Supporting Applied Research and Early Stage Innovation in a Distributed, Postsecondary Vocational Environment

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Abstract: Federal and provincial governments in Canada have begun in recent years to offer targeted funding programs for applied research and innovation activities in postsecondary vocational institutions. Such activities have previously been the almost exclusive province of universities and government research organizations in Canada. The primary goals of these programs are to generate more highly qualified personal for local industry and to support the unmet applied research needs of small and medium sized enterprises. Canadian vocational institutions have historically been well suited to meet these goals. This paper reports on the design, implementation, and interim results of the Mobile First Technology initiative of New Brunswick Community College, an applied research and education enterprise designed to serve six campuses distributed across a semi-rural province. The design of this enterprise is drawn from several areas of applied research and innovation practice, including agricultural extension services, the evolving global cultures of hacker spaces and maker spaces, and industrial design. This paper provides a survey each of these facets of the enterprise, describes the infrastructure and programs offered, and suggests approaches that are generalizable to other types of postsecondary programs and areas of research.

Keywords: Design, Experimentation, Human Factors, Management

INTRODUCTION

A 2011 report commissioned by Industry Canada, a federal ministry, marks a shift in strategy and policy for research and development (R&D) in Canada (Jenkins, 2011). The recommendations of the report, *Innovation Canada: A Call to Action*, have had a far-reaching impact on the role of postsecondary institutions in Canada. The report recommended, in part, support for "programs that support business-focused R&D through federal granting councils and other departments and agencies, including research performed in universities and colleges that fosters support for business R&D, such as the Centres of Excellence for Commercialization and Research program."

The result has been an evolution of the traditional role of Canadian colleges – as distinct from universities - beyond trades-based training to included applied research and innovation.[1] Publically supported R&D had been the exclusive province of universities and provincial and federal governmental institutions in Canada until recently.

The impetus for the Industry Canada report was a concern that "[s]tudies have repeatedly documented that business innovation in Canada lags behind other highly developed countries." There are two critical performance metrics, among others, that relate specifically to the mission of Canadian colleges:

- The production of highly qualified and skilled personnel (HQP), and
- Commercialization of publically funded R&D.

[1] There is a distinction between the terms "college" and "university" in Canada, where the former refers to institutions for vocational postsecondary training.

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The first metric, HQP, is mandated across most funding and R&D programs in Canada (Government of Canada, 2009). A 2013 Information and Communication Technology Council report indicates that skills shortages and mismatches are a major barrier to Canadian innovation in areas involving or related to computer science education, including mobile information and communication technologies (ICT) (Information and Communication Technology Council, 2013). A study commissioned by New Brunswick Community College (NBCC) suggested that the province would be well-served by a two-year ICT program in mobile application development, the core of which would include cross-platform development, native app development, fundamental ICT concepts, user interface design, security, and business cases based on New Brunswick businesses (MQO Research, 2013).

A number of factors impacting the second metric cited above, commercialization of publically funded R&D, have been identified by recent studies, including the Industry Canada report. The primary factor involving colleges is the need for research capacity within small and medium-sized enterprises (SMEs). Both universities and colleges are seen as critical types of institutions within Canada for providing this missing R&D capacity. Federal and provincial R&D funding has since the 2011 report been earmarked for collaborative R&D activities between postsecondary institutions and SMEs. The particular role for colleges within such funding envelopes is applied research.

The Province of New Brunswick has, in particular, faced challenges in improving its innovation ecosystem.[2] A study commissioned by the Province of New Brunswick, the *Manship Report*, cited the need for improvements in R&D investment, education, and access to capital, among other recommendations (Government of New Brunswick, 2012).

NBCC began strategic development of its applied research and innovation capacity as a result of the policy developments and recommendations cited above. The Government of New Brunswick's mandate for NBCC to become an independent Crown Corporation also spurred this strategic development. NBCC created an Office of Applied Research and Innovation in 2012 and began to identify strategic areas for applied research. A broad, consultative process involving key stakeholders in New Brunswick's ICT ecosystem resulted in mobile ICT being identified as a strategically area for teaching and applied research, among several others.

NBCC created the Mobile First Technology initiative (MFTI) in 2013 as a result of this strategic development process, with primary support from the Natural Sciences and Engineering Research Council of Canada (NSERC). The applied research priorities of MFTI are interoperability, interconnected user experience, and security in the context of mobile ICT. The primary goals of MFTI include the following:

- Enhancing the teaching and learning environment for mobile ICT topics within the College;
- Developing facilities for NBCC students, faculty, and staff to engage in early-stage innovation, including collaboration;
- Engage in applied research with SMEs; and
- Mobilize research and practical knowledge for the benefit of the broader New Brunswick ICT Community.

