The Economic Impact of Applied Research at Canada's Polytechnics

August 2024

POLYTECHNICS CANADA

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About

Polytechnics Canada is the voice of leading research-intensive, publicly supported polytechnics and institutes of technology. We advocate for federal action in areas where polytechnics provide solutions for a more innovative, productive and globally competitive country. Polytechnics Canada members play a critical role in addressing some of the country's greatest challenges. Through their facilities and networks, our members provide meaningful solutions to industry problems and accelerate knowledge transfer.

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1.0 Executive Summary

This study estimates the return on investment to the applied research carried out by the 13 leading, publicly assisted polytechnics and institutes of technology represented by Polytechnics Canada. While the analysis is relevant to applied research conducted by other colleges, conclusions apply solely to the 13 whose data informed specific findings. The study refers to these institutions collectively as "polytechnics."

The data collected and analyzed for this study included:

- A literature review on the return on research and development (R&D) investments
- A special tabulation by Statistics Canada of the income received by polytechnics for operating, capital and research
- Applied research data collection surveys administered by Polytechnics Canada
- A special tabulation prepared by the Natural Sciences and Engineering Research Council (NSERC) based on completion reports submitted by polytechnic collaborating partners
- 30 case studies of recently completed or ongoing polytechnic applied research projects
- A canvass, administered by Ipsos Canada and Prism Economics and Analysis, of 26 private-sector partners who had recently collaborated on a polytechnic applied research project

The research carried out by polytechnics is applied rather than basic. The function of applied research is to solve problems and is almost always undertaken in collaboration with an industry partner who defines the focus. By contrast, basic research is more commonly undertaken by universities and aims to advance theoretical knowledge. It rarely involves a private sector partner and is generally defined by a principal investigator. While basic research is critical to advancing theoretical knowledge, applied research solves practical problems and thereby generates productivity gains.

There are a number of challenges to formulating an estimate of the return on investment to polytechnic applied research. Among these challenges are:

- That faculty and students are often subject to non-disclosure agreements to protect the intellectual property rights of the private sector partner, making it challenging to gather detailed project information
- Polytechnics rarely have detailed or complete insight into the subsequent commercial application or patent activity derived from the applied research to which they contribute
- Many aspects of the social return to applied R&D are difficult to measure including, for example, reductions in waste, noise or greenhouse gas emissions, or improvements in worker or public safety
- Though projects play an important role in the career readiness of technologists and other professionals critical to innovation capacity within the Canadian economy, it is difficult to measure the value of talent development to the economy

In consideration of these challenges, this study uses a methodology developed by Benjamin Jones and Lawrence Summers for the U.S.-based National Bureau of Economic Research. The results of this application of the Jones-Summers model leads to the following conclusion:

> Every $1.00 invested in the applied research carried out by polytechnics generates a combined private and social return ranging from a low estimate of $8.09 to a high estimate of $18.49. Additionally, there are other social benefits that accrue such as reductions in waste or carbon emissions and improvements in public well-being that are difficult to quantify in monetary terms, but which support an estimate closer to the upper boundary.

Canada's investment in R&D and, by inference, our rate of innovation, lags the OECD average. Indeed, the gap between Canadian spending on R&D and the OECD average has been widening. Part of this challenge can be attributed to Canada's considerable reliance on small- and medium-sized enterprises (SMEs) as they are a larger share of the private sector than in many other countries, notably the United States. Closing the innovation gap among SMEs must be an important part of a broader strategy to accelerate innovation.

While studies show that Canada's SMEs under-invest when compared to other jurisdictions, they face a number of unique barriers, namely a shortage of technical staff, lack of facilities, capital constraints and high regulatory burdens. For many SMEs, the cost of investing in R&D entails significant risk. This report illustrates that polytechnic applied research addresses a number of these obstacles, derisking innovation.

Polytechnics engage in some 4,000 applied research projects each year. Roughly 85 per cent of the private sector partners in these projects are SMEs, which define the purpose of the research. Approximately 20 to 25 per cent of total research costs are contributed by private sector partners who also, in many cases, provide additional in-kind contributions. The applied research of the polytechnics can therefore be described as demand-driven. The applied research carried out by polytechnics makes a distinct and important contribution to addressing Canada's productivity challenge among SMEs.

For many SMEs, working with private consultancies on R&D projects or using private laboratory or testing facilities is too costly. Collaborating with universities can be impractical owing to the extended timelines, the scale required and the inability to protect intellectual property. University researchers must be free to publish results – a requirement often incompatible with the intellectual property needs of companies, but especially SMEs. Studies show that SMEs are more likely to rely on security protocols and non-disclosure agreements than patent protection.

Polytechnics accommodate the short timelines that characterize the R&D needs of many SMEs. They are also able to work with small and micro enterprises since scale is not a constraint.

Because polytechnics allow intellectual property to reside with the partnering company, a major impediment to collaboration with private sector partners is avoided. The polytechnics have historically developed close connections to regional businesses. For all of these reasons, the polytechnics are uniquely positioned to build the R&D capacity of Canada's SME sector and produce direct and meaningful rates of return on research investment.

The economic benefits of polytechnic collaboration with non-governmental partners is apparent in the results reported to NSERC by project partners:

- 51 per cent stated that their collaboration increased their R&D capability
- 48 per cent indicated improved competitiveness
- 26 per cent gained access to new markets, including export markets
- 21 per cent reported increased productivity
- 14 per cent reported that their collaboration assisted in attracting new investment
- 13 per cent described improved access to specialized skills or hard-to-reach workers
- 12 per cent created new jobs

Studies show that businesses that export have a greater propensity to invest in R&D. By supporting exporters and building export capacity, applied research partnerships directly contribute both to improved export performance and increased R&D investment. Partner completion reports gathered by NSERC and reviewed for this study suggest intent to continue or extend collaboration with a polytechnic, many at their own cost. This implies that applied research encourages private-sector investment by addressing risk factors.

These results illustrate in concrete terms the implications of the macro-economic estimates of the return on investment to polytechnic applied research. That return is also highlighted in the case studies undertaken for this report. Among the 30 projects profiled are research projects that:

- Enabled small businesses to grow their market share, including for export
- Supported automation, extended equipment life and derisked the adoption of new technologies and software
- Optimized environmental systems, leading to greater energy efficiency and diverting materials from landfill
- Improved environmental systems, including those affecting forests, soil, water, animals and food
- Optimized the design and delivery of social programs

With additional support, polytechnics have the potential to significantly increase their contribution to Canada's applied research ecosystem and increase the rate of innovation and productivity growth in the Canadian economy. The return on such an investment will be substantial.

2.0 Introduction

2.1 Purpose of Report

The purpose of this report is to describe the applied research activity of Canada's polytechnics and to estimate the return on investment generated by this research.

2.2 Polytechnics Canada

Polytechnics Canada represents 13 of the largest, publicly assisted polytechnics and institutes of technology in the country. The programs delivered by the members of Polytechnics Canada are developed in collaboration with industry partners and always incorporate a practical, experiential component. To ensure the career readiness of their graduates, polytechnics engage industry in the development and delivery of curricula, graduating more than 100,000 career-ready professionals each year. With the number of applied research projects undertaken by polytechnics approaching 4,000 annually, businesses, non-profits, governments and other stakeholders benefit from direct support to address their challenges while also connecting with the technical talent pipeline.

Figure 1 - Member Institutions

Algonquin College of Applied Arts and Technology
British Columbia Institute of Technology
Conestoga College Institute of Applied Arts and Technology
Fanshawe College of Applied Arts and Technology
George Brown College
Humber College Institute of Technology and Advanced Learning
Kwantlen Polytechnic University
Northern Alberta Institute of Technology
Red River College Polytechnic
Saskatchewan Polytechnic
Seneca Polytechnic
Sheridan College Institute of Technology and Advanced Learning
Southern Alberta Institute of Technology

2.3 Return on Investment in Applied Research

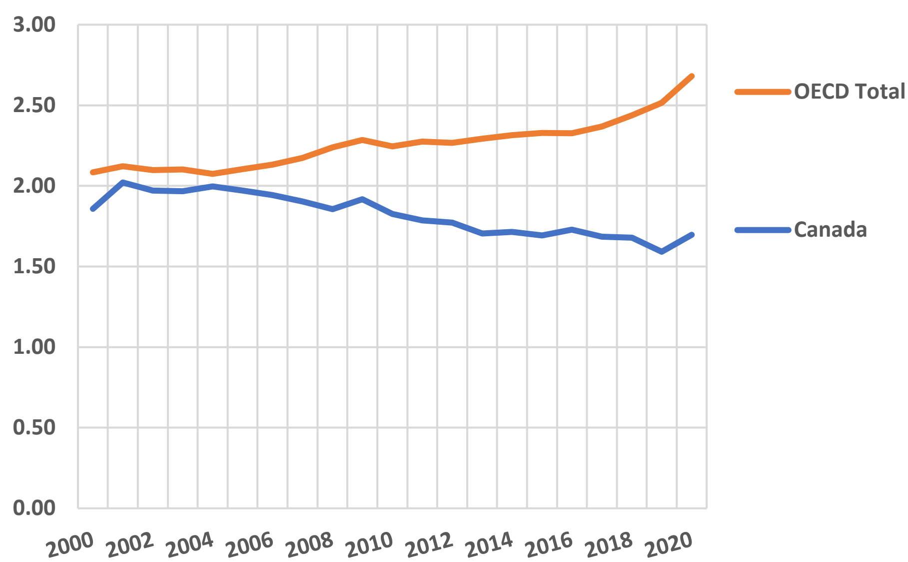
The central conclusion of this report is that polytechnics make a vital contribution to addressing Canada's productivity challenge. Polytechnics have the capacity to make an even greater contribution by further leveraging their relationships with industry, especially with small- and medium-sized enterprises (SMEs).

Some aspects of the rate of return are difficult to measure. However, using a methodology developed by Benjamin Jones and Lawrence Summers, we can conservatively conclude that every $1.00 invested in polytechnic applied research generates a combined private and social return that ranges from $8.09 to $18.49. Given that social benefits are difficult to quantify in monetary terms, such as those related to reductions in waste and carbon emissions, and improved health and safety practices, the research supports an estimate closer to the upper boundary.

2.4 Canada's Productivity Challenge

Canada lags its Organization of Economic Cooperation and Development (OECD) peers in investments in research and development (R&D). This lag restrains innovation, contributes to a decline in productivity and leads to stagnation in real income. More recently, output per person (as measured by Gross Domestic Product per capita) has declined. This trend, if not reversed, has serious implications for future living standards. The conventional measure of R&D investment is R&D spending as a percentage of GDP. Figure 2 shows that, since at least 2000, Canada's investment in R&D, as a percentage of GDP, has been below the overall total for the OECD. More significantly, this gap has widened over the past 20 years.

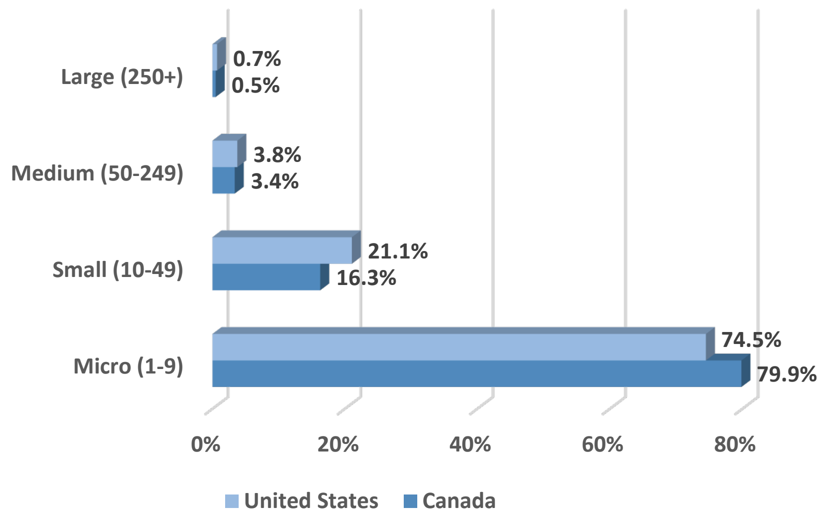
Figure 2 - Spending on R&D as a percentage of GDP (2000 – 2022)



Source: OECD Main Science and Technology Indicators (March 2022)

An important factor in determining the trajectory of investment in innovation is the role of SMEs in the Canadian economy. Figure 3 shows that, compared with the United States, micro-enterprises (1-9 employees) constitute a larger share of the enterprise base in Canada (79.9 per cent versus 74.5 per cent). Conversely, the share of small (10-49 employees), medium (50-249 employees) and large (250+ employees) all comprise a larger share of the U.S. enterprise base. The implication is that fewer micro-enterprises in Canada make the transition to small or medium-sized businesses and fewer medium-sized enterprises transition to large ones. A lower rate of investment in innovation is an important factor in explaining this difference.

Figure 3 - Share of enterprises by size in Canada and the US (2001 – 2011 Average)



Source: OECD Studies on SMEs and Entrepreneurship (https://www.oecd-ilibrary.org/sites/9789264273467-6-en/index.html?itemId=/content/component/9789264273467-6-en)

Accelerating the rate of innovation among SMEs is critical to reversing the decline in productivity growth in the Canadian economy. There are a range of factors that encourage or constrain SMEs from investing in innovation. Among these are access to technical expertise and technical facilities, the cost of innovation investments and the related business risk. The R&D needs of SMEs often differ from the R&D undertaken by large enterprises. SME investment in R&D is often focused on short-term projects that will yield a pay-off within a narrow timeframe. It is also important to many SMEs that ownership of the intellectual property generated by an R&D project resides with the company, where it can be protected by 'trade secret' protocols or, in some cases, patents. These needs can make collaboration with universities difficult because of a preference for longer-term projects and the career imperative for researchers to publish results.

2.5 Polytechnics and Business Innovation

This report will show that Canada's polytechnics are uniquely positioned to support accelerated innovation and they have an impressive track record of doing so. Polytechnics accommodate both shorter R&D timeframes and enable partners to protect their intellectual property. More importantly, polytechnics have the capacity to significantly expand their applied research enterprises to support a greater number of partners.

Polytechnic support for innovation is not a magic bullet solution to Canada's lagging productivity nor its poor record of business investment in R&D. However, expanding capacity among polytechnic institutions stands to have a sizable impact on innovation activity and should be a critical element of Canada's innovation strategy.

