

CENTRES FOR RESEARCH IN YOUTH, SCIENCE TEACHING AND  
LEARNING (CRYSTAL)

MID-TERM REVIEW

FINAL REPORT

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## Table of Contents

1.	Introduction.....	1
1.1	Overview of CRYSTAL Pilot Program.....	1
1.2	CRYSTAL Pilot Program Logic Model.....	2
1.3	Mid-term Review Objective and Questions.....	4
2.	Methodology.....	6
2.1	Case Studies.....	6
2.2	Unfunded Applicant Interviews.....	8
2.3	Peer Review Findings.....	8
2.4	Internet-based Review of Comparable Science Education Programs.....	8
2.5	Analysis and Reporting.....	8
3.	CRYSTAL Pilot Program Centres.....	9
3.1	CRYSTAL Atlantique.....	9
3.2	CREAS Sherbrooke.....	10
3.3	CRYSTAL Manitoba.....	11
3.4	CRYSTAL Alberta.....	13
3.5	CRYSTAL Pacific.....	14
4.	Success and Impacts.....	16
4.1	Collaborations.....	16
4.2	Training of Highly Qualified Personnel.....	23
4.3	Research and Knowledge Translation.....	26
5.	Delivery and Design.....	32
5.1	Delivery of CRYSTAL Pilot Program.....	32
5.2	Design of CRYSTAL Pilot Program.....	35
5.3	Alternatives to the CRYSTAL Pilot Program.....	38
6.	Conclusions.....	41

## 1. Introduction

This chapter provides a brief overview of the Centres for Research in Youth, Science Teaching and Learning (CRYSTAL) Pilot Program as well as the objectives and questions addressed by the mid-term review.

### 1.1 Overview of CRYSTAL Pilot Program

The CRYSTAL Pilot Program was created as a result of commitments stemming from NSERC's Vision, which was approved by Council in October 2003. As one of three pilot programs initiated, CRYSTAL provides a forum for the many partners who share an interest in developing and enhancing the skills of, and resources available to, science and mathematics teachers and in enriching the preparation of Canadian children in these foundation subjects. The improvement of science literacy and numeracy among Canadian youth will help to increase the supply of students qualified for and interested in science, mathematics and engineering programs at the university level. The advanced training received by students enrolled in such programs will, in turn, contribute to the availability of a highly skilled labour force, capable of thinking critically and creating and applying knowledge in all sectors for the benefit of Canada.

The CRYSTAL Pilot Program provides funding to five Centres to establish effective collaborations between researchers in education with those in science, mathematics and engineering, as well as with the education and science promotion communities, and others (as appropriate) at the national, regional, provincial and local level. Together, each Centre develops a cohesive, interdisciplinary research program to:

- ❑ increase our understanding of the skills and resources needed to improve the quality of science and mathematics education (K-12); and
- ❑ increase our understanding of the best ways to enrich the preparation of young Canadians in these foundation subjects.

In addition to these objectives, each Centre is expected to evaluate and develop knowledge translation and outreach activities related to its research program. These activities involve the practical application of research results and the transfer of expertise to the user community. Further, the Centres also support the successful training of university students as highly qualified researchers and/or professional educators in science and mathematics.

Collectively, the Centres form a national network for the exchange of research results and best practices. The national network is lead by one Centre which received additional funding to take on the role of overall national networking and leadership. This role includes organizing events, such as the National Meeting, and other means for encouraging the exchange of research results and best practices between Centres and stakeholders.

Each Centre is hosted by one or more of the faculties of education, science and engineering of the lead institution(s). Centres consist of a grantee and co-applicants, which include researchers from education and the natural sciences and engineering (NSE) as well as other relevant research areas. Centres are expected to develop a management structure to plan, direct and integrate all of its activities, including an evaluation plan to assess success in meeting objectives and the resulting outcomes and impacts, and a communication plan to ensure the timely exchange of information and results.

In addition to the grantee and co-applicants, the Centres involve partners from the “user community” including: teachers, students and parents from primary and secondary schools; school boards; provincial ministries of education, colleges, and non-governmental organizations involved in science promotion; museums; science centres; learned societies; policy makers; curriculum developers; and text book publishers. Partners are expected to play a key role in all stages of the Centre’s research through ongoing interaction with the grantee and co-applicants.

