Linking Education and Research

A Strategy for Introducing and Sustaining Multi-Disciplinary Academic Programs

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***Abstract*—Most engineering careers will require engineers to work in multi-disciplinary teams. It is necessary for post-secondary institutions to provide opportunities for engineering students to work in multi-disciplinary teams during their education so that they can function and thrive in these environments upon graduation. One model for introducing and sustaining multi-disciplinary engineering education has been to link a number of the British Columbia Institute of Technology's (BCIT) engineering and technology capstone projects with the hub of multi-disciplinary researchers at the BCIT Technology Centre.**

Keywords- linking education and research; multi-disciplinary teams; sustainable programming

I. INTRODUCTION

Project-based learning has been used in a variety of ways to teach engineering students about working in multidisciplinary teams, ranging from combining engineering and the arts to working directly with industry [1, 2]. Project-based learning is a proven method for providing engineering students conducting capstone projects with the opportunity to learn in a multidisciplinary setting [3, 4, 5].

Project-based learning in multidisciplinary teams has now become a required outcome for engineering education in the United States; the Accreditation Board for Engineering and Technology in the U.S. now requires that student outcomes for engineering programs include the ability to function on multidisciplinary teams [6]. Also, at the Canadian National Engineering Summit in Montreal in 2009 there was a declaration by Canada's engineering profession to 1) pursue greater collaboration across disciplines and professions and 2) transform engineering education and practice. Clearly the engineering profession agrees that both project-based learning and working in multi-disciplinary teams is beneficial to engineering students and necessary for them to develop the ability to function effectively in the current work environment.

There are many wide-ranging examples of how student capstone projects have been conducted. In this paper, we present several case studies that have utilized capstone projects to provide students with the opportunity to solve engineering problems while drawing support from a multidisciplinary research group. The project case studies provide examples of how students can work directly with industry clients in a supportive setting. This paper also focuses on outlining a sustainable approach to providing students with an opportunity to work with a multi-disciplinary research group to help them be able to function on multi-disciplinary teams upon graduation. The benefits and challenges of providing faculty, students and industry with a supportive setting for conducting problem-based capstone projects are also discussed.

II. EDUCATIONAL AND RESEARCH GROUPS AT BCIT

A. Educational Engineering and Technology Programs

The British Columbia Institute of Technology (BCIT) in Vancouver, Canada offers Bachelor of Engineering degrees including Electrical Engineering and Mechanical Engineering. These four-year applied degrees enable a new generation of engineers to be industry practitioners and contributors to society, on the job, from day one. BCIT also offers two-year Technology diplomas in a wide range of areas including Biomedical Engineering Technology and Mechanical Engineering Technology. These engineering and technology programs span a number of different schools at BCIT including the School of Health Sciences and the School of Manufacturing, Electronics and Industrial Processes.

In both engineering degree and technology diploma programs students have a capstone project in their final year or term that is characterized by being industry sponsored and enables the students to bring their skills, knowledge and capabilities to solve a real world problem through technology development.

B. Multi-disciplinary Research Centre

BCIT also conducts applied research to enhance the learner experience and advance the state-of-practice. The BCIT Technology Centre (http://www.bcit.ca/appliedresearch/part) is a hub of multi-disciplinary research and development at BCIT. It was started twenty years ago when BCIT was given a mandate by the Province of BC to conduct applied research. It started with a small number of researchers in information technology and health technology. The health technology group grew from 3 engineers in 1996 to 15 multi-disciplinary researchers in 2010. See Table 1 for a listing of the professions and disciplines represented.

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TABLE I. MULIT-DISCIPLINARY RESEARCH TEAM

# of Researcher	Multi-disciplinary research team	
	Profession	***Discipline***
3	Engineer	Biomedical
1	Industrial Designer	
1	Prosthetist/Orthotist	
1	Gerontologist	
1	Biomechanist	
7	Technologist	Robotics, automation, plastics, electronics, mechanical
2	Trades	Machinist, Electrician

Some researchers have more than one profession.

The group was deliberately grown to include a wide variety of professions and disciplines to be able to work together to develop solutions to complex problems for its clients. This group of researchers provide applied research services to companies, inventors, entrepreneurs and other academic institutions. They develop, validate and commercialize medical, industrial and consumer products and processes, and perform contract services to research and develop proof of concept prototypes.