2.6 Data Sources and Methodology

This report draws on several data sources:

- Literature Review: A literature review on the rate of return on investment to basic and applied research
- Statistics Canada – Special Tabulation: A special tabulation of a data series on the income received by Canada's polytechnics for operations, capital and research
- Polytechnics Canada – Annual Survey of Applied Research: These surveys are completed by Directors of Applied Research at each member institution. Information collected includes data on research expenditures, the number of research projects, the types of collaborating partners and the number of students engaged
- NSERC – Special Tabulation of Completion Reports: A special tabulation was prepared by the Natural Sciences and Engineering Research Council (NSERC) of completion reports submitted by collaborating partners at the end of a project. NSERC provided anonymized data in aggregate covering two NSERC funding programs, Engage (n=209) and Applied Research and Development (ARD) grants (n=34). Engage had a maximum funding allocation of $25,000 per project and a timeframe of six months. ARD projects have a maximum grant level of $150,000 and may run for up to three years. ARD projects require a 20 per cent cash contribution from the partner, whereas Engage projects had no co-funding requirement. During recent efforts to modernize the granting program for colleges, Engage funding has been folded into the new Mobilize grants and are no longer offered as a standalone grant type
- Case Studies: 30 case studies were undertaken of recently completed or ongoing applied research projects carried out by polytechnics. Case study summaries are presented in Appendix A
- Ipsos/Prism Canvass of Collaborating Partners: 26 partners who had recently collaborated with a polytechnic on an applied research project reflected on their experience. Of the 26 partners, 11 were interviewed by Ipsos Canada, 11 completed an online survey and four were interviewed by Prism Economics and Analysis.

2.7 Outline of Report

Section 3.0 profiles the applied research undertaken by polytechnics. The chapter shows that polytechnics are uniquely positioned to build innovation capacity among research partners. The chapter also describes the impact of the applied research projects drawing from the data sources described above.

Section 4.0 estimates the return on investment to polytechnic applied research. The chapter begins by distinguishing between basic and applied research, and the role of applied research in generating an overall return on investment. The section then discusses the factors that go into estimating the private and the social return on this investment. This chapter concludes by estimating the return on investment to the research undertaken by Canada's polytechnics. Appendix B sets out the detailed calculations.

Section 5.0 summarizes the findings and conclusions of the report and their implications for public policy.

3.0 Profile

This section profiles the research carried out by Canada's polytechnics. It is based on 30 case studies of research projects and three data sources. These are: (1) the Annual Applied Research Survey undertaken by Polytechnics Canada; (2) a special data tabulation of polytechnic revenues and expenditures data provided by Statistics Canada; and, (3) aggregated data provided by NSERC using information in the project completion reports submitted by organizations that partnered with polytechnic institutions.[1]

3.1 Rapid Growth in Research Activity

In 2004, NSERC established the College and Community Innovation Program (CCIP). This program was later expanded to include a funding stream for social innovation – the College and Community Social Innovation Fund (CCSIF). These programs enable Canada's polytechnics to engage in partner-driven research. Several provincial governments also provide funding for applied research of the type carried out by polytechnics.[2]

Recent data illustrate the impact of this funding. Between 2014-15 and 2021-22, the number of projects undertaken annually more than doubled. In 2021-22, more than 3,800 projects were either active or completed during the year.

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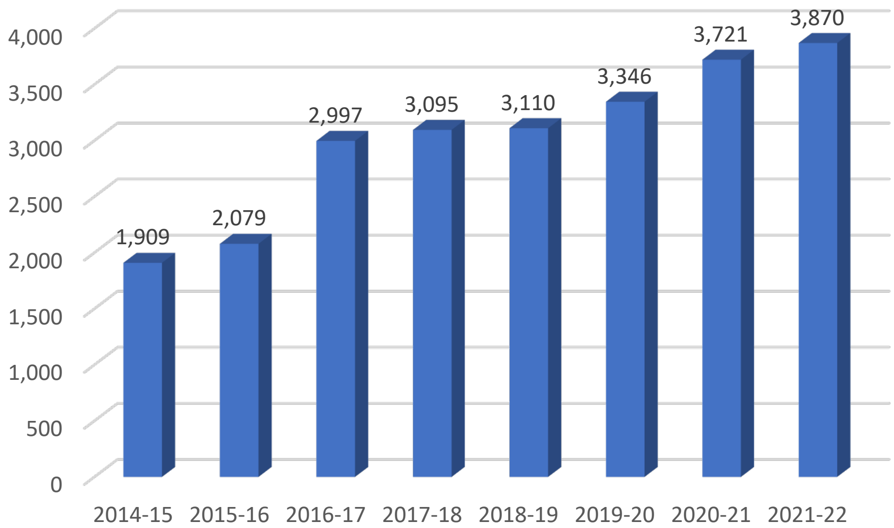
[1] Both Statistics Canada and the Polytechnics Canada Survey provide estimates of funding for applied research. Owing to differences in definitions and accounting procedures, there are moderate differences between these two data sources, though both show the same trends. Among the accounting procedures that account for these differences are: fiscal vs. calendar year reporting, the timing of when expenditures are recorded, and whether funding is reported as income received for a project or expenditures incurred by the project. The Completion Reports submitted to NSERC by partner organizations are subject to confidentiality protection. NSERC provided only aggregated data that could not be used to identify any partner organization.

[2] Reflecting on the changes in funding made available to polytechnics and colleges, Fisher remarks in a 2009 article that Canada's polytechnics and colleges were called upon to "… extend their historical mandates (of career-related education and regional economic development) by incorporating research, especially applied research, into their traditional programs." Roger Fisher, "A Framework for Research at Canadian Colleges," College Quarterly, Fall 2009, vol. 12, no. 4. Holmes describes the expansion of the colleges research mandate in Ontario and the subsequent increase in applied research activity. Krista M. Holmes, (2017) "Research at Colleges in Ontario: Learning from the Past and Looking Towards the Future", *College Quarterly*, vol. 20, no. 3.

Figure 4 - Number of research projects active or completed



Source: Polytechnics Canada Applied Research Survey

In 2021-22, more than 20 per cent of these projects were contract research projects undertaken for a non-governmental partner and financed wholly by that partner. The principal investigators interviewed for the case studies indicated there is still significant capacity to expand this research activity.

3.2 Demand-Driven

The research carried out by Canada's polytechnics is *applied* research. Virtually all of this research is undertaken in collaboration with an industry partner that defines the research problem. This partner is usually a business and often an SME. The applied research of polytechnics is, therefore, demand-driven. This focus aligns with the federal innovation strategy, which seeks to accelerate private-sector innovation. While universities also undertake applied research, the primary focus of their research activity is *basic* research. The purpose of basic research is to advance theoretical understanding of phenomena. The focus of a basic research project is determined by its principal investigator, not by an industry partner.

The portfolio of case studies outlined in this report illustrates the practical, demand-driven nature of polytechnic applied research projects.

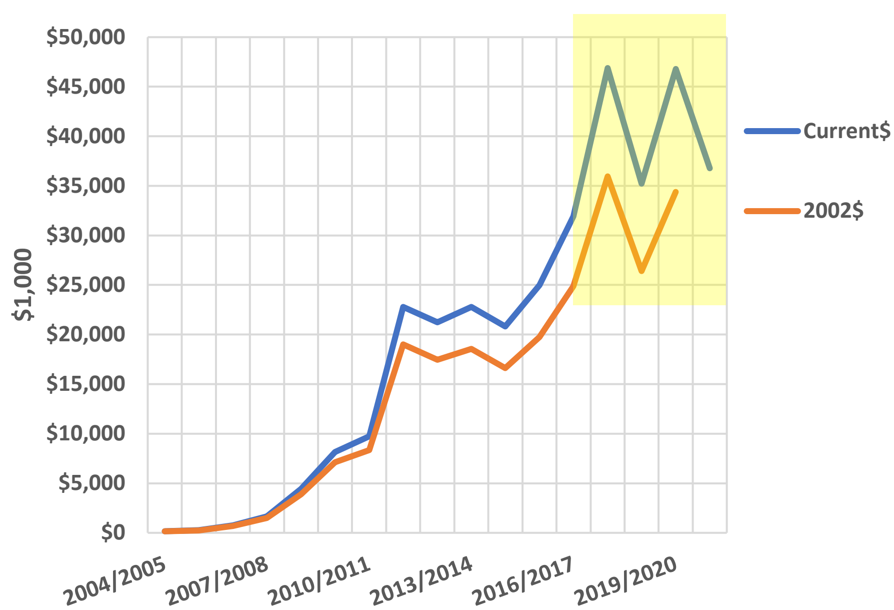
3.3 Funding

Polytechnic applied research is funded from a range of governmental and non-governmental sources. The largest source of funding, but accounting for less than half of the total, is grants from federal research agencies. Of these NSERC is the most prominent as it administers the College and Community Innovation Program.

Polytechnics also access research funds through other federal government programs designed to support R&D, notably the National Research Council's Industrial Research Assistance Program (IRAP) and their respective provincial governments. Finally, and of particular importance, the polytechnics receive support from their non-governmental partners (chiefly businesses). This support may take the form of contract research where the private partner funds 100 per cent of the research costs, co-funding where the private partner contributes a portion of the costs with the balance being financed by a grant, or in-kind support where the private partner provides expertise and physical resources that would not otherwise be available.

Figure 5 shows the funding for polytechnic applied research based on a special tabulation by Statistics Canada. It illustrates the real level of funding using the Consumer Price Index to deflate nominal funding to constant 2002 dollars.

Figure 5 - Funding for Polytechnic Applied Research (2002 dollars)

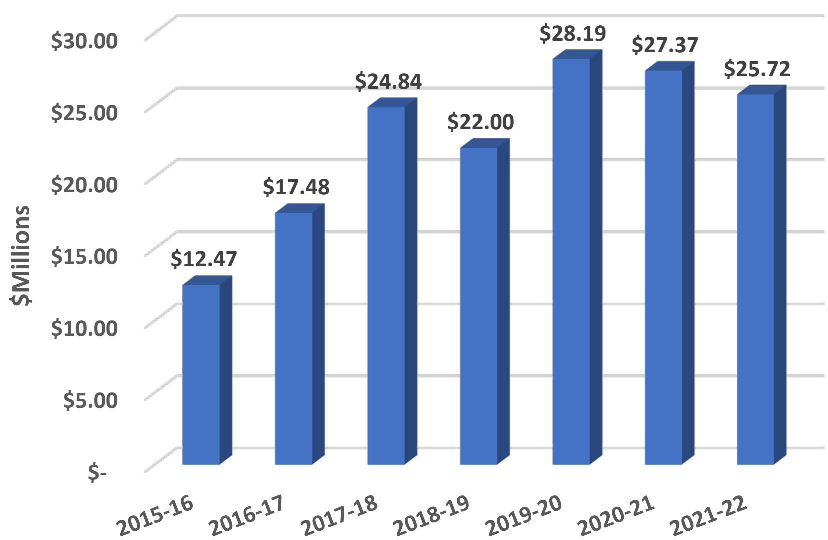


Source: Statistics Canada, special tabulation

Figure 5 shows that, since approximately 2017-18, the funding for applied research in Canada's polytechnics has been inconsistent. This makes it difficult to sustain innovation activity and retain research staff. In light of Canada's productivity challenge and the particular problem of lower rates of innovation among SMEs, this approach should be reconsidered.

A distinctive feature of the funding of polytechnic applied research is the important contributions made to that research by non-governmental partners, mainly businesses. Figure 6 shows the estimated private sector contribution to polytechnic applied research activities. These data are based on the Polytechnics Canada Applied Research Survey. Owing to differences in accounting practices across the 13 polytechnics, the aggregated totals should be understood as estimates rather than precise measures. These data cannot be compared to the Statistics Canada data series used in Figure 5.

Figure 6 - Estimated Private Sector Contribution to Polytechnic Applied Research



Source: Polytechnics Canada Applied Research Survey

Both the Statistics Canada data series and the Polytechnics Canada Applied Research Survey indicate that the private sector contribution to polytechnic applied research ranges from 20 to 25 per cent of total research funding. Much of this private sector contribution is linked to co-funding under an NSERC program, leveraging the investment made by granting agencies. In addition to cash contributions, the private sector partners also provide in-kind contributions to the polytechnics. This has an estimated value of approximately 50 per cent of the cash contribution, based on data collected by the Polytechnics Canada Applied Research Survey.

3.4 Intellectual Property

Survey evidence indicates that most companies in Canada, especially SMEs, do not use the patent system to protect their intellectual property.[3] A series of roundtables with SMEs by the Canadian Intellectual Property Office found that the cost of obtaining patent protection, the complexity of the patenting process and the length of time required to obtain a patent discourage many SMEs from using the patent system.[4] Most SMEs rely on 'trade secrets' strategies such as security protocols and non-disclosure agreements. In most cases, this precludes researchers from publishing their research results. For polytechnic faculty, this constraint does not impede collaboration, whereas, for university-based researchers, a publishing requirement often makes collaboration with a private company impractical when the company requires a non-disclosure agreement. In the case study portfolio, there are numerous projects in which the applied research contributed to creating intellectual property that resides with a private sector partner. The ability of polytechnics to support this type of applied research is fundamental to the viability of their partnerships with private companies and to the return on investment generated by this research.

3.5 Ability to Operate within Compressed Timeframes.

Polytechnics have two distinct advantages when collaborating with private sector partners. First, thanks to block funding arrangements with NSERC, institutions can quickly approve proposed collaborations. This contrasts with the much more drawn-out approval process that companies encounter when considering collaboration with university-based researchers. Many companies, especially SMEs, are deterred from collaborations that have a lengthy application process. Were it not for the expedited approval process that block funding enables, many of the applied research projects in the portfolio of case studies would not have been undertaken.

The second distinct advantage of polytechnics is that they can undertake short-term projects. While many research projects in the traditional universities have a three- to five-year lifecycle, the research needs of companies generally have a much shorter planning horizon. Polytechnics are well positioned to accommodate this compressed timeline.

3.6 Small- and Mid-Sized Business Partners

Polytechnics Canada's annual Survey of Applied Research shows that over the most recent five years for which there are data (2017-18 to 2021-22), 85.3 per cent of applied research project partners were SMEs. This clearly differentiates polytechnic applied research from the research carried out in the university sector. As noted previously, Canada's SME sector lags other jurisdictions in its investment in innovation. Given the size of the SME sector in Canada, this lag is a

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[3] John R. Baldwin, "The importance of research and development for innovation in small and large Canadian manufacturing firms." (1997) *Statistics Canada Analytical Studies Paper*, Issue 107.