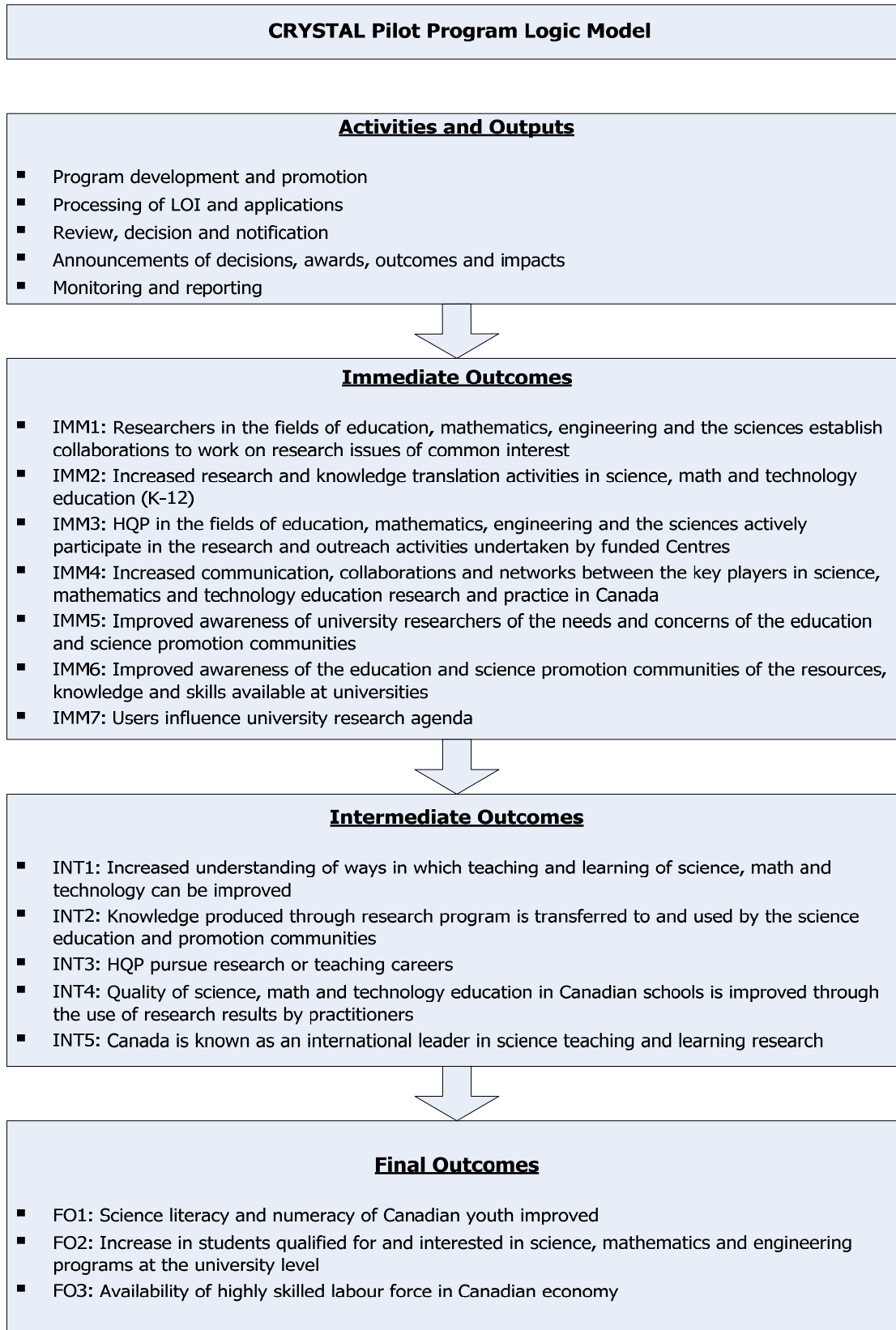
The CRYSTAL Pilot Program is intended to be flexible to accommodate a variety of research themes and activities that address the different needs and concerns of diverse partners. While the broad, long-term objective is to improve the quality of science and mathematics education in Canadian schools (K-12), the short-term impacts of the program depend, to a large extent, on the specific objectives, themes and activities of the Centres. The intended outcomes for CRYSTAL are presented in section 1.2. Each Centre has developed its own specific research theme reflecting the research expertise of the grantee and co-applicants as well as the needs and interests of the partners from the user community. The research theme focuses on one or more areas that specifically address the objectives of CRYSTAL, and is reflected in the Centre’s expected outcomes and impacts.

## 1.2 CRYSTAL Pilot Program Logic Model

The CRYSTAL Pilot Program logic model is presented in Exhibit 1.1. The logic model outlines the program’s key activities, outputs and outcomes as well as the relationships among these components. The following is a brief description of the components of the logic model:

- ❑ **Activities and Outputs:** The activities and outputs generally revolve around program development as well as the administration of the application and review process, which includes communication with stakeholders and monitoring of the grant, once awarded.
- ❑ **Immediate Outcomes:** The immediate outcomes represent the short-term results and impacts of the Centres’ research, knowledge translation and outreach activities. These outcomes stem directly from Centre activities and can be expected to occur within the period of the grant. The outcomes include the establishment of collaborations between researchers, increased research and knowledge translation activities, and the participation of HQP in Centre research and outreach activities.
- ❑ **Intermediate Outcomes:** The intermediate outcomes flow from the achievement of the immediate outcomes and, typically, occur toward the end of, or after, the funding period of the program. These outcomes cover a wide range of potential impacts, including: increased understanding of ways in which teaching and learning of science, mathematic and technology can be improved; knowledge produced through research programs that is transferred to, and used by, the science education and promotion communities; and HQP pursuing research or teaching careers.
- ❑ **Final Outcomes:** The final outcomes represent the broad societal impacts that the program will contribute towards, along with other programs and initiatives.