Section 2 surveys the conceptual models and innovation policy research underlying the pedagogical and research environments that MFTI has been implementing in pursuit of these goals. Section 3 presents the current implementation of MFTI, in particular its Mobile Ideaspace. Section 4 discusses the results of MFTI thus far. Section 5 gives concluding remarks, including future directions within MFTI for research in discipline-based education and pedagogical environments fostering training in applied research for students and innovation.

[2] The term "innovation ecosystem" would appear to be overused, but it remains an apt analogy to the biological concept. See Jackson, D. J. (2011). "What is an innovation ecosystem." Arlington, VA: *National Science Foundation*. http://www.erc-assoc.org/docs/innovation_ecosystem.pdf.

THEORY, POLICY, and MODELS

The overarching design for MFTI derives from a notion of socio-technical innovation (McIver, 2012). Socio-technical innovation can be defined as a form of ingenuity that is simultaneously social and technical: innovation that is intentionally focused on the development of technologies that are designed to assist in the improvement of institutions or social arrangements. This type of innovation integrates – by necessity -- scientific research, experimental development, and the study of the social contexts in which technologies are to be used.

Conceptual models and policy research in the following areas have been drawn upon in the conceptualization of MFTI:

- Agricultural extension services;
- Design and innovation models in communities, industry, and academia;
- Regional and national studies of innovation policy; and
- Examples of knowledge mobilization in skills development.

Supporting innovation means supporting the methods and processes necessary for producing novel and useful technologies. This includes, but is not limited to, scientific and engineering methods, organizational culture, funding policies, and diffusion and dissemination policies.

Most ICT comprise results and artefacts from multiple scientific disciplines, each with their attendant research methods. The scientific disciplines represented in socio-technical innovations include, but are not limited to, computer science, communication theory, human communication, cognitive sciences, and sociology. Research methods and knowledge developed within the cognitive sciences – which include psychology and neuroscience -- have been critical to understanding and improving human interactions with ICT, such as making airplane cockpits safer; understanding how to best support human cognitive processes, such as creating designs that take into account the limits of human memory; and attempts at simulating or augmenting human cognitive processes, such as the creation of decision support technologies for fire control situations that would be too complicated for humans to manage in a timely fashion. Sociological research methods have also been important in helping designers of ICT understand the behaviour of humans at organizational and community levels, such as the conditions under which people co-operate most effectively or how people react in emergencies. Other non-scientific disciplines have also been important in socio-technical innovation. It is often important, for example, to understand the historical context into which an ICT is being introduced.

The linkages between science, technology, scientific methods, and engineering are all supported within what the Organisation for Economic Co-operation and Development (OECD) defines as research and experimental development (R&D) activities: basic research, applied research, and experimental development (OECD, 2002). The OECD describes R&D broadly as comprising "creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications" (OECD, 2002). Basic research is defined as "experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view" (OECD, 2002). Applied research is defined as "original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective" (OECD, 2002). Experimental development is defined as "systematic work, drawing on existing knowledge gained from research and/or practical experience, which is directed to producing new materials, products or devices, to installing new processes, systems and services, or to improving substantially those already produced or installed" (OECD, 2002).

The core disciplines for socio-technical innovation related to MFTI are computer science research and experimental development, as defined by the OECD. Dogig-Crnkovic (2002) has given a detailed and historical characterization of computer science as a scientific discipline. Computer science is "strongly connected to technology" for some of its methods, as are most other scientific disciplines due to its relationship with industry; however, the computer itself "is not the focus of scientific investigation" (Dodig-Crnkovic, 2002). Computer science research methods exist in four categories according to Dogig-Crnkovic: theory, modelling, experimentation, and simulation.

The process of creating a novel or improved technology – our definition of innovation – falls within the area of engineering. Software engineering is the corresponding discipline for computer science, which concerns the design, implementation, and maintenance of software systems. Socio-technical innovation may require other engineering disciplines, especially electrical, computer, mechanical, and civil engineering.