[4] Canadian Intellectual Property Office, "Intellectual Property Roundtable Discussions with Innovative Canadian SMEs: Report following May and June 2012 (Wave One)", online: https://ised-isde.canada.ca/site/canadian-intellectual-property-office/en/report-following-may-and-june-2012-wave-one

major contributor to the slower rate of productivity growth and per capita GDP growth that characterizes the Canadian economy. Since 2014-15, when Polytechnics Canada began collecting applied research data, its members have undertaken more than 20,000 applied research projects with SMEs. This experience illustrates capability among the polytechnics to build innovation capacity among small- and mid-sized enterprises.

3.7 Impact

The discussion in this section draws on the NSERC completion reports data, the Ipsos/Prism canvass of partners and the case studies.

3.7.1 Success Rate

The NSERC completion reports submitted by collaborating partners indicate that 88 per cent of the projects generated a benefit to the partner and were, therefore, judged to be a success. In the Ipsos/Prism canvass, 25 of 26 partners described their collaboration as a success.

3.7.2 New Markets

In the NSERC completion report data, 25.5 per cent of partners reported access to new markets because of the research project.

Assisting partners in the effort to identify and access markets is a key contribution of many applied research projects. This support can take two forms. The first is research to identify potential markets for a product or service. This is especially important because the founders of many SMEs have a technology background but only limited understanding of marketing their product or service. Studies of the SME sector identify weaknesses in marketing as a major cause of small business failure.[5] In the food products sector, a major obstacle faced by SMEs seeking to enter the mainstream retail market is regulatory compliance. For example, to move from 'farmers markets' to retail marketing, a food product requires a nutrition label and a shelf-life assessment. These must be supported by laboratory testing. Larger firms internalize these laboratory functions or hire costly third-party testing services. Neither of these options is feasible for a small business. Without access to testing support from polytechnics, many – perhaps most – of these small enterprises would be unable to access the mainstream retail market and grow their business operations. Other projects provide direct support for marketing by undertaking market research or supporting the development of marketing tools.

Examples:

- Case Study 1: Beck's Broth Shelf Stability and Packaging Study (Conestoga)
- Case Study 3: GoodPud Shelf Stability Testing (Fanshawe)

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[5] Tamara Jovanov and Mitre Stojanovski, "Marketing knowledge and strategy for SMEs: Can they live without it?" (2012); online: https://eprints.ugd.edu.mk/29500/

3.7.3 Exporters

The NSERC completion reports indicate that more than 62 per cent of partners export to international markets. Studies show that SMEs that export have a greater propensity to invest in R&D.[6] By supporting exporters and building the capacity to export, the applied research partnerships directly contribute both to improved export performance and increased R&D investment.

Examples:

- Case Study 7: Mobile Agent for the Industrial Internet of Things Workforce (Algonquin)
- Case Study 8: Automated Aircraft Maintenance Data Processing and Analytics (Humber)
- Case Study 11: Cold Spray Repairs of Aerospace Components (RRC Polytech)
- Case Study 29: Reading Assistance Software (Seneca Polytechnic)

3.7.4 Improved Competitiveness

Completion reports indicate that 48 per cent of partners believe they were able to improve competitiveness because of their involvement with the research project. While there are many economic interpretations of competitiveness, it is, for many companies, the single most important metric for judging business performance. In the Ipsos/Prism canvass, 19 of 26 partnering companies reported that the results of their collaboration led to increased competitiveness.

3.7.5 R&D Capacity

Of the partners in NSERC's Engage program, 51 per cent indicated that their participation in the applied research project improved their company's research and development capabilities. This is a particularly important contribution. It was noted earlier that Canada's SME sector appears to lag other jurisdictions in its propensity to innovate. One of the factors behind this lag is barriers to accessing technical expertise and physical resources to undertaking R&D. By reducing these barriers, polytechnics make an important contribution to building capacity to invest in R&D and undertake both product and process innovation.

Polytechnics work with numerous private companies to develop prototypes for new products or to carry out proof-of-concept analysis for improved production processes. These are among the most important channels for generating a return on investment. Polytechnics augment the R&D capabilities of SMEs in two ways. The first is by providing access to costly equipment and software applications. The second is by drawing on faculty expertise, staff technologists and students to augment R&D staffing resources.

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[6] Lyming Huan, "Canadian High-Growth SMEs and their Propensity to Invest in R&D and Export" (2019) Innovation, Science and Economic Development Canada Small Business Branch, Research and Analysis. See also: John Baldwin and Belling Yan, "Empirical from Canadian Firm-level Data on the Relationship Between Trade and Productivity Performance", Statistics Canada, Economic analysis Research Reports, Cat. No. 11F0027M — No. 97

In the Ipsos/Prism canvass, only 5 of 26 companies reported that they had dedicated research facilities. Of the 26 partners canvassed, 16 reported that they could not have undertaken the applied research project without collaborating with a polytechnic. Significantly, 20 of 26 partnering companies indicated that their collaboration experience would lead to increased involvement of their company in future applied research activity.

Improved quality of a product or service was reported by 22 of 26 partnering companies. The case studies demonstrate that the opportunity to collaborate with a polytechnic accelerates the development of new products and services or the adoption of cost-saving technology solutions.

Examples:

- Case Study 6: Real-time Projected Images for Virtual Production (Sheridan)
- Case Study 25: Design SER System with the Ability to Process and Classify Speech Signals to Detect Emotions (Humber)
- Case Study 27: Bovine Pathogen Genomics (Kwantlen Polytechnic University)
- Case Study 30: Noise Cancelling Acoustic Technology (Southern Alberta Institute of Technology)

3.7.6 New Jobs & Employment

In the NSERC completion report data, 12 per cent of partners reported that the results of the applied research created new jobs. Furthermore, in the Ipsos/Prism canvass, 10 of 26 partnering companies expected increased employment to result from their research collaboration with a polytechnic.

The case studies also show that student engagement in applied research facilitated their entry into employment related to their training. Some partners reported that they used the student engagement in the applied research as a screening mechanism to support their hiring decisions.

Examples:

- Case Study 8: Automated Aircraft Maintenance Data Processing and Analytics (Humber)
- Case Study 14: Creating Affordable Adaptive Garments by Extending the Clothing Lifecycle (George Brown)
- Case Study 19: Air Tightness Testing (RRC Polytech)

3.7.7 Access to Specialized Skills

The NSERC completion reports show that 13.2 per cent of partners identified access to specialized or hard-to-reach workers as a benefit of their participation in the project. Collaboration with polytechnics thereby facilitated hiring necessary expertise and also reduced an important barrier to innovation and increased investment in R&D.

Examples:

- Case Study 18: EV Tundra Buggy (RRC Polytech)
- Case Study 26: Aeromonas salmonicida Genome Sequencing and qPCR Test Development (Kwantlen Polytechnic University)

3.7.8 Productivity

In the NSERC completion reports, 21 per cent of partners reported an improvement in productivity. In the Ipsos/Prism canvass, half of partners reported that they expected increased productivity from their collaboration. These are particularly important findings in light of Canada's slow productivity growth.

3.7.9 Continued R&D Investment

More than half (53 per cent) of the partners indicated in their completion reports that they had plans to continue collaboration with a polytechnic. A further 27 per cent indicated ongoing discussions about future partnerships were underway. Significantly, 45 per cent of partners indicated that future research partnerships would be funded internally. The NSERC completion reports illustrate that one of the notable impacts of applied research collaboration is its ability to strengthen the propensity to invest in innovation.

3.7.10 New Investment

In the NSERC completion reports, 14 per cent of partners reported that they were able to attract new investment as a result of their participation in the research projects. This is a notable finding. Studies have concluded that while business start-up is comparatively unimpeded in Canada, SMEs face significant barriers to accessing the capital needed to scale up their operations.[7] For around one in seven collaborating partners, the results of the applied research facilitated accessing additional investment capital.

3.7.11 Social Benefit

In the NSERC completion reports, 37 per cent of partners reported that the research project led to a reduced environmental impact. More than a third (35 per cent) reported that the project led to improved health and safety. Just under a quarter (23 per cent) reported reduced energy consumption. The true value of these social benefits is often under-estimated by conventional cost-benefit or econometric procedures. The social benefits are nevertheless significant and need to be incorporated into a holistic view of the return on investment.

The case studies illustrate instances of applied research generating these social benefits.

[7] Miwako Nitani and Aurin Shaila Nusrat, "Scaling Up Is Hard To Do: Financing Canadian Small Firms" (2023) C.D. Howe Institute, online: https://www.cdhowe.org/public-policy-research/scaling-hard-do-financing-canadian-small-firms

Examples:

- Case Study 21: The Baby Calmer (BCIT)
- Case Study 23: SafeCuffs (George Brown)
- Case Study 24: COVID-19 Response – A Scalable Sanitizing Sensing Solution using IoT-enabled Dispensers (Humber)

3.7.12 Restoring Land after Resource Extraction

The role of forests in combatting climate change is widely accepted, as is the negative impact of the loss of boreal forests.[8] Mining and forestry necessarily cause a degradation of the natural environment, an unavoidable consequence of resource extraction. Conventional GDP accounting does not incorporate the environmental damage as a cost, although it does incorporate the expenditures related to restoring the environment through reforestation. This accounting procedure, however, underestimates the value of reforestation because it only counts the expenditures. The subsequent contribution of reforested areas to removing carbon from the atmosphere is not factored into conventional GDP calculations.[9] Polytechnics have made notable contributions to reforestation efforts through their applied research. This is an important aspect of the return on investment to applied research, which is not fully captured by conventional econometric measures.

Examples:

- Case Study 15: Boreal Forest Restoration (NAIT)
- Case Study 16: Peatland Restoration (NAIT)

3.7.13 Increasing Recycling Capacity

All manufacturing processes generate waste. Industrial waste can be incinerated, discarded into landfill sites or recycled. Recycling is unquestionably better for the environment. In conventional GDP accounting, any remunerated activity contributes to GDP. Hence, the system of national accounts makes no distinction between incinerating waste, transporting it to a landfill site or recycling the waste into value-added products.[10] In environmental accounting, the distinction between environmentally damaging activities, such as incinerating waste or transporting it to a landfill site, is critical.

In the portfolio of case studies, two applied research projects illustrated collaborations to recycle industrial and other waste into value-added products. Conventional estimates of the return on investment do not fully capture the social benefits of advancing recycling technology.

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[8] Canadian Council of Forest Ministers, "Forests: A Stabilizing Force for the Climate" online: https://www.ccfm.org/climate-conscious/forests-a-stabilizing-force-for-the-climate/

[9] United Nations, "System of Environmental Accounting" online: https://seea.un.org/news/rise-fall-and-rethinking-green-gdp

[10] Jonathan M. Harris and Brian Roach, "National Income and Environmental Accounting" Chapter 10 in *Environmental and Natural Resource Economics: A Contemporary Approach* 5th edition, Routledge, 2022.

Examples:
- Case Study 13: Reuse of Spent Grains from Breweries (Conestoga)
- Case Study 20: Recycling Wood to Produce Plastics (Saskatchewan Polytechnic)

3.7.14 Improved Worker Safety
In the Ipsos/Prism canvass, 4 of the 26 partnering companies indicated that an ancillary benefit of their applied research collaboration was an improvement in worker safety.

3.7.15 Public Health Research
There is a substantial return on investments in public health.[11] Disease prevention reduces demands on the health care and social service systems, and extends the productive life of individuals. However, investments in public health generate little or no return that can be captured privately. Consequently, public investment is essential, although private-sector grants may augment it.

A clear example of this is the ongoing project at the Northern Alberta Institute of Technology. Supported by students, researchers at NAIT are sampling water and soil to establish baseline estimates of micro-plastic accumulation. This also entailed developing extraction processes to isolate the microplastics in the water and soil samples. Funding was a combination of public support (NSERC) and industry grants (Case Study 17).

Two further projects undertaken by the genomics specialists at Kwantlen Polytechnic University also contribute to human health outcomes by testing dairy cows and salmon stocks for bacteria and viruses that stand to have adverse effects in the food chain (Case Studies 26 and 27).

3.7.16 Optimizing the Design and Delivery of Social Programs
While there is an established methodology in health economics (quality-adjusted life years) to estimate the benefits of healthcare interventions, there is no comparable metric to gauge the impact of improved design and delivery of social programs owing to the diversity of these programs and their intended outcomes. The case studies, however, demonstrate a significant social return when program design and delivery are strengthened.

Examples:
- Case Study 10: Data Management System and Portal (Humber)
- Case Study 22: Virtualized Experience Learning Platform (BCIT)
- Case Study 28: Science to Practice Playing: Transferring the Best of Early Child Development Evidence to Parents Through Integrated Health Equity Teams (RRC Polytech)

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[11] Rebecca Masters, Elspeth Anwar, Brendan Collins, Richard Cookson, Simon Capewell, "Return on investment of public health interventions: a systematic review" (2016) *Journal of Epidemiol Community Health* (2017), Vol. 71, No. 8, pp. 827-834. The authors report that the median ROI for public health interventions was 14.3 to 1. For local interventions, the ROI was 4.1 to 1 and for nationwide interventions it was 27.2 to 1. (Nov 1, 2022).

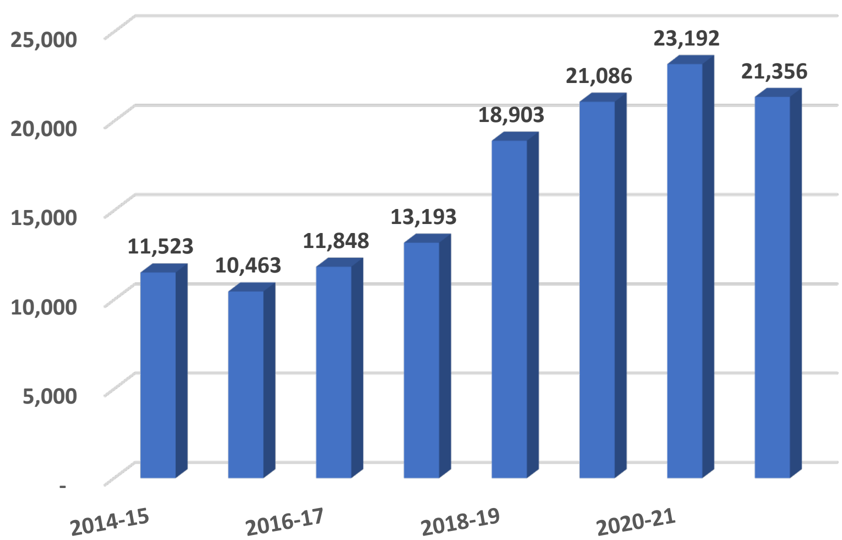
3.7.17 Building Human Capital

Canada's polytechnics play a key role in training successive cohorts of technicians, technologists and other professionals in hands-on occupations. The graduates who enter these roles enable organizations in both the public and private sectors to achieve their goals and increase productivity. Without this level of expertise, innovation and productivity in the Canadian economy – especially in the SME sector – would be reduced.