A subset of the research group that works on health technology runs under both ISO 9001 and ISO 13485 quality management systems (QMS). This characteristic of the research group distinguishes them from most post-secondary research groups and ensures they work in a way that serves their industry clients. Students working with researchers that work under an ISO certified QMS get first hand experience with quality systems before they graduate. The QMS lays out how we conduct research projects and puts considerable emphasis on the development of project requirements before the project team moves into the conceptual design phase. This characteristic helps students understand their job is to first fully understand the project requirements before starting to design.

The Technology Centre researchers do not have any mandatory teaching loads and operate under a 60% cost recovery model. However many of the researchers have taught courses in a variety of programs at BCIT. The Technology Centre is a sustainable source of multi-disciplinary researchers at BCIT.

III. MODEL FOR LINKING BCIT EDUCATIONAL ENGINEERING AND TECHNOLOGY PROGRAMS AND THE TECHNOLOGY CENTRE

At the time of this writing the educational programs at BCIT and the BCIT Technology Centre do not have any formal affiliation other than they are both part of BCIT and both report to the same Vice President responsible for Education, Research, and International. However over the last 3 years groups within the Technology Centre have been given Key Performance Indicators that have included supporting students. In addition BCIT has recently released its 5 year strategic plan for 2009 – 2014 and has a mandate to offer experiential and contextual teaching and learning with the interdisciplinary experiences that model the evolving work environment.

The educational and research groups have self-organized in a way that supports capstone projects in a multi-disciplinary research team environment. Faculty members from the educational programs have contacted researchers in the Technology Centre to support their students with their industry sponsored project needs. Fig. 1 demonstrates the generalized model.

The support that is provided depends on the project needs. For example students from the Biomedical Engineering Technology program were able to access support from Technology Centre researchers with plastics, industrial design and electronics backgrounds. The student is part of a multi-disciplinary team and gets experience working with people from other disciplines. The project outcome is more complete as well as many projects are about developing new products to solve complex problems requiring a multi-disciplinary approach. The responsibility for the capstone project remains with the educational faculty.

This activity has been growing as researchers from the Technology Centre have made enquires to teaching faculty regarding potential student projects and faculty have made enquires regarding support the Technology Centre can provide to the students. Table II lists several students from 4 technology diploma programs that have been or are currently being supported by researchers from the Technology Centre in this way.

The Technology Centre is also currently working with the Electrical Engineering program to develop a program of support for the 4th year electrical engineering capstone projects that are due to begin in September 2010.

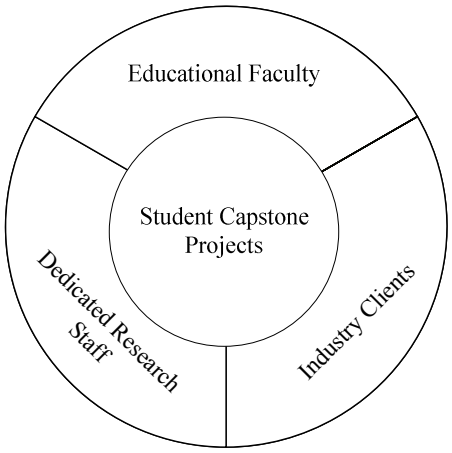

Figure 1. Model for linking education and research to support industry sponsored student projects

TABLE II. EDUCATIONAL PROGRAMS AND EXTERNAL CLIENTS THAT THE TECHNOLOGY CENTRE IS SUPPORTING

# of Programs	Educational Program and External Client	
	Educational Program	***Client***
1	Biomedical Engineering Technology Diploma	ALS Society of BC
2	Prosthetics and Orthotics Diploma	OrthoCare Innovations
3	Mechanical Engineering Technology Diploma – Design Option	Science World, Hawk Forest Holdings, Peak Interiors
4	Mechatronics and Robotics Diploma	Rostrum Medical

The focus is on supporting the student and the responsibility for the student and their capstone project remains with his or her faculty member. The source of the project for the capstone design course is industry and in some cases the project has come directly from a client of the Technology Centre. In these cases the research staff and their clients may benefit from the solutions developed by the students.