Each scientific method, such as theoretical computer science, involves specific or dominant types of logical reasoning methods that are employed by scientists in their search for answers: *deduction* and *induction* (Dodig-Crnkovic, 2002; Martin, 2009). Theoretical computer science is dominated by deduction, for example. Most scientific methods employ deduction or induction within a *reductionist* framework, where the method involves the examination of parts of a natural phenomenon or technical mechanism as an incremental step in constructing a holistic understanding of the system in which the phenomenon exists or the technical mechanism must operate.

Reductionism has been shown, however, to be insufficient for constructing complex models or constructing hypotheses as a means of positing explanations of complex systems (Dodig-Crnkovic, 2002). It is a tautological point to say that reductionism is also an incomplete approach for the linking of scientific research with the engineering methods required to develop – instead of analyze – complex socio-technical systems.

Pierce (1906) identified a third form of reasoning that has been used to address the shortcomings of reductionism. He called this form of reasoning *abduction.* Pierce showed how abduction is a convergent process used by researchers to draw on collections of scientific facts to construct initial hypotheses about unexplained phenomena. Reductionist approaches can be seen -- in contrast to abduction -- as divergent processes that are complementary to abduction in that they generate the facts that are used in the process of abduction. This relationship between reduction and abduction demonstrates a critical complementarity that exists between basic research and applied research and, transitively, innovation; and it exposes some of the problems in the arguments for one type of research activity over the other.

Abduction has been identified – if not always in name -- as a foundation of best practices in design methods that have come to be called *design thinking* (Brown, 2006; Kelley, 2007; Martin, 2009). Hypothesis construction from collections of facts translates to experimental development in socio-technical innovation, where scientific facts and technical artefacts are leveraged using the engineering methods of design and construction to produce candidate solutions to a given problem. Each candidate solution then becomes a specific hypothesis that posits itself as the suitable socio-technical innovation to solve the problem. Each hypothesis – a design of a socio-technical innovation -- is then subjected to experimental evaluation and comparison to other candidate designs. This process of experimental evaluation is part of what we define as applied research.

The methodological and process aspects of R&D are usually supported within some organizational model. Some see socio-technical innovation as being best supported by governments in what the European Union defines as public research organisations (PROs) (Hyytinen et al., 2009). The Industry Canada report argues the following (Jenkins, 2011):

> The fundamental motivation for government intervention in private sector commercial activity is to improve market outcomes for the betterment of society at large. There are

> conditions under which markets do not allocate resources efficiently, and governments intervene to try to correct or at least diminish 'market failures' — for example, to guard against monopoly, to protect property rights, to provide public goods such as basic research that generate benefits for society at large or to overcome problems of inadequate information.

This is not to suggest that socio-technical innovation cannot be initiated or supported by the market, only that PROs may be more likely than the market to ensure that this type of innovation is initiated. The introduction and use of socio-technical innovations are, however, often made by PROs through market-oriented mechanisms. Another organizational model related to the PRO is that of the Research and Technology Organization (RTO), which is analogous to the PRO model, but is not necessarily public (Clark & Jávorka, 2010).

PROs carry out research and experimental development on behalf of government and the private sector (Hyytinen et al., 2009). PROs often have a special focus on small and medium enterprises (SMEs), which are often seen as lacking the resources and knowledge necessary to leverage the latest technologies. A preliminary survey of the OECD (2002), Finland (Hyytinen et al., 2009), the European Association of Research and Technology Organisations (EARTO) (Clark & Jávorka, 2010), and the Government of Canada (Jenkins, 2011) shows a common set of services offered by most PROs and RTOs to external clients in support of innovation. External clients include governmental, public, and private sector entities. The common set of services includes basic research, applied research, extension services, infrastructure, diffusion, and dissemination. Extension services include a range of activities by which scientific and technological expertise is shared by the PRO with external clients, such as training and consulting on domain-specific and leading edge technologies. Infrastructure services include the management of capital-intensive research facilities for use by external clients who would otherwise not have access to them. Diffusion and dissemination represent a range of services designed to make innovation available outside the PRO, including publication of scientific papers, sharing of experimental data, distribution of software, or the licensing of intellectual property. These PRO services may be offered in revenue-generating, cost-recovery, or non-cost-recovery scenarios.

The knowledge transfer dimension and some aspects of the applied research functions of MFTI resemble classic agricultural extension services. These are institutions that evolved around the world as ways of synthesizing and transferring knowledge of best practices to farmers, contextualized to the region in which they operate. Most extension services arguably represent socio-technical innovation models and many of these have been based in post secondary institutions in North America (Swanson, 1997; Swanson, 2008; Swanson & Samy, 2002). IBM's alphaWorks Community offered examples of how an organization can transfer ICT-based knowledge to communities and SMEs in a manner akin to agricultural extension services. IBM alphaWorks provided open access to white papers and software source code downloads that helped developers get a head start in using cutting edge technologies for developing Web services software. This approach helped to catalyse new areas of innovation, such as semantic web and social networking technologies (Capek, 2005).