Polytechnic applied research plays an important role in preparing talent for key technical roles. The portfolio of case studies illustrates that virtually all of these projects engaged students. In some cases, the research contributed to capstone projects carried out in the final year of a program. In others, students were hired by the project or in co-op positions by partnering companies or organizations. This experience is not only a critical part of their training, but better prepares graduates for the real-world challenges they will face in their future workplaces. This is a key aspect of the return on investment of research activities.

Figure 7 shows that as applied research activity increased, so too did the number of students engaged in those projects. More than 20,000 students participate in applied research annually.

Figure 7 - Number of Students Engaged in Applied Research Projects



Source: Polytechnics Canada Applied Research Survey

This section has profiled polytechnic research activity, stressing the practical, applied nature of the research. Research projects are generally undertaken with a collaborator, usually a company and often an SME. Evidence from various sources illustrates the breadth of the return on investment, using tangible examples to showcase both the private and social return. Section 4.0 discusses this return in more detail and develops estimates of the return on investment.

4.0 Return on Investment

The first part of this section reviews the difference between basic and applied research. The implications of this distinction for the return on investment (ROI) to research are discussed. Part I also elaborates on an important theme of this report: that the applied research ecosystem supports Canada's small- and mid-sized enterprises.

The second part, beginning at Section 4.4, considers the factors that determine the return on investment in research and the implications of these factors for research undertaken by polytechnics.

Beginning at Section 4.5, methodologies for estimating the ROI on research are considered and the methodology used for this report is described.

Section 4.6 applies this methodology to develop an estimate of the return on investment to polytechnic applied research. The estimates are framed as high, low and mid-point estimates. Important aspects of the return on investment that this methodology cannot capture are noted.

4.1 Basic and Applied Research

Polytechnics conduct applied research, not basic. The distinction between basic and applied research is important to understanding the distinct role of polytechnics in Canada's research ecosystem.

Basic research is fundamental to the mandate of Canada's universities, although they also undertake applied research. The OECD's Frascati Manual provides guidance to governments on the collection and classification of data on R&D spending.[12] The Manual defines basic research as follows:

> "Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, *without any particular application or use in view*."

Statistics Canada adopts this definition.[13]

The characteristics of basic research are:

- The principal investigator defines the research interest and the research objective

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[12] OECD, Frascati Manual 2015, Guidelines for Collecting and Reporting Data on Research and *Experimental Development* (2015) online: https://doi.org/10.1787/9789264239012-e

[13] Statistics Canada, "Canadian Research and Development Classification (CRDC) 2020 Version 1.0 - Type Of Activity (TOA)" online: https://www23.statcan.gc.ca/imdb/p3VD.pl?Function=getVD&TVD=1277856&CVD=1277856&CLV=0&MLV=1&D=1

- The primary objective of a basic research project or program is always to advance theoretical understanding of phenomena
- Commercial applications of the research findings are either secondary or not a consideration

The findings from basic research are disseminated through specialist conferences and peer-reviewed scholarly journals. For most basic research projects, intellectual property ownership is not a consideration. Methodologies must be reproducible by other researchers.

Applied research differs from basic research. The OECD's Frascati Manual defines applied research as follows:

> "Applied research is original investigation undertaken to acquire new knowledge. It is, however, *directed primarily towards a specific, practical aim or objective.*"

Statistics Canada adopts this interpretation of applied research. The "specific, practical aim" of an applied research project is defined not by the principal investigator but by the sponsoring partner. The sponsoring partner is usually a private company with a commercial objective but it may also be an industry association, health or community service body, or not-for-profit organization. Unlike basic research, applied research almost invariably generates intellectual property. In a majority of cases, the intellectual property created during a polytechnic applied research project is transferred to the partner, enabling unencumbered commercialization and use by the sponsor for economic gain. Companies may protect this intellectual property through patenting or through "trade secret" practices, including security protocols and non-disclosure agreements. The results of most applied research undertaken by polytechnics, therefore, are usually not disseminated at conferences or through academic publications.

While some applied research projects may be longer (three to five years), it is more common for them to be undertaken in a more compressed timeframe – one year or less. This contrasts with basic research programs, which are usually long-term undertakings.

Basic research is financed predominantly by public agencies and foundations. Applied research draws on public agency funding but is often supported, in whole or in part, by partner contributions.

By solving a practical problem, applied research supports productivity gains. This productivity gain may be a new product or service with commercial value, an improved production or service delivery process or a reduction in externality costs. Externality costs include, among others, waste, noise, environmental degradation and greenhouse gas emissions. These costs are termed 'externality costs' because they are borne by society, not by the company that generates them. Basic research often has long-run implications for productivity. However, the productivity gains from basic research are often distant and always require that the theoretical advances generated by the basic research be utilized by applied research to address specific technical problems.

Figure 8 highlights and summarizes the key differences between basic and applied research.

Figure 8 - Comparison of Basic and Applied Research

	Basic Research	Applied Research
Initiation and definition of the research	Principal Investigator	Partner
Primary goal of the research	Advance theoretical knowledge	Solve a practical problem by applying established theory
Research funding source	Public agency (e.g. NSERC, SSHRC, and CIHR) or foundation	Public agency (e.g. NSERC, SSHRC, and CIHR) or foundation Partner
Intellectual property created	Usually not	Always
IP ownership	University policies vary	Partner
Dissemination of results	Academic conferences and peer-reviewed journals	Results are usually protected by trade secrets or practices, or patents
Timeframe	Usually 3-5 years	Sometimes 3-5 years, but often 1 year or less
Commercial application	Secondary or not a consideration	Primary purpose
Impact on productivity	Distant	Immediate

4.2 Implications for Return on Investment

In most methodologies, estimates of the overall rate of return on investments in research combine basic research and applied research. While this procedure is valid for generating a macroeconomic estimate of the return on investment, combining applied research with basic research obscures how the return on investment arises. As discussed above, the primary objective of basic research is to advance theoretical understanding of phenomena. Basic research, on its own, does not generate a return on investment. The return on investment arises when the theoretical advances achieved by basic research are incorporated into applied research projects, thereby increasing productivity. Understanding the return on investment in research in this way does not diminish the importance of basic research. Advances in theory underpin advances in applied research.

However, it is applied research that gives rise to productivity gains and, therefore, a return on overall investments in research.

4.3 SMEs and the Innovation Gap

A flourishing ecosystem of applied research is key to innovation and productivity growth. Therefore, strengthening Canada's productivity growth requires building up the ecosystem of applied research, especially in the SME sector. As noted earlier, the SME sector constitutes a larger share of the enterprise base in Canada than in the United States. Building up the applied research ecosystem in the SME sector is, therefore, key to increasing the rate of innovation in our economy and reversing the decline in productivity growth. This view echoes that of the Business Development Bank of Canada.[14]

There is extensive literature on the barriers faced by SMEs to investing in R&D, particularly process innovation.[15] A report by Desjardins found that:

> "Canada has a productivity and innovation problem, and Canadian small- and medium-sized enterprises (SMEs) struggle the most. This is true not just relative to larger Canadian companies, but also to SMEs in other countries."[16]

Among the factors cited are lack of technical staff, lack of facilities and cost. For many SMEs, the cost of investing in productivity-enhancing process innovation entails significant risk. The case studies in this report illustrate how collaboration with Canada's polytechnics lower these barriers. Polytechnics provide access to expertise and well-equipped facilities. Cost-sharing arrangements reduce financial risk while vesting intellectual property with the partner protects their investment.

4.4 Decomposing the Return on Investment in Applied Research

The return on investment to research consists of a private and a social return. The private return is the increment to profits attributable to a company's R&D activities. The future increments to profit are discounted to a present value, which is then compared to the related expenditures on R&D. The resulting ratio is the private return on investment, which accrues solely to the company. The social return encompasses all other benefits from the research investment that do not accrue to the company but to users of the company's products or services or to society. A literature review

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[14] Business Development Bank of Canada, *Canada's Support for Research and Development: Suggestions to improve the Return on Investment* (ROI) online: https://www.bdc.ca/globalassets/digizuite/10648-rdreview_2011_en.pdf

[15] David B. Audretsch, Agustí Segarra and Mercedes Teruel, "Why don't all young firms invest in R&D?", *Small Business Economics*, Vol. 43, No. 4, Special Issue: Firm Growth and Innovation (December 2014: Springer) pp. 751-766.

[16] Jimmy Jean, Randall Bartlett and Kari Norman, "Accelerating Small Business Success: Navigating the Canadian Innovation Landscape" October 16, 2023 online: Desjardins https://www.desjardins.com/qc/en/savings-investment/economic-studies/canada-disruptive-innovation-sme-oct-16-2023.html

concludes that the social return on investments in research exceeds the private return.[17] Indeed, many studies find that the social return is substantially greater than the private return to investment in R&D.

To better understand the social return on investment, it is useful to decompose this return into its components. Many studies describe the social return as "spillover effects." While this is a valid characterization, it is useful to drill down further into these "spillover effects" as there is no standard procedure to measuring or assessing their value. The approach taken in this report highlights the principal components of the social return with particular emphasis on relevance to the applied research activities of the polytechnics.

1. **User Benefit:** This is the benefit that accrues to the users of the technology developed through a research project. For example, Case Study 30 describes a noise-cancelling technology used to create cones of silence in manufacturing or resource-extraction settings characterized by the operation of noisy machinery. Users of the technology reduce the risk of hearing loss in their operations and also reduce the risk of industrial accidents attributable to misheard or unheard instructions or warnings. Case Study 29 describes a reading assistance software application. The software assists persons with weak reading skills or learning disabilities to improve their reading capability. Some boards of education have adopted the software. In both research projects, a private ROI accrues to the company that developed the technology and a broader social ROI accrues to its users.

2. **Reductions in Externality Costs:** Externality costs are costs arising from a production process that society bears rather than the company that produces the product or service. Examples of externality costs include waste, degradation of land by resource extraction and risks to public or worker health. Greenhouse gas emissions are also externality costs. However, owing to the importance of decarbonization in combating climate change, the reduction in greenhouse gas emissions is treated separately. Case Study 13 describes a research project to support marketing uses of spent grains used by breweries. In the absence of alternative uses, these grains would end up in landfill sites. In addition to the private return earned by the company that has developed alternative use technologies for these waste products, there is also a reduced externality cost that arises from diverting waste from landfill sites. Case Study 15 describes a research program to identify strains of seeds most suited to restoring boreal forests degraded by resource extraction. Indigenous communities often undertake the commercialization of the seed banks. Companies use the seed strains to meet their statutory obligations for reforestation. The companies benefit from the more efficient seed strains, which

[17] Bronwyn H. Hall, Jacques Mairesse and Pierre Mohnen, "Measuring the Returns to R&D" in Bronwyn H. Hall, Nathan Rosenberg, eds, *Handbook of the Economics of Innovation,* Volume 2, (2010), Chapter 24. "We review the econometric literature on measuring the returns to R&D. ... In general, the private returns to R&D are strongly positive and somewhat higher than those for ordinary capital, while the social returns are even higher, although variable and imprecisely measured in many cases."

reduce their reforestation costs. The Indigenous communities benefit from the opportunity to manage commercial seed banks. Society benefits from the restoration of degraded forests.

3. **Reductions in Environmental Costs**: As noted above, greenhouse gases are an externality cost. This social return is treated separately due to the importance of decarbonization in mitigating climate change. Case Study 19 describes a project that developed air tightness testing protocols to identify the severity of air leaks in building envelopes and support remedial retrofitting. In collaboration with Canada Mortgage and Housing Corporation, the testing protocols reduce energy usage in older buildings. In a similar vein, Case Study 9 describes the development of sensor and testing protocols to optimize the use of older control technology for heating, ventilation and air conditioning systems in buildings constructed before the introduction of modern control systems. This enables the owners of these buildings to reduce energy use and reduce greenhouse gas emissions. Case Study 20 describes a project to support the use of recycled wood as a source of polymers for plastics production. This reduces the demand for petroleum-based polymers. For each project, the social ROI is the contribution to reduced energy use and decarbonization.

4. **Human Capital:** The principal mandate of the polytechnics is to train successive cohorts of qualified professionals to support Canada's public and private sectors. Virtually all applied research projects undertaken by the polytechnics engage students who learn to apply scientific and/or technological principles to solve practical problems. Graduates play a key role in enabling Canada's public and private sectors to innovate.

5. **Building the R&D Ecosystem**: As noted in Section 3.0, approximately 85 per cent of the applied research projects undertaken by Canada's polytechnics support innovation at SMEs. These companies benefit not only from the intellectual property created by the applied research project but also from the increase in their capacity to undertake applied research. While most accounts of the social return would not isolate the role of SMEs in the innovation process, it is appropriate to do so considering the enterprise structure of the Canadian economy.

6. **Quality of Life**: In many cases, it is not practical to assign a dollar value to the results of applied research projects undertaken in collaboration with public sector or not-for-profit organizations. The metrics used to evaluate these research projects are typically non-monetary. The social return, however, is real. Case Study 26 describes a project undertaken with the B.C. Ministry of Agriculture and Food to test for bacterial disease in salmon that causes severe harm to salmon populations and other fish species.

4.5 Methodologies

4.5.1 Metrics

A well-established branch of growth economics explains the sustained growth of economies despite diminishing marginal returns to factors of production such as labour and capital as technological advancement.[18] In this sense, technology is understood as how inputs are transformed into output. Technological advancement arises from improvements in the quality of labour inputs (increases in human capital), learning by doing (experience), improvements in the quality of capital inputs (technical advances) and the development of new products or services (advances in design). The last of these – advances in design – is sometimes encompassed by definitions of technical advances and other times isolated as a distinct contributor to total factor productivity (TFP) (hence theories of the "creative class").