IV. CASE STUDIES

A. ALS Society of BC Engineering Design Competition

Amyotrophic Lateral Sclerosis (ALS) is a debilitating neurodegenerative disease that is characterized by the degradation of motor neurons. The "Excellence in Engineering Design Competition to Improve Quality of Life of People Living with ALS" was organized and sponsored by the ALS Society of BC. The awards were established to encourage and recognize innovation in technology to substantially improve the quality of life of people living with ALS. Students at the undergraduate or graduate level in engineering or a related discipline at a post-secondary institution in British Columbia or elsewhere in Canada were eligible for the Awards.

In 2008 the Biomedical Engineering Technology Program approached the Technology Centre to seek support for the ALS Society of BC sponsored capstone project. The students worked with a range of multi-disciplinary researchers and achieved award winning designs that will substantially improve the quality of life for people living with ALS. Biomedical students collaborated with researchers in industrial design, plastics, electronics, robotics and automation.

Projects outcomes were better able to serve the client and students had an opportunity to work with people from other disciplines in a structured project management environment. An Automated Communication Board, developed by two Biomedical Engineering Technology students won the ALS Innovation Award. The Automated Communication Board provides a means for an ALS patient to communicate 30 messages by voice using a single switch only. The messages can be easily changed and in case of loss of battery power the communication board can be used manually.

B. Prosthetics and Orthotics Diploma Project – OrthoCare Innovations

A student in the School of Health Sciences Prosthetics and Orthotics program invented a magnetic prosthetic liner that fits the residual limb of amputees as part of his 4th term capstone project. The student took his idea to the BCIT Technology Centre where he was mentored to follow their ISO certified product development process that resulted in a proof of concept prototype. After verifying the performance of the prototype using stress testing equipment from the BCIT School of Manufacturing, Electronics and Industrial Processes, the student was able to further develop his idea into a pre-commercial product.

Once connected with the Technology Centre, the student was introduced to OrthoCare Innovations, a leading American prosthetics and orthotics company. The company instantly recognized the student's idea had potential, and invited him to join their team. The student signed a contract with OrthoCare to develop his idea further and is currently testing another prototype model.

C. Mechanical Design Diploma Project – Science World, Hawk Forest Holdings, Peak Interiors, Inc. and Mechatronics Diploma Project – Rostrum

In January 2010, four groups of students have begun work on their 4th term capstone projects working with the Technology Centre researchers and their clients. In this case study the projects' industrial clients come from the Technology Centre itself. Each group of students will have an opportunity to work with Technology Centre researchers on projects for Technology Centre clients. The main focus of the project will continue to be a learning experience for the students however the Technology Centre researchers and their clients may benefit from student project outcomes.

Science World has contracted the BCIT Technology Centre to develop an automated film reel exchanger to reduce the risk of musculoskeletal injury to the film technicians. Hawk Forest Holdings has contracted the BCIT Technology Centre to improve the reliability of its Hawk Scalper, a tool that is used in removing brush from the forest. Peak Interiors put forward a student project to assist with the design of an inexpensive height adjustable table for people with disabilities. Lastly Rostrum has contracted the BCIT Technology Centre to develop a proprietary medical device. BCIT students from the Mechanical Design diploma and/or Mechatronics Diploma will be working on the projects for their capstone project. For the contracted projects the BCIT Technology Centre researchers remain responsible for meeting the contract deliverables and will conduct project activities independently of the students.

D. Electrical Engineering Capstone Project

In 2009 the Electrical Engineering Degree Program approached the Technology Centre to seek support for the capstone project beginning in September 2010 with the first graduating class from this program. Table III lists the support requested from the Technology Centre for the capstone project students.

TABLE III. SUPPORT FOR CAPSTONE PROJECT FOR ELECTRICAL ENGINEERING STUDENTS

	Type of Support Requested
1	Identification and scoping of project
2	Facilitation of student – industry liaison
3	Collaboration with multi-disciplinary team
4	Assistance in project mentorship
5	Assistance in instruction and guidance on project management

V. DISCUSSION

A. Benefits to Students

Engineering degree and diploma students are working with multi-disciplinary researchers on product development projects for industry in their capstone projects. This hands-on experience prepares them to deal with the issues that can arise when working in multi-disciplinary teams and exposes them to the different expertise different disciplines and professions bring to the product development process. In the United States an engineering graduate must demonstrate "an ability to function on a multi-disciplinary team" and Canada may be moving in the same direction. This experience will help students gain this skill.