## Exhibit 1: CRYSTAL Pilot Program Logic Model



### 1.3 Mid-term Review Objective and Questions

The objective of the mid-term review of the CRYSTAL Pilot Program is to provide NSERC management and Council with the information needed to assess the effectiveness of the Pilot Program's approach and inform program planning and decision-making. The mid-term review addressed questions pertaining to program design and delivery, success and alternatives. The evaluation questions are presented in Table 1. The development of the mid-term review questions was based on a review of relevant documentation as well as consultations with Pilot Program staff and members of the CRYSTAL Steering Committee.

**Table 1: Mid-term Review Issues and Questions**

<i>Issue/Question</i>
<i>Design and Delivery</i>
1. To what extent is CRYSTAL appropriately designed to achieve its objectives?
1.1. What are the strengths/weaknesses of CRYSTAL's design?
1.2. What changes/improvements should be made to the design of CRYSTAL?
1.3. Is there a need for a national networking and leadership role within CRYSTAL?
2. To what extent has CRYSTAL been delivered as designed?
2.1. Have the Centres implemented their research and knowledge translation, and outreach programs as planned?
2.2. How has implementation been similar or different across Centres?
<input type="checkbox"/> Focus of research program
<input type="checkbox"/> Approach to training HQPs
<input type="checkbox"/> Outreach and knowledge translation programs
2.3. What are the strengths of the Centres?
<input type="checkbox"/> What are some of the best practices?
2.4. What are the weaknesses of the Centres?
<input type="checkbox"/> What are some of the lessons learned?
2.5. Have the Centres encountered any challenges in implementing their programs?
<input type="checkbox"/> What changes/improvements should be made to the CRYSTAL Centres?
<i>Success</i>
3. To what extent has CRYSTAL achieved its immediate outcomes?
3.1. What has been the impact of CRYSTAL on the relationship between the education research community and the natural science and engineering research community?
3.2. To what extent has CRYSTAL established the following types of collaborations:
<input type="checkbox"/> Researchers in education with those in science, mathematics and engineering?
<input type="checkbox"/> Researchers in education with the education communities* at the national, regional, provincial and/or local level?
<input type="checkbox"/> Researchers in science, mathematics and engineering with education communities at the national, regional, provincial and/or local level?
<input type="checkbox"/> Researchers (education and science, mathematics and engineering) with science promotion communities? (IMM1)
<input type="checkbox"/> To what extent did these collaborations exist prior to CRYSTAL?
3.3. Has CRYSTAL lead to increased research activities in science, mathematics and technology education?
<input type="checkbox"/> Has CRYSTAL lead to increased knowledge translation activities in science, mathematics and technology

\* Education communities are defined as the end users of the research (e.g., ministries of education, school boards, schools and teachers)

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**Issue/Question**

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education?

- To what extent have Centres integrated research, knowledge translation and outreach activities with their main objectives?

3.4. To what extent has CRYSTAL contributed to the training of HQP in the following areas:

- Education professionals (e.g., pre-service and in-service teachers)?
- Education (e.g., undergraduate and graduate students, postdoctoral fellows, and research assistants)?
- Science, mathematics and engineering (e.g., undergraduate and graduate students, postdoctoral fellows, and research assistants)?
- Science promotion professionals (e.g., facilitators and consultants)?

3.5. Has CRYSTAL increased communications, collaborations and networks between key participants in science, mathematics and technology education research and practice across Canada?

3.6. Has CRYSTAL improved the awareness of university researchers in education, science, mathematics and engineering of the needs and concerns of the education and science communities?

3.7. Has CRYSTAL improved the awareness of the education and science promotion community to the resources, knowledge and skills available at universities?

- Are partners from the user community influencing the research programs of the Centres?
- 

4. To what extent has CRYSTAL made progress toward achieving its intermediate outcomes?

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4.1. To what extent have the Centres increased understanding of ways to improve the teaching and learning of science, math and technology?

4.2. Is the knowledge produced by the research programs of the Centres being transferred and used by end users?

- To what extent is the education community using research results to improve the quality of science, math and technology education?
  - To what extent is the knowledge produced by the research programs contributing to the revision of curricula and teaching methods (via collaborations with the education community)?
- 

5. Has CRYSTAL had any unintended impacts to date, either positive or negative?

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**Alternatives**

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6. Are there alternative ways to achieve the same or better results?