As noted above, the total return on investment consists of the private and social return. Two distinct approaches have been developed to measure the return on investment in research activities. The first uses patent data. The second uses either growth in per capita gross domestic product or increases in total factor productivity.

4.5.2 Patents

A longstanding and extensive literature uses patent activity to measure R&D and estimate its return on investment.[19] The rationale for using patent data to estimate the return on investment to research is that, as discussed earlier, only applied research generates a return on investment and patents are a proxy for the level of R&D activity. Treated as a measure of R&D activity, patenting can be correlated with per capita GDP or TFP. From this correlation, a rate of return on investment can be inferred. There are, however, drawbacks – both practical and theoretical – to relying on patent data to estimate the return on investment to the applied research undertaken by Canada's polytechnics.

First, there is limited data on patenting activity arising from the applied research undertaken by polytechnics. Principal researchers at the polytechnics are often unaware that their business partner has applied for a patent on the prototype or process developed by the research project. Moreover, even if a patent were sought, the patent may cover more than the output of the research project. The company may have further refined the prototype or process using its own resources.

Second, most SMEs do not rely on the patenting system to protect their intellectual property. SMEs are more likely to rely on "trade secrets" protocols such as non-disclosure agreements or security

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[18] Paul M. Romer, "Endogenous Technological Change" (1990) *Journal of Political Economy* Vol. 98, No. 5 pp. 71–102.

[19] Dennis C. Mueller, "Patents, Research and Development, and the Measurement of Inventive Activity", *Journal of Industrial Economics*, (1996) Vol. 15, No. 1, pp. 26-37

Linda Ponta, Gloria Puliga and Raffaella Manzin, "A measure of innovation performance: the innovation Patent Index" (2021) online: https://www.emerald.com/insight/content/doi/10.1108/MD-05-2020-0545/full/pdf?title=a-measure-of-innovation-performance-the-innovation-patent-index protocols. There is no reliable way to infer the volume of R&D activity in SMEs from their patenting activity. Public-sector bodies and not-for-profit organizations generally do not use the patent system. Innovation in the public and not-for-profit sectors should not be omitted from an estimate of the return on investment to research.

Third, a methodology that is centred on patent data implicitly focuses on the private return on investment. It does not take account of the social rate of return.

For these reasons, methodologies that rely on patent data to estimate a return on investment to research are not appropriate when considering the ROI of research carried out by Canada's polytechnics.

4.5.3 Per Capita GDP and Total Factor Productivity

Real *per capita* GDP measures the total output (adjusted for inflation) per person. TFP is the ratio of total output to total input, where input consists of resources, labour and capital goods (machinery, buildings, infrastructure). Increases in *per capita* real GDP are largely attributable to improvements in TFP.

There are four drawbacks to relying solely on either increases in *per capita* GDP or improvements in TFP to gauge the return on investment to research.

First, neither metric adequately incorporates improvements in productivity in the public and not-for-profit sectors. In the private sector, increases in the value creation of the business can be measured by comparing the cost of inputs with the market price of outputs. In the public and not-for-profit sectors, this is usually not feasible since there is no market price. The value of the output in these sectors is conventionally equated to the cost of the inputs. This measurement procedure suppresses productivity gains. Given the size of the public and not-for-profit sectors in Canada, this is a serious drawback.

Second, Canada's polytechnics prepare technical professionals in conjunction with carrying out applied research projects. At polytechnics, training and applied research are inextricably bound up with each other. This contribution to improving human capital is arguably encompassed by overall improvements in human capital. However, the overall increase in the productivity of labour is not a proxy for the specific contribution of the polytechnics. Many other factors, such as immigration and demographic trends, influence changes in the overall productivity of labour.
Third, neither change in *per capita* GDP nor increases in TFP take account of reductions in externality costs, such as waste, degradation of land or greenhouse gas emissions.[20] However,

[20] Jonathan M. Harris and Brian Roach, "National Income and Environmental Accounting" Chapter 10 in *Environmental and Natural Resource Economics: A Contemporary Approach* 5th ed, Routledge, 2022.
United Nations, "System of Environmental Accounting" online: https://seea.un.org/news/rise-fall-and-rethinking-green-gdp

these are real costs to society and a reduction in these costs should be reflected in the return on investment to applied research.

Fourth, improvements in well-being arising from better treatment programs or improved design and delivery of social programs do not figure into the calculation of gross domestic product. However, such improvements that result from applied research nevertheless confer real benefits and are regarded as part of the social return on investments in research.

The inference from these considerations is that changes in *per capita* GDP or TFP are only a first approximation of the return on investment to research.

4.5.4 Jones and Summers Model

In a study for the U.S. National Bureau of Economic Research, Jones and Summers describe a procedure for estimating the total return on investment in R&D, i.e., the sum of the private return and the social return.[21] Jones and Summers consider long-run growth in *per capita* GDP to be determined by increases in TFP. Increases in TFP, in turn, are determined by advances in technology, where technology is broadly understood as the means of turning inputs into outputs. Understood in this way, technological advances encompass both engineering improvements and improvements in the overall stock of human capital. For this reason, Jones and Summers argue that the long-run rate of growth in GDP per capita is an appropriate measure of the impact of investment in R&D, where this investment includes all public and private research investment.

In the next section, we draw on this approach to develop a first estimate of the return on investment to the applied research undertaken by polytechnics. We then note that this first estimate undervalues certain impacts, which should also be considered.

4.6 Estimating the Return on Investment of Polytechnic Applied Research

The Jones and Summers model predicts substantial returns on R&D. Three variables drive the model: the long-run growth rate in *per capita* GDP, the share of GDP invested in R&D and the social discount rate. In our adaptation of the model, we use nominal values because rates of return on investment are normally reported in nominal terms.

The model uses a long-run growth rate in *per capita* GDP of 1.1 per cent. This is based on World Bank tables[22] and is somewhat lower than recent nominal growth in GDP, which was elevated by the inflation spike.

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[21] Benjamin F. Jones & Lawrence H. Summers, "A Calculation of the Social Returns to Innovation", Working Paper 27863, DOI 10.3386/w27863, Issue Date September 2020, online: https://www.nber.org/papers/w27863

[22] World Bank. "GDP Per Capita Growth (Annual %)" *World Bank Data*, online: https://data.worldbank.org/indicator/NY.GDP.PCAP.KD.ZG

The share of GDP invested in R&D is also drawn from World Bank tables.[23] The model uses 1.7 per cent.

The social discount rate is the rate used to deflate future gains to present values. The magnitude of the present value is inverse to the magnitude of the social discount rate. That is to say, the greater the social discount rate, the lower the present value of the future benefits. The model uses three social discount rates to generate alternative estimates of the ROI. The first of these, which generates the lowest ROI, is 8.0 per cent. This is based on the Treasury Board of Canada's recommended social discount rate for cost-benefit analyses.[24] The second estimate of ROI is based on a lower social discount rate of 3.5 per cent. This is the rate recommended by Boardman, Moore and Vining, which they published in *Canadian Public Policy* in 2010.[25] Finally, the third estimate of ROI is based on selecting a discount rate that is the mid-point between 3.5 per cent and 8.0 per cent. This is 5.75 per cent. This is higher than the long-term corporate bond rate and, therefore, reflects the greater risk associated with R&D investments.

The details of the calculations are set out in Appendix B. Figure 9 shows the ROI based on the alternative social discount rates.

Figure 9 - Alternative Estimates of ROI on R&D Investments

Social Discount Rate	$1.00 invested in R&D generates a return of:
3.5%	$18.49
5.75%	$11.25
8.0%	$8.09

Figure 9 shows that every $1.00 invested in research at polytechnics generates a total return on investment between $8.09 and $18.49. Taking into account factors that are difficult to measure, such as improvements in well-being or reductions in externality costs, such as greenhouse gas emission, supports an estimate closer to the upper boundary.

The foregoing method of estimating the return on investment only examines the benefits to GDP *per capita*. While this is the largest source of social benefit from R&D, it does not account for other benefits. As discussed, these include the value of reducing carbon emissions, reducing waste or improving social well-being through better-designed social programs.

[23] World Bank. "Research and Development Expenditure (% of GDP) – Canada" *World Bank Data,* online: https://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS?locations=CA
[24] Mark A. Moore, "Social Discount Rates for Canada" (2008) online: http://jdi-legacy.econ.queensu.ca/Files/Conferences/PPPpapers/Moore%20conference%20paper.pdf
[25] Anthony E. Boardman, Mark A. Moore, and Aidan R. Vining "The Social Discount Rate for Canada Based on Future Growth in Consumption" *Canadian Public Policy / Analyse de Politiques* (2010) Vol. 36, No. 3: 325–43, online: http://www.jstor.org/stable/20799660

5.0 Implications

This report reaches three conclusions.

First, every $1.00 invested in polytechnic applied research generates a total return that ranges from $8.09 to $18.49, with the median estimate being $11.25. This does not take into account the impact of the research on reducing carbon emissions and waste or improving the well-being of Canadians through better-designed social programs.

Second, applied research plays a crucial role in generating the overall return to research investments. In the absence of applied research, there are no gains in productivity nor improvements in living standards.

Third, Canada's polytechnics are uniquely positioned to build innovation capacity for businesses of all sizes, but particularly for SMEs.

The return on investment to research includes both a private return and a social return. The social return is significant and, by many estimates, larger than the private return.[26] The private sector, however, is motivated only by the private return, *i.e.*, that portion of the total return that contributes to increased profitability. As a result, the rate of private investment in R&D is always less than the social optimum. For this reason, virtually all governments implement strategies to support basic and applied research.

The contribution of universities to research, especially to basic research, is widely recognized. This contribution is a justifiable source of pride. As this report stresses, however, *realizing the investment return on research requires applied research. Augmenting the investment return can*

[26] The view that the social return to investment in R&D us equal to greater than the private return is widely supported by the empirical literature. See, for example, the following:

- Based on a review of the empirical literature, Hall, Mairesse and Mohnen conclude that "in general, the private returns to R&D are strongly positive and somewhat higher than those for ordinary capital, while *the social returns are even higher, although variable and imprecisely measured in many cases."* [emphasis added]. Hall, Bronwyn H, and Jacques Mairesse and Pierre Mohnen (2010). |Chapter 24 – Measuring the Return to R&D", in Bronwyn H, Hall and Nathan Rosenberg, eds., *Handbook of the Economics of Innovation*, vol 2, Elsevier Publications.
- Bloom, Lucking and Van Reenan conclude that the social return on R&D investment in the United States is approximately four times the private rate of return. Bloom, Nick and Brian Lucking and John Van Reen (2018). "Have R&D Spillovers Changed? ", CEP Discussion Paper No 1548. Centre for Economic Performance, London School of Economics. https://cep.lse.ac.uk/pubs/download/dp1548.pdf
- Based on a review of the literature, a report by Frontier Eocnomics for the U.K. Department of Science, Innovatin and Technology concluded that "relatively conservative approach to modelling the benefits to R&D could be to assume that the social returns to R&D are twice those of the private return." Frontier Economics, (2023). Rate of Return to Investment in R&D: A Report for the Department of Science, Innovation and Technology. London, U.K. https://www.frontier-economics.com/media/015adtpq/rate-ofreturn.pdf#%5B%7B%22num%22%3A84%2C%22gen%22%3A0%7D%2C%7B%22name%22%3A%22XYZ%22%7D%2C33%2C606%2C0%5D

only be achieved by augmenting applied research. This is where Canada lags other jurisdictions, especially among SMEs, which play a larger role in the enterprise structure in Canada than in the United States.

This report shows that:

- Polytechnics are now involved in nearly 4,000 projects annually. All of these projects are demand-driven and are carried out in collaboration with a partner. Approximately 85 per cent of these partners are SMEs. The practice of allowing intellectual property to reside with the partner is an important enabler of this collaboration
- 26 per cent of polytechnic partners gained access to new markets as a result of their applied research collaboration
- 21 per cent of partners reported increased productivity. Half of the partners reported that their collaboration increased their R&D capability. Roughly one in seven reported that their collaboration assisted in attracting new investment capital
- 12 per cent of partners reported that their applied research collaboration led to the creation of new jobs

For many SMEs, working with private consultancies on R&D projects or using private laboratory or testing facilities is too costly. Collaborating with universities is impractical owing to the extended timelines, the scale required and the inability to protect intellectual property. Polytechnics are able to accommodate the short timelines that characterize the R&D needs of many SMEs because size is not a constraint. Finally, because intellectual property is allowed to reside with the company and institutions are able to work within the constraints of non-disclosure agreements and security protocols, polytechnics are uniquely positioned to build the innovative capacity of Canada's SMEs.

The funding data cited in Section 3.0 show that support for polytechnic and college applied research activity has been volatile in the last few years, reflecting short-term investments. With additional support, polytechnics have the potential to significantly increase their contribution to Canada's applied research ecosystem, increasing the rate of innovation and productivity growth in the Canadian economy. This is likely to require sustained, predictable funding levels that grow as the sector's capacity expands.

Appendix A: Case Studies

Case studies were conducted via interviews and project descriptions provided by principal investigators at each Polytechnics Canada member institution. For ease of reference, the case studies are organized by the broad topic area addressed by the applied research project, though many address more than one. Together, this sample showcases the diversity of projects underway at polytechnic institutions, many aligned with Canada's critical challenges and priorities.