B. Benefits to Faculty

Engineering degree and diploma faculty are benefiting from a stable and sustainable source of multi-disciplinary teams of research staff to support their students. The support provided is on a project by project basis and is based on the needs of each student project. Faculty remain in control of the capstone project and only access the support that is needed which varies from student to student, project to project and program to program. In some cases the Technology Centre also provides viable industry sponsored student projects from its own client base which can be beneficial to faculty as well.

C. Benefits to Technology Centre Researchers and Industry Clients

The focus of the capstone project must remain on the learning experience for the student. However as can be seen from the case studies the potential for innovative and useful solutions to come from BCIT students is high. As such Technology Centre researchers and their clients have the potential to benefit from the solutions the students come up with. The Technology Centre researchers also benefit from working with energetic students with new ideas.

D. Sustainability

This model is sustainable as the Technology Centre conducts applied research projects year round and acts as an anchor resource for the capstone projects. The Technology Centre has been in existence for 20 years and has been able to sustain a level of activity to fulfill it's Key Performance Indicators over this time.

E. Challenges

The biggest challenge for expansion of the model of collaboration between engineering and technology educational programs and the Technology Centre on capstone project support will be the demand for support by a growing number of programs and/or students. As such the Technology Centre is looking for external sources of funding to support and expand the program and has identified a potential source of funding from Canada's National Science and Engineering Research Council titled The Collaborative Research and Training Experience (CREATE) Program. If successful the funding would enable new funding for both the students undertaking their capstone projects and for formal development of the training program structure.

VI. CONCLUSIONS AND FUTURE WORK

A self organizing mutually beneficial relationship has formed between a number of engineering and technology programs and the Technology Centre at BCIT for the purpose of supporting 4th term and 4th year capstone projects. By linking education and research at BCIT a sustainable multi-disciplinary capstone project experience has been created for a variety of engineering and technology students at BCIT. Future work remains to explore the potential benefits of formalization of this relationship and to seek sources of funding to continue the support of capstone projects and to expand the support to more programs and students.

ACKNOWLEDGMENTS

The author would like to acknowledge BCIT faculty member, Mr. Bruno Jaggi, for his support of the research conducted in the BCIT Technology Centre and his foresight in utilizing this resource to create a richer learning experience for his Biomedical Engineering Technology students. The author would also like to acknowledge Mr. Ryan Kanigan for his assistance producing Figure 1 and editing the paper.

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Linking Education and Research - A Strategy for Introducing and Sustaining Multi-Disciplinary Academic Programs

By Nancy Paris, MASc, PEng

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Introduction

- In North America the engineering profession agrees that both project-based learning and working in multi-disciplinary teams is beneficial to engineering students and necessary for them to develop the ability to function effectively in the current work environment.

- This presentation describes a model for linking research and education to provide an opportunity for students to work in a multidisciplinary team.

Introduction

- The British Columbia Institute of Technology is located in Vancouver, BC, Canada.
- It has a variety of Schools providing engineering and technology programs including Health Sciences, Manufacturing, Electronics and Industrial Processes.

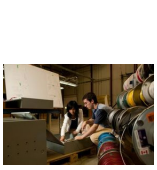
Engineering and Technology Programs

- The British Columbia Institute of Technology (BCIT) offers Bachelor of Engineering degrees including Electrical Engineering and Mechanical Engineering.
- These four-year applied degrees enable a new generation of engineers to be industry practitioners and contributors to society, on the job, from day one.

Engineering and Technology Programs

- BCIT also offers two-year Technology diplomas in a wide range of areas including Biomedical Engineering Technology and Mechanical Engineering Technology.

- These engineering and technology programs span a number of different schools including the School of Health Sciences and the School of Manufacturing, Electronics and Industrial Processes.



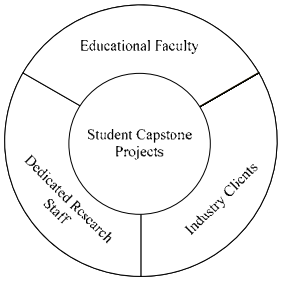

Multi-Disciplinary Research Centre

- BCIT conducts applied research to enhance the learner experience and advance the state-of-practice. The BCIT Technology Centre (http://www.bcit.ca/appliedresearch/part) is a hub of multi-disciplinary research and development at BCIT.