Community-based innovation models have evolved around the world over the past few decades in forms now called *hacker spaces* and *maker spaces* (McIver, 2012). A general do it yourself (DIY) culture has also evolved that cuts across and extends beyond these two models (Anderson, 2011). Hacker spaces are oriented toward software development. Maker spaces are oriented toward projects of a physical nature, including electronics, mechatronics, mechanical innovations, or artistic objects. Many hacker spaces and maker spaces make use of and produce free or open source software and open source hardware as matters of principle, affordability, and practicality. Hacker spaces, maker spaces, and DIY movements are all integrally linked and co-evolutionary. Many innovations in these environments involve the creation of artifacts that have both software and hardware aspects. Resources now common in hacker spaces and maker spaces are data network infrastructure, 3D printers, computer

numerical control machines, laser cutters, inventories of electronic and mechanical components, and inventories of materials. New low cost and free and open technologies coupled with interpersonal and online social networking are allowing people to innovate at levels that were accessible only to major corporations a decade ago. This is now evolving into micro-manufacturing, where DIY designers are now able to manage fabrication themselves or in concert with other DIY enterprises; and into the creation of DIY scientific research labs (Anderson, 2011; King, 2012).

Community-based innovation spaces have evolved around the world to help people who have novel ideas and little capital to innovate. Members of such organizations are often students or are recent graduates who need space and collaborative relationships to fully develop their ideas. Innovation spaces create environments that are ideal for collaboration and innovation, which can also benefit the broader communities in which they operate. Some innovation spaces are focused on specific domains, such as information technology, art and fine craft, community-based enterprise development, or business model innovation. Most innovation spaces offer a membership process; computer and network infrastructure; hot desk leasing; common collaboration areas; public event facilities for revenue generation; and programs that help members develop their ideas and business models. Requirements for an innovation space include open floors for reconfigurable desk space and conference rooms; workshops for prototyping; and event spaces to facilitate demonstrations for the public, investors, and the press. Many innovation spaces have been successful at fostering socially and economically beneficial enterprise development (McIver, 2012).

Academic entities have implemented models of applied research and innovation that relevant to both skills development for students and for collaborative R&D with SMEs. The curriculum of Olin College has been noted for its basis in project-oriented engineering curricula that emphasize collaboration and multi-disciplinarity (Somerville, 2005). Some academic entities have integrated hacker space or maker space models with initiatives for start-up incubation and acceleration, or for design-oriented academic research. Ryerson's Digital Media Zone (DMZ) is a faculty-directed incubator designed to help the university's students and alumni launch technology-oriented businesses through stage-gated and market-driven processes (McIver, 2012). The ThingTank Lab is a combined hacker space and maker space aligned more with academic research than commercialization (McIver, 2012). The Faculty of Information and the Knowledge Media Design Institute at the University of Toronto started the ThingTank Lab to support idea generation, research, and technology development, with an initial exploration of the so-called Internet of Things (Ashton, 2009). The MIT Media Lab offers yet another distinct academic model for research and innovation. The Media Lab is a prominent example of industry-supported research that is interdisciplinary, exploratory, and combines basic and applied research. The Media Lab offers some independence between researchers and their industrial supporters, however, with research results being shared in specified stages according to levels of support (Timmer, 2010).

IMPLEMENTATION

The conception, design, and evolution of the New Brunswick Community College's Mobile First Technology initiative (MFTI) draws in various ways on the theories, policy, and conceptual models surveyed above. New Brunswick has a developing innovation ecosystem, represented in **Figure 1**, with a collection of entities that offer innovators some combination of (1) capital or infrastructure and (2) support geared toward the maturity of their endeavour. This model is achieving success as evidenced by the acquisition of New Brunswick start-ups Radian6 and Q1 Labs by Salesforce and IBM, respectively, between 2011 and 2013 for over $1 billion. NBCC designed MFTI to occupy a specific site that complements existing programs and entities: early-stage innovation for postsecondary students, faculty, and staff.