A1 Market Innovation & Capacity-Building

1. Conestoga: Beck's Broth Shelf Stability and Packaging Study
2. Conestoga: Transportation of Self-Saucing Vegetables
3. Fanshawe: GoodPud Shelf Stability Testing
4. Fanshawe: JC Green Process Improvement
5. Humber: Support of Marketing 3D Virtual Reality Training
6. Sheridan: Real-time Projected Images for Virtual Production

A2 Technology Adoption

7. Algonquin: Mobile Agent for the Industrial Internet of Things Workforce
8. Humber: Automated Aircraft Maintenance Data Processing & Analytics
9. Humber: Data Analytics for Smart Building Controls
10. Humber: Data Management System and Portal
11. RRC Polytech: Cold Spray Repairs of Aerospace Components
12. Southern Alberta Institute of Technology: Engage High-Energy Shock Wave Characterization and Improvement of Components for Electro-Hydraulic System

A3 Environmental Impact & Improvements

13. Conestoga: Reuse of Spent Grains from Breweries
14. George Brown: Creating Affordable Adaptive Garments by Extending the Clothing Lifecycle
15. Northern Alberta Institute of Technology: Boreal Forest Restoration
16. Northern Alberta Institute of Technology: Peatland Restoration
17. Northern Alberta Institute of Technology: Plastics Research in Action
18. RRC Polytech: EV Tundra Buggy
19. RRC Polytech: Air Tightness Testing
20. Saskatchewan Polytechnic: Recycling Wood to Produce Plastics

A4 Health & Wellness

21. British Columbia Institute of Technology: The Baby Calmer
22. British Columbia Institute of Technology: Virtualized Experience Learning Platform
23. George Brown: SafeCuffs
24. Humber: COVID-19 Response – A Scalable Sanitizing Sensing Solution using IoT-enabled Dispensers
25. Humber: Design SER System with the Ability to Process and Classify Speech Signals to Detect Emotions
26. Kwantlen Polytechnic University: Aeromonas salmonicida Genome Sequencing and qPCR Test Development
27. Kwantlen Polytechnic University: Bovine Pathogen Genomics
28. RRC Polytech: Science to Practice Playing – Transferring the Best of Early Child Development Evidence to Parents through Integrated Health Equity Teams
29. Seneca Polytechnic: Reading Assistance Software
30. Southern Alberta Institute of Technology: Noise-Cancelling Acoustic Technology

Case Study 1: Beck's Broth Shelf Stability and Packaging Study
Principal Investigator: Nicole Detlor
Project Partner: Beck's Broth

CONESTOGA
Connect Life and Learning

Project Profile

Beck's Broth is a female-led business located in the Waterloo Region. The founder sold liquid broth at farmer's markets before moving into independent retailers and selling on her digital store. She eventually began making a shift from selling a liquid to a powder. Creating this new product line created a need to meet regulatory requirements, specifically, nutrition labelling and new packaging for the powdered product. A shelf-life study was also required to meet regulatory requirements and determine under which conditions the shelf life could be degraded. A packaging strategy was undertaken to ensure proper product display on store shelves.

Funding

Beck's Broth funded the initial project. The packaging study and the shelf-life stability project were financed by the National Research Council's Industrial Research Assistance Program (IRAP).

Partner Challenges

There are few private laboratories that will perform shelf-life studies and nutritional analysis for small enterprises. Most food product manufacturers internalize these functions. This is not practical for a small enterprise. In the absence of support from organizations like Conestoga, small enterprises face a significant regulatory barrier to entry into the food products business.

Conestoga has software tools that enable it to perform nutritional analysis. This relieves small food product businesses of the need to invest in analytical software and laboratory equipment, a cost which cannot be justified for a single product line.

Student Engagement

Working on projects commissioned by Beck's Broth gave students practical experience. For instance, with the nutrition panel, the students received first-hand experience working with industry-standard software, allowing them to apply the regulatory knowledge they learned in the classroom to a real-world setting.

With the packaging design projects, students also gained experience working with industry-standard software and learned to weigh the trade-offs when making design decisions. Students were expected to incorporate client feedback into their redesign work.

Supporting Industry Networking

Conestoga also assisted the partner by connecting her to other resources available to the food products industry. They provided advice on potential retailers, which is particularly important since relatively few are prepared to work with small-volume suppliers.

Beck's Broth was referred to Conestoga by a local business accelerator. This referral network is typical in the region. Conestoga plays a key role in the region's food products ecosystem.

Case Study 2: Transportation of Self-Saucing Vegetables
Principal Investigator: Nicole Detlor
Project Partner: EarthFresh

CONESTOGA
Connect Life and Learning

Project Profile

EarthFresh is a medium-sized enterprise located in Burlington, ON, focusing on producing potato and other vegetable products. In summer 2023, the company released a vegetable product that had a self-saucing system for microwavable vegetables. They approached Conestoga with concerns that their saucing system might be compromised during transportation. Conestoga has a mechanical vibration table that simulates transportation. In testing, the institution reviewed the product's packaging for potential points of failure. As a result, EarthFresh was able to successfully introduce the product into the retail market. The company required a rapid turnaround on this project. Larger companies address the need for rapid turnaround on applied research projects by internalizing the work. This was not a viable option for this company.

Funding

The need for a rapid turnaround precluded accessing government programs with lengthy application and approval processes. Conestoga was able to undertake this research by drawing on block funding from IRAP and NSERC.

Need for Specialized Equipment

Specialized equipment that simulates the effect of transportation on products is necessary whenever there is a risk that transportation can adversely affect the integrity of a product. Only larger companies have the resources to invest in this equipment. For a small- or medium-sized enterprise, this investment is impractical because it will be used infrequently. By making access to such testing equipment accessible to SMEs, Conestoga was able to support the partner's ability to enter the retail market and expand their offerings.

Student Engagement

Students were involved throughout the testing process and wrote the final report.

Intellectual Property

EarthFresh did not patent the technical solution for this product, which is common among small and medium enterprises which cannot afford the costs of obtaining patent protection. EarthFresh relied on "trade secrets" to protect its intellectual property.

Export Potential

Extending shelf-life through packaging and formula strategies enables products to be exported. Conestoga has collaborated with local companies that now supply the Middle East market as a result of shelf-life improvements to their products.

Case Study 3: GoodPud Shelf Stability Testing
Principal Investigator: Haleh Hashemi Sohi, PhD
Project Partner: GoodPud

FANSHAWE

Project Profile

GoodPud is a small, Ontario-based food products company that manufactures a pudding product. The founders initially sold their product through a local farmers' market but wished to expand into the mainstream retail market. To do so, the company needed to provide valid shelf-life information ("best before date") and extend the shelf-life of its product. This project assisted the company with both needs.

Funding

The project was co-funded by NSERC and the partner.

Student Engagement

The project engaged one student, who assisted in the testing function and learned testing protocols.

Benefits to Company

Fanshawe was able to offer significantly less costly testing to the company. The cost of using a private laboratory would have been prohibitive to a company of this size. As a result of the testing support provided by Fanshawe, the company was able to enter the mainstream retail market and also extend the shelf-life of its product.

Case Study 4: JC Green Process Improvement
Principal Investigator: Sahar Samimi, PhD
Project Partner: JC Green

FANSHAWE

Project Profile

JC Green is a medium-sized cannabis grower based in Thorndale, Ontario, specializing in the production of cannabis for medical use. The project objective was to streamline their process to refine a high-purity product while minimizing waste. The timeline for the project was four months.

Funding

One quarter of the costs of the project were covered by the partner. The remaining 75 per cent of project costs were supported from funds received from NSERC's Innovation Enhance program to facilitate projects in Fanshawe's Centre for Applied Research and Innovation in Biotechnology (CARIB) labs.

Student Engagement

The project employed two students who mainly worked onsite at the partner's production facilities.

Partnership

JC Green contacted Fanshawe after attending an online seminar about Fanshawe's initiative to support cannabis research. The company was then linked with Fanshawe's business development team.

Business Benefits

Fanshawe was uniquely positioned to assist the company based on experience optimizing equipment like that used by JC Green. The institution was able to quickly approve the project and mobilize researchers to support the company. The company benefited from process improvements. The company had invested in new equipment to expand its production but was not achieving optimal efficiency. The process improvements identified through this applied research project overcame these constraints and enabled the company to increase the output of its new equipment, expanding both revenue and its market share.

Case Study 5: Support for Marketing 3-D Virtual Reality Training
Principal Investigators: Eva Ziemsen, PhD
Elizabeth Fenuta, M.Arch
Project Partner: APG Media

HUMBER POLYTECHNIC

Project Profile

APG Media manufactures large, curved screens that can function as virtual backgrounds for filmmakers. This avoids the need for set construction or costly onsite shootings. The technology reduces both production and post-production costs for filmmakers. This project involved creating an application to support product marketing by providing prospective customers with a 3-D simulation of how the product could be utilized in their studio.

Funding

The project was financed using block funding from NSERC. This enabled rapid approval of the project.

Student Engagement

The project employed five students. A former student was also hired for the project. Two of the students involved were featured in the Women in Tech series. Participation in the project increased student employability upon graduation, particularly by expanding their contacts in the industry.

Social Benefit

The software developed through this project is also applicable to virtual training environments. The company agreed that colleges could use the software at no cost.

Export Potential

APG conducts operations in the United States and Canada. This software enables the company to increase its sales in both markets.

Case Study 6: Real-time Projected Images for Virtual Production
Principal Investigator: Mike Darmitz
Project Partner: SpinVFX

Sheridan

Project Profile

SpinVFX is a visual effects studio working in film and television productions. The Toronto region has become an international centre for the visual effects segment of the film industry. The company has worked on well-known series streamed on such platforms as Netflix, HBO and AppleTV. This project focused on developing digital tools and collaboration procedures that reduce the cost of introducing visual effects into productions.

Funding

NSERC funded the project and the company provided a 20 per cent match. The company also provided technical and facility support, including staff time.

Student Engagement

The project engaged four to five students on a part-time basis and as co-op placements. The placements enabled the students to become familiar with costly visual effects applications.

Benefits to Company

Leveraging the outcomes of this research, SpinVFX aims to offer new, cost-efficient services, thereby making high-quality production solutions more accessible to lower-budget projects. Additionally, the company might lower the costs of its existing services. This move towards cost-effectiveness will strengthen the competitiveness of the Canadian film industry against its US counterparts.

Case Study 7: Mobile Agent for the Industrial Internet of Things Workforce
Principal Investigator: Adesh Shah
Project Partner: Contextere

ALGONQUIN COLLEGE

Project Profile

Contextere is a Canadian-based software developer in the AI field. The company has offices in Ottawa and the United States. This project supported the company in the development of an AI application for industrial technicians. The application scanned thousands of product manuals and codes to establish its a language database. Technicians can query the application, which will provide information in plain English. This process is significantly faster than scanning manuals. This collaboration is a continuation of projects first initiated in 2016.

Funding

Funding was provided by NSERC with a 25 per cent partner contribution.

Student Engagement

Numerous students have been employed on this project from a number of different programs at Algonquin.

Company Benefits

Having a polytechnic partner allows this company to test ideas and bring them to other industry partners. This propels projects past the experimental phase and ensures additional resources are committed only as appropriate. The application created during this partnership is now being marketed.

Case Study 8: Automated Aircraft Maintenance Data Processing and Analytics
Principal Investigators: Mihai Albu, PhD, Orren Johnson, M.Sc
Shahdad Shariatmadari, M.Sc
Project Partner: MHIRJ Aviation ULC

HUMBER POLYTECHNIC

Project Profile

MHIRJ Aviation is a subsidiary of Mitsubishi Heavy Industries in Japan, headquartered in Montreal. MHIRJ specializes in the regional segment of the aviation industry, providing maintenance and other support to regional operators.

This was a five-year project that aimed to develop an analytical platform that would use data collected by a plane's operating system to better inform maintenance needs and allow for more rapid preventive maintenance. This will increase flight safety and maintenance efficiency. By reducing a plane's down time, the platform will increase operator profitability.

Funding

NSERC provided 60 per cent of the funding, the company provided 40 per cent. In addition, the company provided support by supervising students and providing access to company-owned equipment and proprietary technology.

Importance of Polytechnic Research

This project did not lend itself to collaboration with a university, although the company has worked with universities in the past. This project was focused on developing and extending existing technologies to increase the efficiency of diagnostics. The project did not contribute to advancing theoretical understanding and was, therefore, not considered appropriate for university-based collaboration. Additionally, the company wished to protect the intellectual property generated by the project. This goal was incompatible with the desire of university-based researchers to publish the results of their research. A key feature of polytechnic research is that the ownership of intellectual property resides with the partner.

Student Engagement

The project engages a Humber professor and two to four students each year. The company uses its experience in the project to screen potential applicants for permanent employment.

Export Potential

The airline sector is global. This technology, when developed, will be applicable to all regional airline operators.

Case Study 9: Data Analytics for Smart Building Controls
Principal Investigator: Timothy Wong, PhD
Project Partner: Carmichael Engineering Ltd.

HUMBER POLYTECHNIC

Project Profile

Older buildings lack the sophisticated control systems that are used to optimize the performance of HVAC systems. As a result, these buildings often overuse their HVAC systems by heating or cooling rooms that are unoccupied. To support buildings with older HVAC systems, the company sought to develop air quality and temperature testing procedures that could be incorporated into system scheduling to improve overall efficiency.

Funding

This project was funded from a block grant provided to Humber by NSERC to support applied research into AI applications. The partner provided access to its software system.

Student Engagement

This project involved three students: two data analysts and one software developer.

Social Benefits

Older buildings are a significant source of GHG emissions owing to the inefficiency of their HVAC systems. This project enabled the company to improve the efficiency of HVAC systems in older buildings.

Case Study 10: Data Management System and Portal
Principal Investigator: Bernie Monette
Project Partner: Windsor Essex Compassion Care Community

HUMBER POLYTECHNIC

Project Profile

Windsor-Essex Compassion Care Community seeks to improve the population's health by applying a strategy that integrates physical care with mental health and community support. The program relies on volunteers in addition to its professional staff. Volunteer record-keeping was inconsistent and idiosyncratic. The organization approached Humber to develop a data management system to standardize and simplify data collection.

Funding

Funding was provided by NSERC.

Student Engagement

Several students were involved in both the back- and front-end development of the database and portal.

Social Benefits

The project improved the administrative efficiency of the Windsor-Essex Compassion Care Community by simplifying and standardizing data collection. This facilitated the training of volunteers and increased the organization's effectiveness in identifying interventions and supports to assist vulnerable persons. These low-cost interventions reduce the burden on the health care system.

Case Study 11: Cold Spray Repairs of Aerospace Components
Principal Investigator: Dr. Janfizza Bukhari
Project Partner: StandardAero

Project Profile

StandardAero performs aircraft maintenance. During maintenance, replacing aircraft components is crucial but the high costs of manufacturing and environmental impacts pose significant challenges. Moreover, the longevity of aircraft often exceeds the availability of replacement parts, making production costly or impractical. The project aimed to use a cold spray to repair magnesium parts damaged by corrosion or wear, thereby reducing the need to replace the component.

Funding

The project was funded jointly by StandardAero and NSERC. Standard Aero also assigned two engineers and a technician to the project, who worked alongside the RRC Polytech researchers and students. The company also made its facilities available.

Student Engagement

The project engaged three students. Other students were exposed to the project. Students gained first-hand experience with robotic technology, data collection and analysis, and metallography.