Product and Process Applied Research Team

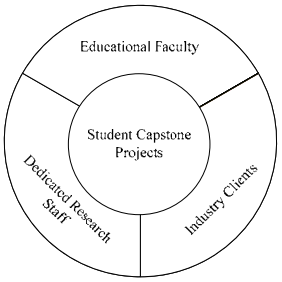
Model for Linking Education and Research at BCIT

- The educational and research groups have self-organized in a way that supports capstone projects in a multi-disciplinary research team environment.
- Faculty members from the educational programs have contacted researchers in the Technology Centre to support their students with their industry sponsored project needs. Fig. 1 demonstrates the generalized model.



Model for Linking Education and Research at BCIT

- The support that is provided depends on the project needs. For example students from the Biomedical Engineering Technology program were able to access support from Technology Centre researchers with plastics, industrial design and electronics backgrounds.
- The student is part of a multi-disciplinary team and gets experience working with people from other disciplines. The responsibility for the capstone project remains with the educational faculty.



Case Studies

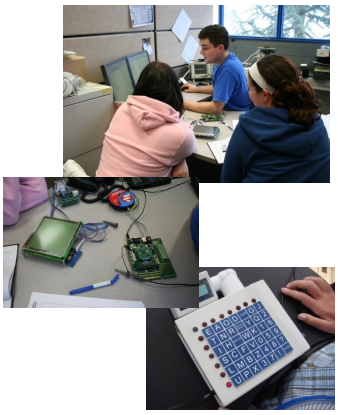
- Biomedical Engineering Technology Diploma - ALS Society of BC Engineering Design Competition
- Prosthetics and Orthotics Diploma Project – OrthoCare Innovations
- Mechanical Design Diploma Project – Science World, Hawk Forest Holdings, Peak Interiors, Inc.
- Mechatronics Diploma Project – Rostrum
- Electrical Engineering Capstone Project

ALS Society of BC Engineering Design Competition

- Amyotrophic Lateral Sclerosis (ALS) is a debilitating neurodegenerative disease that is characterized by the degradation of motor neurons.
- The "Excellence in Engineering Design Competition to Improve Quality of Life of People Living with ALS" was organized and sponsored by the ALS Society of BC, Canada.
- The awards were established to encourage and recognize innovation in technology to substantially improve the quality of life of people living with ALS.

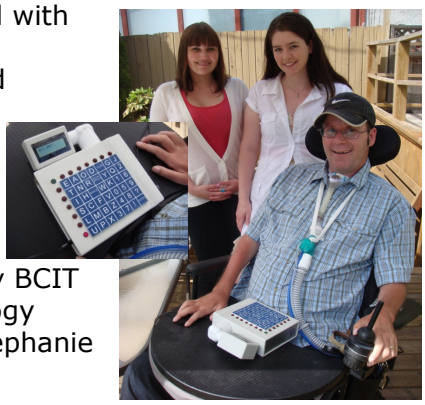
ALS Society of BC Engineering Design Competition

- In 2008 the Biomedical Engineering Technology Program approached the Technology Centre to seek support for the capstone project.
- The students worked with a range of multi-disciplinary researchers and achieved award winning designs that will substantially improve the quality of life for people living with ALS.



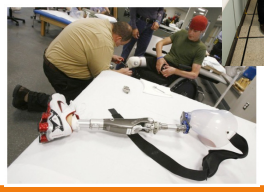
ALS Society of BC Engineering Design Competition

- Biomedical students collaborated with researchers in industrial design, plastics, electronics, robotics and automation.
- Mr. Les Hart, a person living with ALS, tested the Single Click Communication Device. This device was designed and built by BCIT Biomedical Engineering Technology students, Jennifer LeRoy and Stephanie Nelson.



P&O Diploma Project – OthroCare Innovations

- A student in the School of Health Sciences Prosthetics and Orthotics program invented a magnetic prosthetic liner that fits the residual limb of amputees as part of his 4th term capstone project.
- The student took his idea to the BCIT Technology Centre where he was mentored to follow their ISO certified product development process that resulted in a proof of concept prototype.



P&O Diploma Project – OthroCare Innovations

- After verifying the performance of the prototype using stress testing equipment from the BCIT School of Manufacturing, Electronics and Industrial Processes, the student was able to further develop his idea into a pre-commercial product.

- Once connected with the Technology Centre, the student was introduced to OrthoCare Innovations, a leading American prosthetics and orthotics company.

- The company instantly recognized the student's idea had potential, and invited him to join their team.

