research project?
7) What were the outcomes of your research project?
8) Do you think that this research would have been possible without the funding provided by Mitacs and the partner organization?

Future:

9) Would you try to negotiate for a Mitacs internship in the future? *If Yes, why, If, No, why - what is the challenge*?

10)Is there anything you would like to see change in terms of the Mitacs internship?

Draft Mitacs Internship Interview Guide

Students

General Questions

1) Where did you receive your most recent degree prior to the Mitacs internship?

2) What internship program were you part of through Mitacs?

3) How long did your internship last?

4) Where were you placed and what was your primary role there?

5) What were the outcomes/benefits from your internship:

a) for yourself? *Prompts: What was the major benefits of your time as an intern? For instance, what skills or knowledge did acquire? Furthermore, how have these skills and knowledge helped you since the conclusion of your internship?*

b) What do you think the benefits were for your academic supervisor?

c) What do you think the benefits were for the partner organization?

d) Could you describe whether you made connections outside the University during the internship?

6) What were some challenges, if any, that you faced as an intern?

7) Did being paid for the work you did benefit you?

8) Would you have been able to undertake this research without the funding providing by Mitacs?

9) From your experience, what are some values of an organization like Mitacs to student interns?

10) Did you receive other sources of funding to continue working on research related to this internship?

11) Reflecting on your experience as an intern, what are some -ways to improve the Mitacs internship program?

Situational: If the intern identified as a non-Canadian citizen ask if the internship had an impact in their decision to stay in or return to Canada?

12) Can you describe why the research you were involved in is important? Who and what will it impact?

Partner Organization Interview Guide

Broad questions

1) Can you please describe your organization in 2-3 sentences?

2) How did you hear about the Mitacs internship program?

3) Why is it valuable for your company to be involved in research?

4) What has been the value for you to have a research partnership with a university professor and a graduate level student?

5) How did Mitacs aid in facilitating the partnership with the professor and student?
   Prompts/clarification if needed: facilitating can mean formal paperwork, contract development and financial support

About your research project:

6) What is your research project in 2-3 sentences?

7) What was your involvement in the development of the project?

8) What were the outcomes of your research project?

9) What has been the immediate impacts for your company that are attributed to the research conducted during the Mitacs internship?

10) How has or how do you think the research conducted during the Mitacs internship will affect the economics and/or projected sales/value of your company?

Appendix 3. Interview Surveys

Survey for Mitacs Academic Supervisors

1) How many of your graduate students and/or post-doctorate fellows received internships from Mitacs?

2) How did you use the $5,000 provided to support the research costs?

__ Software licences

__ Computer: desktop, monitor, or laptop

__ Lab equipment (please specify what it was)

_____

_____

_____

__ Hiring a research assistant

__ Other (please specify)

_____

_____

3) Were the items purchased with the $5,000 financial support utilized after the Mitacs internship to support other research?

☐ Yes ☐ No

4) Did other students benefit from the items purchased with the $5,000?

☐ Yes ☐ No

Survey for Mitacs Interns

1) What was the last degree you completed?

2) At what university did you complete your most recent degree?

3) Did you develop any of the following workplace skills in your internship (please check the boxes that apply):

__ Communication

__ Team Work

__ Ability to Problem Solve

__ Business knowledge and skills

4) What other agencies have you received funding from?

__ University of Brandon

__ Canadian Foundation for Innovation

__ University of Manitoba

__ Canadian Institute of Health Research (CIHR)

__ National Science and Engineering Research Council (NSERC)

__ Other (Please specify): _____

5) When did you participate in the Mitacs internship program?

_____

_____

Appendix 4. Theory of Change