Importance of Polytechnic Research

Retention of intellectual property was an essential aspect of this partnership, which precluded working with a university. However, the principles that inform the technology are more generally applicable. The partnership substantially increased the company's capacity to develop this repair process and bring it to market.

Export Potential

The company operates internationally.

Case Study 12: Engage High Energy Shock Wave Characterization and Improvement of Components for Electro-Hydraulic Pulse System
Principal Investigator: Todd Parke
Project Partner: Blue Spark Energy

SAIT Southern Alberta Institute of Technology

Project Profile

In collaboration with SAIT, Blue Spark Energy has improved the reliability of its BLUESPARK® technology. This technology generates powerful mechanical waves through an electrical arc discharge in a brine medium, which effectively breaks up debris and scale buildup in wellbores and improves flow in the near wellbore region.

The initial challenge was the inadequate operational life of a critical design element, limiting the technology's business applications. The BLUESPARK® technology is required to work in harsh downhole environments and to withstand the intense mechanics of the plasma arc to the acoustic wave generation process. The first project was to understand the root causes of the durability issues and a re-design of the pertinent components, which resulted in the desirable outcome of an over 20x improvement in service life. With this success, a subsequent project was launched to further explore enhancements that could increase the performance and durability of the system. This SAIT and Blue Spark Energy collaboration resulted in a commercial success.

Funding

The first project to support Blue Spark Energy was an exploratory project funded through block funds made available to SAIT by NSERC. A second project developed the technology. The company co-funded this project, contributing 30 per cent of the costs, plus in-kind resources and equipment.

Student Engagement

Students were involved in the exploratory phase of the project.

Link to Company R&D

This project was part of Blue Spark Energy's broad R&D investment to enhance the performance of its technology. The project accelerated the company's R&D work, which significantly improved the effectiveness and longevity of its equipment. The application of the BLUESPARK® technology has benefited both hydrocarbon and geothermal applications, with cost-effective scale removal and improved flow in the near wellbore region.

Case Study 13: Reuse of Spent Grains from Breweries
Principal Investigator: Nicole Detlor
Project Partner: Terra Bioindustries

CONESTOGA
Connect Life and Learning

Project Profile

Terra Bio processes spent grains from breweries to be used as input into other value-added products. The company is currently working with a local craft brewer. Without recycling, the spent grains would have been deposited into a landfill site or used to feed livestock. The company converts spent grains into plant-based protein and fermentable sugars. Protina – one of the company's spent grain products – recently received approval from Health Canada. Conestoga assisted the company in identifying potential users of its products and testing potential applications.

Funding

The company secured grants from other agencies.

Student Engagement

Conestoga students assisted the company by exploring potential user markets for its products and testing Protina in application.

Intellectual Property

Conestoga has a centre for commercialization, which Terra Bio is currently working with to determine the best protection strategy for its intellectual property.

Export Potential

The company intends to export its products after establishing a presence in the Canadian market.

Environmental Implications

Small-scale breweries typically dispose of spent grains in landfill sites. Aside from reducing the requirement for landfill sites, the upcycling of spent grains into animal feed reportedly reduces the emission of methane gas by cattle by up to 13 per cent.

Case Study 14: Creating Affordable Adaptive Garments by Extending the Clothing Lifecycle
Principal Investigator: Milan Shahani
Project Partner: Pegasus Shoppe

Project Profile

This project employed fashion design students to modify clothing provided by thrift stores for suitability for persons with disabilities. Persons with disabilities often require modified clothing, which can be difficult to find. Custom design is too costly for most persons with disabilities. Pegasus is a retailer that used the modified garments for a fashion show.

Funding

The project was funded by a grant from the Social Sciences and Humanities Research Council (SSHRC).

Student Engagement

The project operated from 2021 – 2023 and provided students with design and customization experience. Students also learned to identify customer needs. All graduates from the program secured employment in the industry.

Social Benefits

The program provides low-cost adaptive clothing for persons with disabilities, many of whom live on low-income supplements. The program also supports the recycling of used clothing, diverting used clothing from landfills.

Case Study 15: Boreal Forest Restoration
Principal Investigator: Jean-Marie Sobze PhD
Project Partner: Resource Extraction Firms and First Nations Communities

NAIT

Project Profile

These projects involve the study of plant propagation and seed delivery to support boreal restoration after forestry or other resource extraction processes. Different strategies are needed for boreal restoration depending on the region and the type of resource extraction. The Alberta Land Stewardship Act requires companies that disturbed land for resource extraction to put the land back on a trajectory to its prior state. This requires a complex analysis of soil and environmental conditions. Complex analysis like this requires that industry and government have specialty knowledge that experts in the field can best provide. Boreal restoration often requires using seeds that have not been researched previously because they lack commercial application. The research project required natural collection of seeds, study of germination and propagation conditions and testing the viability of various restoration strategies. The project trained First Nations peoples to identify and gather the seeds. Germination and propagation were studied at NAIT facilities.

Funding

When boreal restoration work is being undertaken for a company with statutory obligations to restore the land, funding is supplied by the company. When restoration work is being undertaken in collaboration with a First Nations community, initial funding is often supplied by NSERC or another agency. Some First Nations communities have established commercial seed banks that sell seeds to companies that need to restore land. These communities are able to fund subsequent research from the funds generated by their commercial seed banks.

Student Engagement

Research projects typically employ up to six students during the spring and summer season.

Company Benefits

The applied research projects undertaken by NAIT enable resource companies to fulfill their statutory obligations to restore land that was damaged by resource extraction.

Social Benefits

The applied research projects support the restoration of boreal forests, which play an important role in mitigating climate change. The applied research projects also support revenue-generating operations (seed collection and seed banks) on First Nations' lands.

Case Study 16: Peatland Restoration
Principal Investigator: Bin Xu, PhD
Project Partner: Various

Project Profile

Peatland restoration is a particular concern for the oil and gas industry, which is mandated to restore the lands it disturbs through extraction. The industry needs science-based, innovative reclamation approaches suitable for peatland ecosystems. The regulating body needs the scientific and practical knowledge to develop regulatory guidelines and standards for restoring these lands.

This project aims to provide industry and government with expert advice on developing guidelines and assisting in their implementation. It also creates a pool of practical knowledge from which industry and government can draw.

Funding

NSERC provided the initial funding through the Industrial Research Chair for Colleges grant. Subsequent funding was provided by provincial and federal government, agencies and industry partners.

Partners

Both provincial and industry partners were part of the program. Subsequently, other levels of government, including municipalities, Indigenous communities and additional industry organizations joined the program.

Student Engagement

There are various ways students are engaged during the research. The research program hires four to six students from NAIT and partner universities. Over the last ten years, this program has employed close to 100 students.

Social Benefits

This project supports the restoration of peatlands damaged by resource extraction.

Case Study 17: Plastics Research in Action
Principal Investigator: Jeremiah Bryksa
Project Partner: Heartland Polymers

NAIT

Project Profile

This project is part of a 10-year partnership between NAIT Applied Research and Heartland Polymers (a subsidiary of Inter Pipeline Ltd.) to develop solutions to develop solutions that ensure waste plastics are reused while reducing their environmental impact. This specific project is a three-year project that is developing methods to identify, quantify and monitor microplastics – small plastic particles less than 5 millimetres long – in freshwater and river sediments found in the North Saskatchewan River. Currently, there are no standard methods of extracting these contaminants from freshwater and sediment samples, which leaves gaps in the knowledge of the types and sizes of microplastics in freshwater and their impact on the environment.

Funding

This project is supported by NSERC and also draws funds from $10 million allocated by Heartland Polymers to the Plastics Research in Action project. This $10 million is part of a larger grant received by Inter Pipeline Ltd. as part of a Strategic Innovation Fund (SIF). Heartland Polymers contributes the time of its professional scientific staff to work with NAIT students and faculty on the project. This project has received additional support from NSERC and MITACS.

Student Engagement

Over the course of the project, ten students will collect samples and do related laboratory work.

Social Benefits

Microplastics are pervasive in water, soil and the atmosphere, but little is known about their prevalence and effect. This project is developing a set of baseline measurements for the Northern Alberta region, while also developing and refining sample collection procedures and microplastic extraction methodologies.

Scientists are particularly concerned about the ability of microplastics to carry toxic substances, which may lead to chemical exposure when ingested.

Case Study 18: EV Tundra Buggy
Principal Investigator: Jojo Delos Reyes
Project Partner: Frontiers North Adventures

Project Profile

This project was a proof of concept for Frontiers North Adventures to determine the technical feasibility of converting their Tundra Buggies into electric vehicles. RRC Polytech also partnered with Noble Northern, a small Manitoba-based company specializing in converting diesel to electric vehicles. While issues with the cost of batteries caused delays, the institution learned about an available supply of used batteries that were suitable for this use.

Funding

For this project, Frontiers North Adventures provided the funds for converting their fleet. The salary costs for students and faculty were covered by NSERC funding focused on applied research related to electric vehicles.

Student Engagement

Six students were employed through full-time co-op placements to assist in the battery repurposing. Two graduates of the program were subsequently hired by another company to service electric vehicles and monitor their battery performance.

Future Partnerships/Expansion

The success of this project led other companies to partner with RRC Polytech to adapt their gasoline and diesel vehicles to electric power and utilize repurposed batteries.

Environmental Impact

Electric vehicles reduce CO_2 emissions as well as noise pollution. Repurposing used batteries reduces waste and the greenhouse gas emissions associated with battery conversion and disposal. This work also assists sectors using low-speed vehicles to accelerate their transition to electric vehicles in line with government policy. Without collaboration with RRC Polytech, the company would not have adopted a repurposed battery solution to its transition needs.

Case Study 19: Air Tightness Testing
Principal Investigator: Alireza Kaboorani
Project Partner: Various

RRC POLYTECH

Project Profile

This is a decade-long program developing expertise through the Building Efficiency Technology Access Centre (BETAC). The Centre's expertise focuses on improving building construction and maintenance to reduce air leaks. This contributes to energy efficiency as well as occupant comfort and building durability. Testing procedures developed help to identify air leaks, quantify their severity and aid in devising remedial strategies. The testing protocols developed have been applied to a range of buildings in collaboration with Canada Mortgage and Housing Corporation (CMHC) and other property owners.

Funding

NSERC supported the creation of BETAC. All airtightness tests are fully funded by the partners.

Student Engagement

Students are trained in the testing protocols and work with various partners during their co-op term. Most students subsequently obtain employment in the industry.

Social Benefits

Envelope tightness is important to energy efficiency, comfort and building durability. This is especially true in more extreme climate conditions. The testing and analytical advice support owner investment decisions in retrofits that generate employment, reduce energy use and increase the longevity of buildings.

Case Study 20: Recycling Wood to Produce Plastics
Principal Investigator: Satyanarayan Panigrahi, PhD
Project Partner: Titan Clean Energy Projects

Project Profile

Titan Clean Energy Projects is a small enterprise focused on the circular economy by transforming biomass waste into advanced carbon materials. This project sources polymers from urban waste wood to manufacture plastics. Manufacturing plastics from wood reduces GHG emissions by more than 90 per cent compared to petroleum-based products.

Funding

This project receives support from multiple sources, including NSERC, IRAP, REMAP (a technology accelerator) and the Agricultural Development Fund. The partner contributed in-kind resources, including raw materials.

Student Engagement

Four students work on this project, along with three university students: a research engineer, a research scientist and a pure research post-doctoral student.

Company Benefits

The project enables the company to diversify its product portfolio.

Social Benefits

The project contributes to proving the viability of a low-carbon technology for manufacturing plastics.

Case Study 21: The Baby Calmer
Principal Investigator: Gordon Thiessen
Project Partner: BC Women's Hospital + Health Centre

BCIT BRITISH COLUMBIA INSTITUTE OF TECHNOLOGY

Project Profile

The Baby Calmer is a device that fits into a neonatal incubator or crib and calms babies born prematurely. The technology emulates parental physical contact, breathing and heartbeat. The device effectively calms premature babies during and after a stressful procedure. BCIT scaled the technology to be used in conjunction with an incubator, where the original version was too large for use.

Funding

Donations from the BC Women's Health Foundation provided funding for this project's second phase.

Intellectual Property

The device has been patented by the Provincial Services Health Authority, which assisted in sponsoring this project.

Social Benefits

While there is inherent social value in reducing stress levels in babies, there are also several developmental reasons to value it. The less stress the baby has in the early stages of life, the better their brain development. This is because stress lowers oxygen levels in the brain, which hampers brain development. The Baby Calmer has been shown to stabilize oxygen levels in infants born preterm.

Case Study 22: Virtualized Experience Learning Platform (VELP)
Principal Investigator: Dr. Moein Manbachi
Project Partner: Siemens Canada, Future Skills Centre

BCIT BRITISH COLUMBIA INSTITUTE OF TECHNOLOGY

Project Profile

The Virtualized Experience Learning Platform (VELP) was developed by BCIT to train electrical engineers, technicians and others in the cybersecurity requirements of utility systems. After the interruption of classroom learning by the COVID-19 shutdowns, BCIT adapted this platform to provide remote training in vocational skills. This two-year project was funded by the Future Skills Centre and supported by Siemens Canada, among other partners.

Funding

The VELP platform was initially developed with industry partners in the utilities sector. The federally supported Future Skills Centre provided support to adapt VELP to deliver remote training to vocational students.

Student Engagement

During the three-year development phase, the project employed four students annually. Based on this work, the BCIT team also developed two micro-credential badge courses *Fundamentals of Substation Automation Systems* and *Clean Energy Power Plants, Operation and Maintenance*.

Business Benefits

The VELP applications enable companies to more economically train and retrain operating staff in the utilities sector. VELP is now also being used for energy infrastructure training, such as advanced digital substations, resilient smart grid and microgrid operations and design.

Social Benefits

Public Safety Canada and the Department of Energy in the US rank cyberattacks as the number 1 risk to critical infrastructure. This application strengthens the training of utilities staff to thwart such attacks. The extension of this platform to vocational training potentially allows for remote delivery of training in the skilled trades.

Case Study 23: SafeCuffs
Principal Investigator: John-Allan Ellingson
Project Partner: Paratin Corporation

Project Profile

This project supported the development of a product which enables an individual to cuff themselves rather than be handcuffed by a police officer. The most common use of this equipment involves mental health crises. Research indicates that more than 40 per cent of police injuries occur when attempting to handcuff a person. The SafeCuffs product both reduces officer injury and diminishes the trauma experienced by otherwise compliant persons.