Mechanical Design Diploma Projects

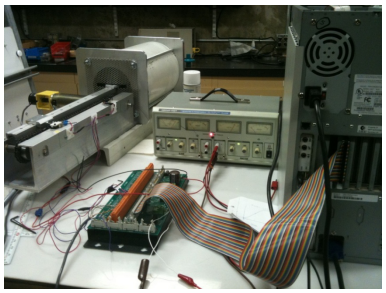
- In January 2010, four groups of students have begun work on their 4th term capstone projects working with the Technology Centre researchers and their clients.

- In this case study the projects' industrial clients come from the Technology Centre itself.

- Peak Interiors, Inc. provided a project for the design of a height adjustable table for persons with disabilities.

Mechatronics Diploma Project

- Students from the Mechatronics Diploma Program worked on the development of a test gig for a Technology Centre client that is developing a medical device to test lung function.
- The students worked with the device development team which includes a variety of people with different research backgrounds.
- The responsibility for the students remained with the faculty member.



Electrical Engineering Capstone Project

- In 2009 the Electrical Engineering Degree Program approached the Technology Centre to seek support for the capstone project beginning in September 2010 with the first graduating class from this program.

The type of support requested included:

- Identification and scoping of project
- Facilitation of student – industry liaison
- Collaboration with multi-disciplinary team
- Assistance in project mentorship
- Assistance in instruction and guidance on project management

Benefits to Students

- Engineering degree and diploma students are working with multi-disciplinary researchers on product development projects for industry in their capstone projects.
- This hands-on experience prepares them to deal with the issues that can arise when working in multi-disciplinary teams and exposes them to the different expertise different disciplines and professions bring to the product development process.
- In the United States an engineering graduate must demonstrate "an ability to function on a multi-disciplinary team" and Canada may be moving in the same direction. This experience will help students gain this skill.

Benefits to Faculty

- Engineering degree and diploma faculty are benefiting from a stable and sustainable source of multi-disciplinary teams of research staff to support their students.
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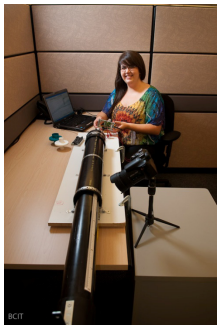
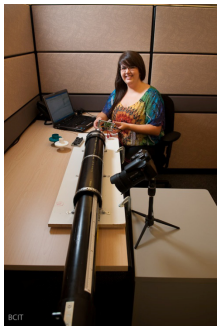


Benefits to Faculty

- Faculty remain in control of the capstone project and only access the support that is needed which varies from student to student, project to project and program to program.
- In some cases the Technology Centre also provides viable industry sponsored student projects from its own client base which can be beneficial to faculty as well.



Benefits to Technology Centre Researchers and Industry Clients

- The focus of the capstone project must remain on the learning experience for the student.
- However as can be seen from the case studies the potential for innovative and useful solutions to come from BCIT students is high.

- As such Technology Centre researchers and their clients have the potential to benefit from the solutions the students come up with.

- The Technology Centre researchers also benefit from working with energetic students with new ideas.

Sustainability

- This model is sustainable as the Technology Centre conducts applied research projects year round and acts as an anchor resource for the capstone projects.
- The Technology Centre has been in existence for 20 years and has been able to sustain a level of activity to fulfill it's Key Performance Indicators over this time.

Challenges

- The biggest challenge for expansion of the model of collaboration for capstone projects will be the demand for support by a growing number of programs.
- As such the Technology Centre is looking for external sources of funding to support and expand the program and has identified a potential source of funding from Canada's National Science and Engineering Research Council titled The Collaborative Research and Training Experience (CREATE) Program.

Challenges

- If successful the Collaborative Research and Training Experience Program funding would enable new funding for both the students undertaking their capstone projects and for formal development of the training program structure.

Conclusions and Future Work

- A self organizing mutually beneficial relationship has formed between a number of engineering and technology programs and the Technology Centre at BCIT for the purpose of supporting 4th term and 4th year capstone projects.
- By linking education and research at BCIT a sustainable multi-disciplinary capstone project experience has been created for a variety of engineering and technology students at BCIT.

Conclusions and Future Work

- Future work remains to explore the potential benefits of formalization of this relationship and to seek sources of funding to continue the support of capstone projects and to expand the support to more programs and students.

Acknowledgements

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