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6.1. What would be the impact of no CRYSTAL funding?

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## 2. Methodology

This chapter presents the methodology for the mid-term review. Given that the CRYSTAL Pilot Program consists of five Centres, a case study methodology was used to collect quantitative and qualitative data on each Centre's delivery of activities and progress toward objectives. In addition to case studies, the mid-term review also drew on the findings from interviews with unfunded applicants, a Peer Review of CRYSTAL Centres' Year 3 Progress Reports, and an Internet review of comparable science and education programs.

### 2.1 Case Studies

The case study methodology relied largely on qualitative data and consisted of conducting one case study per Centre. This approach enabled an assessment of each Centre's research, knowledge translation and outreach activities and also allowed for a cross-case analysis to provide an assessment of the Pilot Program as a whole. Specifically, the case study methodology enabled the review to examine how the CRYSTAL grant has been implemented in the context of each Centre, identify intervening variables and assess the Centre-specific impacts. The case study approach was used to address all mid-term review questions (see Table 1). The case study approach consisted of the following data collection methods: review of Centre documents and performance measurement data; and key informant interviews. These data collection methods are described in greater detail below.

An external consultant, Barrington Research Group, was contracted to conduct three of the five case studies: CRYSTAL Atlantique, CREAS Sherbrooke and CRYSTAL Manitoba. NSERC evaluation staff conducted the case studies of CRYSTAL Alberta and CRYSTAL Pacific.

#### 2.1.1 Review of Centre Documentation and Performance Measurement Data

The review of Centre documentation included a review of the Centre's application as well as a review of the annual progress reports for Years 1, 2 and 3. The applications provided background information on proposed research, knowledge translation and outreach activities to address Pilot Program objectives. The review of progress reports provided information on the delivery of planned activities and the achievement of Centre objectives.

In addition, other relevant Centre documents and information was requested and reviewed as part of the document review. For example, other information reviewed included presentations from the CRYSTAL National Meetings, resources produced to support knowledge translation and outreach activities, and information posted on the Centres' Web sites. The review of Centre documents and information was guided by the applicable evaluation questions and indicators.

As part of the annual reporting, each Centre is required to complete a performance measurement indicators table, which is appended to their progress report. The performance measurement data for each Centre was reviewed for Years 1, 2 and 3. The performance measurement data provided quantitative data on key performance indicators related to Centre activities, including baseline data and projected targets for Year 3.



### 2.1.2 Key Informant Interviews

Interviews with senior university administrators, grantees, co-applicants, researchers, partners, teachers and students were conducted, and represent the main data source for each case study. Key informant interviews helped reviewers to gain an understanding of the perceptions and opinions of individuals who have a significant role in the design and/or delivery of the Centre, have a stake in the Centre, or are expected to benefit from the Centre. Overall, the interviews addressed most of the mid-term review questions, including design and delivery, success and alternatives.

Key informants interviewed were selected from a list of Centre participants provided by each Centre. Table 2 summarizes the key informant interviews conducted for each Centre case study. The following is a brief description of the respondent groups:

- ❑ Deans of Education, Science and Engineering;
- ❑ Grantee and Centre Management: Professors from Faculties of Education, Science and Engineering;
- ❑ Co-applicants: Professors from Education, Science and Engineering;
- ❑ Partners: Ministry of Education and school district representatives;
- ❑ School Teachers: Elementary, middle and secondary school teachers;
- ❑ Science Promotion Professionals: Representatives from non-profit and private sector organizations active in science education and promotion; and
- ❑ Students: PhD students (Education); master's degree students (MEd, MA, and MSc); undergraduate students (BEd, BA, and BSc) and research assistants.

**Table 2: Summary of Case Study Key Informant Interviews**

Respondent Group (target)	CRYSTAL Atlantique	CRYSTAL Manitoba	CREAS Sherbrooke	CRYSTAL Alberta	CRYSTAL Pacific	Total
Deans (2)	2	2	2	2	2	10
Centre Management (3)	3	3	5	3	3	17
Co-Applicants (3)	6	4	3	5	5	23
Partners (2)	2	2	4	2	2	12
Teachers (2)	2	4	3	2	3	14
Science Promotion Professionals (1)	3	1	1	2	2	9
Students (2)	3	2	5	2	4	16
<b>Total</b>	<b>21</b>	<b>18</b>	<b>23</b>	<b>18</b>	<b>21</b>	<b>101</b>

Standardized, open-ended interview guides were developed for the interviews. The inclusion of open-ended questions allowed interviewees to explain their responses in depth and detail, while a standard interview guide reduced variation among interviewers across case studies. Each guide was tailored to each respondent group's knowledge base and level of involvement in Centre activities. The interview questions were linked to indicators identified in the mid-term review matrix to help ensure that the required information was collected in a consistent manner across Centres.