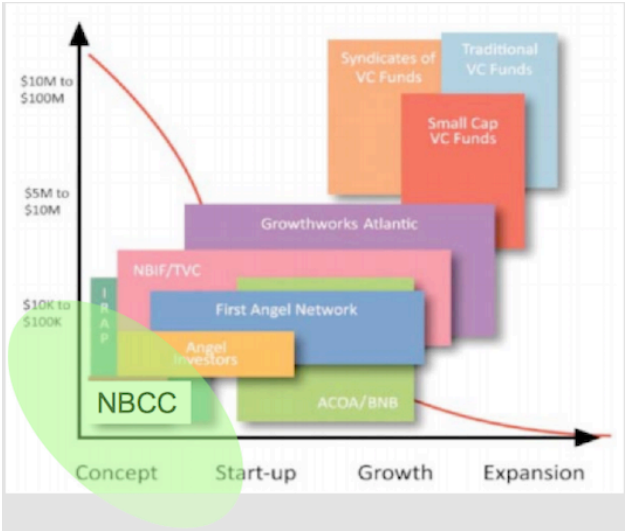

Figure 1. NBCC's position in the New Brunswick Innovation Ecosystem.

The MFTI was launched in this space with the goals of helping New Brunswick companies develop the following through applied research and enhancing NBCC's teaching and learning environment:

- Producing products and services for mobile platforms; and
- Developing highly qualified personnel (HQP) to help New Brunswick companies and individuals capture the market upside in mobile ICT has been paramount for NBCC.

The applied research priority areas of the initiative are interoperability, interconnected user experience, and security on mobile ICT platforms.

The MFTI has in its first two years given priority to enhancement of innovation capacity at NBCC to achieve these goals. A dual development strategy for MFTI has been adopted:

- *Inception phase*: Build a core of applied research capacity; and initiate applied research activities in collaboration with its NSERC IRCC partners, focusing on MFTI's priority areas.
- *Sustainability phase*: Develop additional opportunities and resources for students and faculty to enhance their applied research skills; carry out applied research and innovation activities in collaboration with SMEs; and refine the MFTI Process of Innovation.

A key dimension of the MFTI's efforts in innovation enhancement has been the development of the *Mobile Ideaspace*, a physical and virtual facility spanning all six NBCC campuses, which are distributed across the Province of New Brunswick.

Figure 2. New Brunswick Community College sites.

The Mobile Ideaspace is designed to support applied research and early-stage innovation by NBCC students, alumni, faculty, and staff, as well as industrial partners of the College. The Mobile Ideaspace offers the following:

- Software, hardware, and educational resources for mobile ICT development;
- Physical hacker spaces and on-line collaboration tools that enable expertise across all six NBCC campuses and 90 academic programs to be leveraged in pursuit of applied research and innovation;
- No barriers to entry and no time constraints for exploration and experimentation; and
- Resources and training in processes of innovation.

The wide geographic coverage of the Mobile Ideaspace allows NBCC to engage stakeholders and to provide opportunities for innovation in many New Brunswick communities.

Another key dimension of the MFTI's efforts in innovation is its *Prototype Discovery* program (PDP). PDP is a crosscutting effort with respect to most applied research projects and project requests that MFTI receives. The PDP will support development of advanced mobile ICT prototypes in the following two modes:

- *Convergent innovation activities*, focused on implementing a solution to a defined problem, through the selective convergence of any number of existing component technologies; and
- *Divergent innovation activities*, involving the generation of or experimentation with individual component technologies to identify novel applications or novel technology domains.

Figure 3. The Mobile Ideaspace

The development of and experimentation with prototypes has been a critical part of MFTI applied research activities with industrial partners. Prototype develop will have an expanded role as current projects progress and as the MFTI project portfolio expands. The Mobile First Technology initiative (MFTI) at New Brunswick Community College (NBCC) has developed a growing portfolio of applied research and innovation project requests from the New Brunswick business community and within NBCC, which are addressed within the PDP.

Many of the projects in this portfolio have commercial potential and are ideal platforms for entrepreneurship by NBCC students, alumni, faculty, and staff. These project requests include (but are not limited to) mobile app development across many domains, implementation of Internet of Things and machine-to-machine systems to assist senior citizens, and the development of constituent technologies to be used within other mobile ICT systems.

The *MFTI Process of Innovation (PoI)*, an applied research and design thinking methodology developed the author, is employed in the PDP. The PoI is a synthesis of industrial methods, such as (Kelley, 2007; IDEO.org, 2015), intended to help NBCC evolve ideas into mature product or service prototypes suitable for later stage acceleration or incubation processes within New Brunswick's innovation ecosystem. The PoI integrates two areas methodological areas:

- Iterative, user-centred project management methods drawn from Agile software engineering approaches; and
- Idea generation and refinement techniques drawn from industrial *design thinking* literature and practice.