Funding

The project was funded by the Federal Economic Development Agency for Southern Ontario (FedDev).

Student Engagement

The project employed one student in design and prototyping.

Company Benefits

The prototype has proven successful and scalable. The company is now exploring manufacturing and distribution opportunities.

Intellectual Property

The institution encourages small businesses to protect their IP through a trade secret during the development stage and then file for patents later. The inventor did file for and received a patent for the invention before the project.

Case Study 24: COVID-19 Response – A Scalable Sanitizing Sensing Solution using IoT-enabled Dispensers

Principal Investigator: Timothy Wong, PhD

Project Partner: Mero

HUMBER POLYTECHNIC

Project Profile

Mero is a facility cleaning company that operates across Canada. This project developed and optimized a sensor to determine when soap and hand sanitizer dispensers needed replenishment. As a result of the COVID-19 pandemic, the use of hand sanitizers is widespread. This technology ensures that these devices are always functional.

Funding

The funding for this project was provided by NSERC.

Student Engagement

Two students were engaged in this project. The first student focused on testing the technology. The second focused on software development.

Social Benefits

This technology optimizes the performance of hand sanitizers by ensuring that they are replenished in a timely manner. Hand sanitation is an important public health measure to impede the spread of viral infections, such as influenza and COVID-19.

Case Study 25: Design SER System with the Ability to Process and Classify Speech Signals to Detect Emotions

Principal Investigator: Parisa Pouladzadeh, PhD

Project Partner: Press'nXPress

HUMBER POLYTECHNIC

Project Profile

Press'nXPress develops customer feedback software to enable companies to improve their services. This project focused on improving the quality of call centre interactions with customers by optimizing a Speech and Emotion Recognition (SER) application. A SER application identifies and classifies real-time emotions like frustration, confusion and concern during phone conversations. A key challenge addressed is the reduced performance of SER systems in noisy conditions and with typical call centre phone quality.

Funding

The project was funded through block funding made available to Humber from NSERC.

Student Engagement

Three students, plus several student volunteers, were engaged in this project. The project resulted in a publishable paper which students can also cite as an example of their work.

Benefits to Company

The company optimized its product and thereby strengthened its position in the market. The company sells in both Canada and the United States. The project duration – six months – aligned with the company's business needs. This compressed timeframe was feasible for a collaboration with Humber but would not have been practical for collaboration with a university. The use of block funding from NSERC also expedited the project approval process.

Case Study 26: Aeromonas salmonicida Genome Sequencing and qPCR Test Development
Principal Investigator: Paul Adams, PhD
Project Partner: B.C. Ministry of Agriculture and Food

KPU | KWANTLEN POLYTECHNIC UNIVERSITY

Project Profile

This research involves the development of a qPCR (quantitative real-time polymerase chain reaction) test for bacterial disease in salmon, in particular, *Aeromonas salmonicida*, a hard-to-detect pathogenic bacterium that causes severe harm to salmon populations and other fish species. The goal has been to produce a more rigorous, accurate, faster and cost-effective test to permit better monitoring and management of disease-producing bacteria.

Beginning in 2022, working closely with the B.C. Ministry of Agriculture and Food, KPU researchers identified the need for an advanced molecular test to detect the *Aeromonas salmonicida* bacteria along with several other *Aeromonas* species. Working with KPU's Applied Genomics Centre on this project was a logical choice as few organizations have the equipment and expertise to undertake this work. Active research to perform genome sequencing began in 2023, when a research grant was obtained from the BC Salmon Restoration and Innovation fund of Fisheries and Oceans Canada.

The genome analysis and test development were undertaken at KPU, however, this work was accompanied by considerable field work. While production of the tests was the primary goal of the research, an important byproduct has been high-quality annotated genomes for several *Aeromonas* that is helping understand these bacteria and their evolution. Lab testing is currently underway, with the goal of making diagnostic tools and genomes available publicly via Fisheries and Oceans.

Funding

The project is wholly funded through the BC Salmon Restoration and Innovation fund, a contribution program funded jointly by the governments of Canada and British Columbia.

Student Engagement

Over the course of this project, four students have been engaged. Benefits to the students include honing of analytical skills and the opportunity to work directly with industry stakeholders. The ability to translate and link the science of genomics to industry business needs is a critical element of developing an innovation-enabled talent pipeline. This practical application has also helped to reinforce the understanding of research techniques and the underlying science. A student participant in the case study interview noted how participation in this project had inspired his decision to pursue graduate studies. He has already contributed to five research articles in production from this research.

Company Benefits

Although not intended for commercial purposes, the results of this research will have a direct and immediate economic impact on Canada's fishing industry by improving its ability to detect pathogens, deploy effective disease-management strategies, improve the health of fish stocks and reduce economic loss due to disease.

Social Benefits

Keeping fish populations healthy and disease-free is extremely important to the industry and the public. Effective testing for harmful pathogens is essential and current testing is not sufficiently accurate or fast to adequately address the risk associated with this bacterium. Food safety, biosecurity and improved management of the health of fish populations are important social benefits of this project.

Case Study 27: Bovine Pathogen Genomics
Principal Investigators: Abhinaya Venkatesan, PhD
Paul Adams, PhD
Project Partner: WestGen

KPU KWANTLEN POLYTECHNIC UNIVERSITY

Project Profile

This research involved the development of a qPCR (quantitative real-time polymerase chain reaction) test for bacterial diseases in dairy cattle, specifically *Mycoplasma bovis* and *Salmonella Dublin*. The goal of this project was to produce tests for these pathogens that are better, faster, and cheaper using qPCR test methods, a diagnostic technology which proved valuable during the COVID pandemic because it is low cost, easy to use and rapidly returns results.

WestGen, a beef and dairy industry group of companies focused on genetics and reproduction, articulated the need for better tests for these diseases. A research plan to produce targeted diagnostic tests was developed in collaboration with the Applied Genomics Centre at KPU. Funding was first received in 2019. Since that time, KPU has worked closely with WestGen and their industry partners (e.g. farmers, veterinarians).

The genome analysis and test development were undertaken at KPU, however, this work was accompanied by considerable field work on dairy farms. As well, while production of the tests was the primary goal of the research, an important byproduct of this project has been the development of improved disease management and testing practices in the industry. The qPCR tests for the *Mycoplasma bovis* and *Salmonella Dublin* pathogens are now in the initial stages of commercialization.

Funding

The project is co-funded by the WestGen Endowment Fund and NSERC.

Student Engagement

One or more students have been involved with this project every year, both in the lab and in the field. As much of the fieldwork has been with the end-user farming community, this experience has been particularly valuable for enabling students to connect scientific research with the needs of industry and understand how solutions will be implemented. Involvement in the Bovine Pathogen Genomics project led two of the students to pursue graduate studies.

Company Benefits

An important partner benefit of this project was the ability to focus on a tangible industry-identified issue. Dairy farmers who provided their farms for testing are already experiencing direct and immediate economic impacts due to the improved ability to detect pathogens and then deploy effective disease management strategies which improve animal health outcomes and reduce economic loss. Commercialization of these tests will expand these benefits to the rest of the Canadian dairy industry. Beyond these benefits, reducing the likelihood and impact of these pathogens also serves to decrease the potential harm to export markets for affected animals and/or their products.

Social Benefits

Keeping cattle healthy and disease-free is extremely important to the public, so effective testing for harmful pathogens is essential. Food safety, biosecurity and improved management of animal health are important social benefits of this project.

Case Study 28: Science to Practice Playing – Transferring the Best of Early Child Development Evidence to Parents Through Integrated Health Equity Teams
Principal Investigator: Jamie Koshyk
Project Partner: Lord Selkirk Park Child Care Centre

Project Profile

The program was targeted in the Lord Selkirk Park housing complex, one of Winnipeg's largest social housing developments. According to the census, it is one of the most impoverished areas in the city. The focus of this program is verbal language skills and literacy, along with growth and development. Unlike many other programs that focus only on the child, this program sought to include parents and to measure the broader impact of a child support strategy on families and communities. This involved three broad outcomes for the parents: strengthening their relationship with their children and the wider community, better understanding their role in their child's development and self-improvement, such as going back to school. Most residents of the housing complex are First Nations, Métis or recent immigrants.

Funding

Funding for this project originated from provincial housing grants and other social programs. SSHRC funding supported analysis of the effects of the program on parents.

Expansion of Program

The success of the program led to its expansion to four other communities.

Student Engagement

Five students were involved in the project. One was in an early childhood education program, three were in a creative communications program and the other was enrolled in the digital media program. The students were central to the knowledge mobilization initiative. Most were involved in the design of the project identity, website design, the creation of promotional materials and the creation of annotated literature reviews.

Social Benefits

The project generated significantly better literacy outcomes among the children than many other support strategies. The project's engagement of parents also contributed to its superior outcomes. There is evidence that the project motivated some parents to undertake self-improvement steps.

Case Study 29: Reading Assistance Software
Principal Investigator: Asma Paracha, PhD
Project Partner: Quillsoft

Seneca POLYTECHNIC

Project Profile

This project enhanced the WordQ software application developed by Quillsoft. The company is a joint venture of its founder and Holland Bloorview Kids' Rehabilitation Hospital. The software assists individuals with reading and writing impairments. These impairments are often a result of conditions such as dyslexia or ADHD. The software uses predictive capacity to assist with writing and text-to-speech to assist with reading comprehension. The product is available on several platforms, including Windows, iOS and Chrome browsers. The partnership with Quillsoft is ongoing.

Funding

The project was co-funded by the company and NSERC. The company covered 50 per cent of the project's costs.

Student Engagement

Throughout the project, it generally employed one full-time or two part-time students from the computer science or software development programs. Four students who worked on the project were subsequently hired by the company on a full-time basis. The company uses its co-op and applied research collaborations to recruit qualified employees.

This collaboration empowered Quillsoft to hire additional staff. Seneca Polytechnic graduates were identified as having the high-level practical skills necessary for these roles.

Intellectual Property

Quillsoft has opted to protect its intellectual property through trade secrets rather than patenting.

Social Benefits

The company's product increases the capability of persons who have challenges with reading or writing, including persons with physical disabilities or recent immigrants with limited English language skills. As such, the product has broad social benefits. The software is widely used in schools throughout North America.

Export Potential

Quillsoft has operations worldwide, with the NISAI Group as a key stakeholder in the company.

Case Study 30: Noise Cancelling Acoustic Technology
Principal Investigator: Todd Parke
Project Partner: ZeroSound

SAIT Southern Alberta Institute of Technology

Project Profile

ZeroSound specializes in digital noise suppression technology, which can reduce noise by up to 92 per cent. Their scalable technology can be applied to large outdoor environments, such as stadiums, and to confined spaces, such as emergency vehicle cabs. The technology has been used in several sectors, including industrial complexes, energy facilities and transportation infrastructure. The project involved modifying their current technology to increase the range of their device.

Funding

Funding for this project came through monies reallocated from a project that proved unsuccessful.

Student Engagement

SAIT has employed a postgraduate to work with ZeroSound full-time for technical support as they implement the new technology.

Business Benefit

The project demonstrated proof of concept through the development of a prototype. This enabled the company to scale up the technology for commercial applications.

Social Benefit

Workplace noise is a significant occupational hazard, primarily due to its impact on hearing health. Prolonged exposure to high noise levels can lead to temporary and permanent hearing loss, particularly when the noise exceeds 85 decibels (akin to heavy city traffic). In addition to hearing loss, constant or high-level noise exposure can result in tinnitus, which manifests as a persistent ringing, buzzing or whistling in the ears, even in the absence of external sound. These auditory issues impair hearing ability and significantly affect quality of life, making it difficult to communicate effectively in personal and professional settings.

Appendix B: ROI Calculations based on the Jones and Summers Model

Jones and Summers developed a model to estimate the returns to R&D. There is a broad consensus in the theoretical literature that improvements in technology are the principal determinant of long-run improvements in living standards. Improvements in living standards are proxied by increases in *per capita* GDP, while investments in technological advancement is proxied by R&D expenditures. It follows, therefore, that if there is no expenditure on R&D for a year, the long-run growth trajectory will be lowered. If R&D investment resumes in the subsequent year, there will be a resumption of long-run growth. However, *per capita* GDP will be permanently lower owing to the one-year interruption in R&D. This is the logical basis for the Jones and Summers model. Their model compares GDP growth with continuous R&D investment with a counter-factual where there is a single-year pause in R&D. The difference is the return that would have accrued had R&D not been paused.

The same logic applies when looking at the costs. Stopping R&D for a year will save on the expenditure that would have otherwise been devoted to R&D. Taking the difference in spending in these two cases will then give the cost of R&D.

The ratio between the benefits and the costs is captured in the following formula:

$$SROI = \frac{g}{rs}$$

The benefits are given by the growth in *per capita* GDP (g) and the costs of R&D (r times s), where s is the share of GDP devoted to R&D and r is the social discount rate, i.e., value society places on money now versus the future. This equation gives us the dollar amount in returns that are generated for every dollar invested in R&D.

We adapt the Jones and Summers model to Canada. The benefits of R&D are the average growth in *per capita* GDP seen in Canada from 2010 to 2019 (1.1 per cent). This is based on World Bank tables.[27] The costs in this application of the model were based on the average share of GDP spent on R&D from 2010 to 2019 (1.7 per cent). This was also drawn from World Bank tables.[28] As described in Section 4.0, we used the social discount rates: 3.5 per cent, 5.75 per cent and 8 per cent. The rationale for these rates was discussed in Section 4.0. Inputting the low social discount rate into the formula along with *per capita* GDP growth and the share of GDP devoted to R&D yields the following:

[27] World Bank, "GDP Per Capita Growth (Annual %)" *World Bank Data*, online: https://data.worldbank.org/indicator/NY.GDP.PCAP.KD.ZG

[28] World Bank, "Research and Development Expenditure (% of GDP) – Canada" *World Bank Data*, https://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS?locations=CA

$$SROI = \frac{1.1\%}{1.7\% * 3.5\%}$$
$$SROI = \frac{0.011}{0.017 * 0.035}$$
$$SROI = \frac{0.011}{0.000595}$$
$$SROI = \$18.49$$

Similar calculations can be made using the higher social discount rates. The results are summarized in Section 4.0.

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130 Albert Street, Suite 608, Ottawa ON K1P 5G4

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