Case study interviews were conducted over a four month period (between February and May 2008). Interviews ranged from 30-120 minutes in length and were conducted in the preferred official language of the interviewees. Most interviewees were conducted in person during site visits, but some interviews were conducted by phone due to the availability or location of key informants. All interviewees were sent an introductory letter and the finalized guide by e-mail in advance of their interview appointment to permit preparation for the interview.

## 2.2 Unfunded Applicant Interviews

Interviews were conducted with nine unsuccessful applicants that submitted full applications to the CRYSTAL Pilot Program in 2004. The purpose of these interviews was to determine to what extent the research, knowledge translation and outreach activities proposed in the full applications have been pursued in the absence of CRYSTAL funding. These interviews were conducted by phone over a two month period (May to June 2008) by NSERC evaluation staff.

## 2.3 Peer Review Findings

Independent of and separate from the mid-term review, the CRYSTAL Pilot Program undertook a Peer Review of CRYSTAL Centres' Year 3 Progress Reports during May and June 2008. The findings and recommendations of the Peer Review Committee were reviewed and, where appropriate, relevant findings have been included in this report.

## 2.4 Internet-based Review of Comparable Science Education Programs

All programs identified by interviewees as comparable to the CRYSTAL Pilot Program were searched on the Internet and a brief description of the programs compiled. In addition, using Google as a search engine, other comparable programs were searched using keywords such as: "improve science teaching and learning," "science and learning programs" and "teaching and learning programs."

## 2.5 Analysis and Reporting

All data collected for each Centre was summarized, analyzed and integrated to produce a case study for each Centre. Each draft case study was forwarded to the Centre for review and validation before being finalized.

The findings from each case study, along with the findings from the other methodologies (i.e., unfunded applicant interviews, peer review findings and review of comparable programs), were integrated and analyzed to provide an overall assessment of the CRYSTAL. This report presents the findings and conclusions of the mid-term review of the CRYSTAL Pilot Program.

### 3. CRYSTAL Pilot Program Centres

As a result of a single competition held in 2004, five applications were selected to receive funding of up to \$200,000 per year, for up to five years. The five selected Centres are based at the following universities: the University of New Brunswick, the Université de Sherbrooke, the University of Manitoba, the University of Alberta and the University of Victoria. NSERC funding supports each Centre's research, knowledge translation and outreach programs by covering such costs as personnel, travel, materials and supplies, administration and dissemination/communications. While a cash contribution from partners is not required, it is hoped that NSERC funding will be used to leverage cash and in-kind contributions from other sources (e.g., corporate, university and provincial). This chapter provides a brief profile of the five funded Centres.

#### 3.1 CRYSTAL Atlantique

Housed in the Faculty of Education at the University of New Brunswick, CRYSTAL Atlantique builds on the unique challenges and conditions that face students, teachers and all concerned members of the scientific and technological communities of Atlantic Canada. The Centre has brought together an Anglophone and Francophone research team consisting of educators, scientists, experts in related disciplines and community organizations to study and promote science, mathematics and technology (SMT) with schools and local communities, and to initiate a sustained dialogue about their contribution to regional well-being and their role in responsible citizenship. The Centre's key partners include: Huntsman Marine Science Centre, New Brunswick Community College (Bathurst), Nova Scotia Agricultural College, Saint Francis Xavier University, Université de Moncton, Nova Scotia Department of Education and New Brunswick Department of Education.

The main theme of the Centre is promoting a culture of science, technology and mathematics with an initial focus on the role of informal learning contexts, which consists of learning that takes place outside the formal structure of the classroom or university. It includes a range of learning opportunities from clubs and organizations to museums and science centres as well as individual learning through everyday experience. In particular, the Centre aims to investigate:

- ❑ The expectations of informal learning contexts on a person's understanding, attitudes or interest toward science and mathematics;
- ❑ The role informal learning plays in the educational process;
- ❑ Learning contexts provided to learners and learning contexts available to teachers; and
- ❑ The effects of grassroots professional development and teacher-directed change on teachers' confidence, pedagogy and classroom practices.

In the first year, research, knowledge translation and outreach activities initiated by CRYSTAL Atlantique were broadly clustered around four research topics: extra-school research projects; technology and learning research projects; professional development research projects; and community-based learning research projects. During the third year, the four broad research topics were revised and Centre projects were organized under the following three aspects of informal learning:

1. Studying what happens when we extend learning beyond the school curriculum studies;
2. Understanding the impact of technology and online learning studies; and
3. Examining and extending teachers' understanding of science studies.