The PoI is represented in **Figure 4**. The objective of the PoI is to produce candidate solutions and working prototypes iteratively and continuously throughout a project with stakeholder involvement to learn requirements, elicit feedback, and to identify problems earlier. MFTI will support PoI activities during the initiative proposed here in its Mobile Ideaspace.

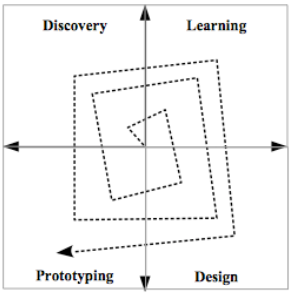

Figure 4. Mobile First Technology initiative Process of Innovation

RESULTS

MFTI has engaged in a number of activities to enhance applied research capacity at NBCC since May 2013. These include the following:

- The establishment of an intake process for research requests from external organizations;
- The establishment of memberships in key academic mobile developer programs, including Apple's University Developer Program, Blackberry Academic Program, IBM Academic Initiative, and CANARIE Digital Accelerator for Innovation and Research (DAIR) cloud services program;
- The launch of the *NBCC Mobile Ideaspace* on six campuses;
- Provided support for part-time secondments for two senior NBCC information technology faculty members each year to assist in applied research, project management, and development of HQP; and,
- The development of HQP by providing applied research and development assistantships for nearly 20 NBCC students and alumni in the form of research assistantships, and two international student internships; and hosted several NBCC students for their practicum requirement.

MFTI has engaged in a number of applied research and technology transfer projects in collaboration with and to the benefit of New Brunswick companies. These include the following:

- Development of Position Identification and Geo-fencing Technologies, with an industrial partner;
- Study and development of software engineering methods geared specifically to mobile software development with an industrial partner;
- Development a mobile app as part of a project to encourage the reduction of greenhouse gas emissions by New Brunswick households, in collaboration with the Province of New Brunswick and the Government of Canada;
- The launch of a project for multichannel content and analytics platform with industrial partners, through the support of the Government of New Brunswick;
- The launch of a project to study and prototype mobile technologies for institutional wellness within NBCC; and
- The development of an assistive hardware device for which a patent application is being prepared.

MFTI has engaged in a number of other knowledge transfer and educational activities as part of its mandate. These include the following:

- The organization of a multi-stakeholder partnership workshop;
- The organization of a public, hands-on mechatronics workshop and student exposition, in collaboration with several New Brunswick SMEs and NBCC Engineering Technology faculty members;
- The development of a mobile app development tutorial across three platforms to contribute to the development of HQP and to bootstrap early-stage innovation at NBCC and in the broader ICT community in New Brunswick;
- Initiating the development of a mobile ICT curriculum, including a survey of postsecondary mobile technology curricula;
- Publishing a public annual report, featuring a survey recent issues and developments in selected aspects of mobile information and communication technologies, with emphasis on MFTI's research priorities (IDEO.org, 2015).

CONCLUSIONS

MFTI has shown the potential to enhance innovation, the production of HQP, and economic development in New Brunswick drawing on the theoretical, policy, and methodological perspectives presented above. The initiative is beginning to contribute to the development of HQP in applied research through research assistantships and faculty secondments, which are vital for increasing productivity in New Brunswick's burgeoning mobile ICT sector. The initiative has also shown the potential to produce commercially viable innovations that could be catalysts for start-ups, including student-initiated enterprises, or licensed to existing companies (McIver, 2014; McIver, 2015).

MFTI is now aggressively pursuing the following outcomes during its second phase:

- Economically viable solutions to socially significant use cases in New Brunswick, such as those impacting senior citizens;
- Refinement of the MFTI Process of Innovation for use within NBCC;
- Developing expanded applied research opportunities for NBCC;
- Developing follow-on opportunities for commercialization by industrial partners and other New Brunswick SMEs;
- Enhancement of NBCC's teaching and learning environment;
- Development of increased numbers of HQP;
- Development of increased numbers of post-graduate entrepreneurial and employment opportunities for NBCC alumni;
- Development of entrepreneurial opportunities for faculty; and
- Preparation of NBCC to engage in a more extensive innovation enhancement initiatives benefitting the College's other applied research areas of focus.

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