The following are examples of Centre projects under these three aspects of informal learning. Science-in-Action falls under the first aspect of informal learning and is designed to provide students in grades three through eight with extracurricular science experiences through two programs: The Whoooo Club for grades three to five and the ECO Action for grades six to eight. These programs will explore questions such as: Will these learners develop more complex understandings of science and mathematics than with school-based studies alone and would more of them pursue science careers? Under the second aspect of informal learning, the Communauté d'apprentissages scientifiques et mathématiques interactifs (CASMI) project focuses on the development of scientific and mathematical literacy through problem solving using a collaborative virtual environment in mathematics and science education and to determine how it contributed to the realization of student's intellectual potential. CRYSTAL Physics Teachers is a project under aspect three of informal learning that aims to develop and refine teacher professional development in the context of a Physics Teachers' research group.

The CRYSTAL Atlantique research team meets biannually in May and November to provide one another with updates, share research findings, discuss regional and national concerns and issues, and set goals. The Centre's Program Review Committee holds an annual colloquium to provide researchers with an opportunity to share their work and findings over the past year. At the second colloquium, held in May 2007, four lines of inquiry were identified as cross-cutting threads, and working groups were established to trace and develop each of the threads:

1. Interactions between science and non-science communities, including: ways that professional scientists and mathematicians can interact effectively with their wider educational communities to support science and math learning; and the mentorship of teachers.
2. Cultures of science learning, including: cultural contexts; learning in cultural contexts; and the Centre's view of the cultures of science.
3. Theoretical and methodological frameworks, including: research methodology; mentorship of new researchers; and multiple informal learning contexts.
4. Impact on students, including: mentorship of students; way that students pose problems; factors that affect students' understanding of science; impact of learning in informal contexts on students; and impact of online learning communities.

### 3.2 CREAS Sherbrooke

CREAS Sherbrooke is a single overall project located in the Faculty of Education at the Université Sherbrooke covering three broad research and development themes:

1. Teachers' science, mathematics and technology (SMT) teaching competencies;
2. Integrative approaches (problem-based learning, project-based learning and interdisciplinary education); and
3. Development of didactical resources.

An interfaculty team is responsible for each of the three themes. The overall objective of the Centre is to develop the competence of natural sciences, engineering and mathematics high-school teachers through collaborations with the education community, including the Department of Leisure and Sports, five school districts, and research centres. Other important partners for the Centre include the following organizations from science promotion community: La société pour la promotion de la science et de la technologie, le Conseil de loisir scientifique de l'Estrie and le Musée de la nature et des sciences de Sherbrooke.

The Centre's research team is composed of 25 specialists from various disciplines and institutions. During Year 1, the Centre laid the groundwork for the research, knowledge translation and outreach activities that would commence in Year 2. In Year 2, Centre activities included data collection and analysis. In Year 3, the Centre focused on interdisciplinary approaches to teaching SMT.

The Centre's knowledge translation activities focus on the testing, validation and dissemination of education program units centred on SMT teaching competencies' development, teaching-and-learning situations based on integrative approaches, and a framework for analyzing didactical resources in SMT. In particular, knowledge has been transferred and outreach has taken place in several key ways:

- ❑ Work-study Days for Teachers. The objective of the work-study days is to work with teachers to develop their competencies in teaching of SMT. Preparatory work is done beforehand, and researchers are available to teachers throughout the year for follow-up assistance. The research team also goes into classrooms and films teachers while they deliver the materials developed during the work-study days (the teaching-and-learning situations), which will be played and discussed during follow-up "reflection" days.
- ❑ "Noon Workshops" ("midi-rencontres"). These workshops are held by the Centre provide an opportunity for Centre researchers and/or students to present initial research findings. These workshops are open to the university community.
- ❑ Publications, Lectures and Conferences. For example, a special session on SMT teaching, organized by the Centre during ACFAS (Association francophone pour le savoir) conference.
- ❑ CREAS Sherbrooke Bulletin. The first one, published in September 2007, provides detailed information on research underway into the program's three broad themes as well as information on partner and student involvement in the Centre.
- ❑ CREAS Sherbrooke Web site. The Centre has produced a Web site, which provides detailed information on Centre activities as well as links to all partners.

### 3.3 CRYSTAL Manitoba

Located in the Department of Botany in the Faculty of Science at the University of Manitoba, CRYSTAL Manitoba is guided by two central questions: first, what factors impede, contribute to, and have the greatest consequence on science and mathematics success for students?; and second, how can a CRYSTAL use this understanding to empower the user community to contribute to improved science and mathematics success for students?

The educational foundations for CRYSTAL Manitoba stem from the recognition that student success is a function of "risk" factors, which have a negative impact, and "protective" factors, which have a positive impact. In this context, risk factors are processes that contribute to negative trajectories in science and mathematics (e.g., poor classroom instruction), whereas protective factors are processes that contribute to positive outcomes (e.g., a committed family member). The combined effect of risk and protective factors is "resiliency." The aim of this Centre is to increase resiliency by minimizing risk factors and maximizing protective factors. The risk factors and protective factors reside in four nested "systems":

#### System A: The Individual Learner –The Micro System

The focus of this system is to investigate the attributes of the learner as they impede, contribute to, and sustain personal science and mathematics success. The key research question for this system is: How do the attributes of the learner combine to impede, contribute to and sustain personal science and mathematics success? In particular, research projects focus on the personal attributes and disposition of minority francophone students; classroom interventions and the application of assessment tools; and the critical thinking and environmental factors at play at critical decision-making times.

#### System B: The Individual Learner as Part of a Classroom and School Community – The Meso-system

The system focuses on investigating the attributes of the classroom and school community as they combine to impede, contribute to, and sustain science and mathematics success. The key research question for this system is: How do the attributes of the classroom and school community combine to impede, contribute to and sustain science and mathematics success? The projects examine school and instructional improvement; curriculum design in terms of humanistic approaches and the interplay between culture and history and the mandated curriculum; and the support of at-risk in-service and pre-service teachers.

#### System C: The Individual Learner as Part of a Local Community – The Exo-system

The objective of this system is to develop science and mathematics programs that involve members of the community and evaluate their effectiveness in developing positive attitudes towards science and mathematics. The key research question for this system is: How do the attributes of the local community contribute to the development and success in science and mathematics for students? Research projects are looking at the impact of community-based science outreach; Elder and community member input to culturally sensitive teaching and learning; and the transcription of oral history for incorporation into culturally sensitive teaching and learning.

#### System D: The Individual Learner as Part of a Global Community – The Macro System

This system has two objectives: first, to assess the impact of global participation on the development of positive trajectories in science and mathematics; and second, to investigate the extent to which the recognition by students that they are part of, and not separate from, the global system contributes to their success in science and mathematics. The key research question for this system is: What is the impact of direct involvement with global environmental issues on student attitudes and success in science? Specifically, the research projects examine: the use of experiential data collection and analysis primarily associated with water-based learning programs and science-based sustainability curriculum for middle and senior years.

The Centre's knowledge translation activities vary by system. For example, System A has targeted decision-makers in the user community for knowledge translation; System B, teachers and educational consultants; System C, existing networks in Aboriginal communities; and System D, the advisory support for existing environmental programs.

CRYSTAL Manitoba has reached out to a wide range of partners across four provinces, three northern territories and several countries. The main types of partnerships that have been established are with:

- School Divisions, School Boards and, in some cases, Parent Councils: More than 24 school divisions in Manitoba, and Regina Public School Board;

- ❑ Provincial, Territorial and Federal Government Departments: Manitoba Education, Citizenship and Youth, Manitoba Education Research Network, Saskatchewan Learning, Government of Northwest Territories, and Indian and Northern Affairs Canada;
- ❑ Post-secondary Education Institutions: University of Manitoba, Faculty of Education University of Winnipeg, University of Saskatchewan and University of Regina;
- ❑ Communities and Individuals Rolling River First Nation, Skownan First Nation, Beardy's First Nation, Muskoday First Nation and The Pas; and
- ❑ Non-profit Organizations and Foundations: Career Trek, Manitoba Education for Sustainable Development Working Group (MESDWG), The Natural Step; Imperial Oil Charitable Foundation and Ducks Unlimited.

### 3.4 CRYSTAL Alberta

Based in the Department of Educational Policy Studies within the Faculty of Education at the University of Alberta, CRYSTAL Alberta has established a collaborative team of education researchers, scientists, mathematicians, experienced educators and teachers, and science promotion professionals. CRYSTAL Alberta attempts to address two key concerns identified in the science education and literacy literature: first, that the proportion of Canadian students that like science and mathematics peaks around Grade 4 and declines thereafter; and second, that the general public's knowledge of and about science and mathematics, and interest in and attitudes toward these subjects, have been found wanting in Canada and other industrialized nations.

CRYSTAL Alberta aims to examine and improve the interpretation and critical evaluation of scientific and mathematical text, and the use of visualizations in science and mathematics. To do this, the Centre proposed five specific objectives:

1. Journal for School Science and Mathematics. The journal has been reconceptualized as the CRYSTAL-Alberta Outreach Web site which provides resources for use by teachers and students.
2. Models of Visualization and Visualization Use. These models demonstrate visualizations and effective methods for incorporating visualizations into teaching science and mathematics.
3. Models for Redesigning Text Resources. These models will provide examples of text resources used in a highly dynamic, technical and connected world.
4. Prototype Testing and Evaluation Tools. These tools are intended to provide innovative ways to test students for rich and deep understanding and the soundness of their science and mathematical reasoning.
5. Prototype Curriculum Objectives. The aim is to produce new and testable curriculum objectives that will contribute to the reform of science and mathematics education.

The conduct of Centre research, knowledge translation and outreach activities is guided by a two by two matrix structure with the following four research areas: science reasoning; mathematical reasoning; interpreting visualizations; and interpreting text. Each project is required to fit within this matrix and address at least one of the four research areas. This matrix is the framework for CRYSTAL Alberta activities and is used by the Management Committee for the evaluation and funding of new projects. The Centre's research activities proceed in three stages: research and development; validation; and research translation and outreach. Another key feature of the Centre's structure is that the Management Committee requires that

project proposals submitted involve at minimum a scientist or mathematician, science or mathematics educator, student and teacher.

The Centre's knowledge translation activities focus on the testing, validation and dissemination of prototypes to improve science and mathematics education. In particular the partnership with the Centre for Mathematics, Science and Technology Education (CMASTE) is critical for the dissemination of the prototypes; CMASTE is one of the foremost university outreach organizations in Canada and promotes access to the Centre's resource bank, which enables the dissemination of the prototypes and resources provincially, nationally and internationally. The association of the Centre with CMASTE allows for an indirect, but important, association with other major science education projects, such as WISEST (Women in Scholarship Engineering Science and Technology) and the Alberta Ingenuity projects.

CRYSTAL Atlanta's key partners include: CMASTE, King's University College's Centre for Visualization in Science, Edmonton Catholic Schools and Edmonton Public Schools, Alberta Education, Science Alberta Foundation and the Canadian Centre for Research on Literacy.

### 3.5 CRYSTAL Pacific

Housed in the Faculty of Education at the University of Victoria, the Pacific Centre for Scientific and Technological Literacy (CRYSTAL Pacific) focuses on enhancing the two types of science literacy required in modern society: first, the ability to participate in public debates relating to issues of science, technology, society and environment (STSE); and second, a specific sense of literacy required to pursue a scientific or technological career and become an expert in a related field. To do this, the Centre's research, knowledge translation and outreach activities are intended to achieve two objectives:

1. To provide authentic science learning environments for both outstanding students interested in subsequently engaging in and pursuing science and engineering careers and for all students, enabling them to engage in the ongoing public debates about pressing scientific issues that modern Canadian society faces and;
2. To conduct research that documents the development of scientific and technological literacy in these contexts.

The Centre consists of three nodes aligned with these objectives: Node 1 builds authentic, hands-on, field and lab based science literacy experiences; Node 2 expands and further develops and understands science literacy in the classroom setting; and Node 3 develops teacher leadership in science literacy. The activities of the Centre are guided by a crosscutting objective to address underserved individuals and communities in science, technology, engineering and mathematics (STEM). In terms of activities and resources produced for teachers and students, the Centre has focused on the environment, earth and ocean sciences, water resources and, more recently, computer science and technology. The Centre's key Partners include: Seaquaria in Schools, SeaChange Marine Conservation Society, Lighthouse Schools and the Centre for Excellence in Teaching and Understanding Science.

#### Node 1: Authentic Science Opportunities and Knowledge Building

This node focuses on developing and testing ways to enrich the preparation of youth in science, technology, engineering and mathematics (STEM). In particular, the node develops and tests a broad range of authentic science experiences (both existing and new) for students and their teachers, and evaluates the learning and attitude changes associated with these authentic science experiences. The node is comprised of a suite of researchers, partners and teachers that are providing and studying a



diverse set of authentic science experiences, for elementary and secondary students and teachers, which are informed by a constructivist and inquiry-based approach. Science experiences being researched by this node include participation in university science laboratory research, field-based environmental education and traditional knowledge about nature, use of salt water aquaria in schools, ecological literacy activities, and an ongoing pilot project with two computer scientists entitled Solving Problems with Algorithms, Robots and Computers (SPARCS). Based on this, the node aims to understand the approaches and methods that are best to enrich the science experience of K-12 students.

#### Node 2: Classroom-based Studies of Teaching, Assessment, and Technology Applications

Node 2 explores the relationship between the development of the fundamental sense of science (abilities, attitudes and communications) and the derived sense of science (conceptual understanding). The particular focus is on the outcomes of a variety of explicit instructional approaches regarding thinking, language, mathematics and information communications technology to enhance science and technology literacy; namely, the cognitive abilities, habits of mind and language required to conduct scientific inquiry and technology design and to improve the understanding of science and technology. This node is conducting research on the following activities: use of automated weather stations in local schools to teach science, technology and mathematics literacy; enhancing science for pre-service and practicing teachers; analysis and modeling of large-scale assessment data for science and mathematics literacy; integration of laboratory activities, demonstrations and projects in enriched mathematics 9-12 courses to foster science and mathematics literacy; and explicit scientific language instruction embedded in middle school science programs.

#### Node 3: CRYSTAL Lighthouse Schools

Node 3 focuses on understanding how best to enhance the skills and resources of teachers. Working in partnership with the Centre for Excellence in Teaching and Understanding Science (CETUS)<sup>†</sup> at the University of Victoria, the node examines the implementation of innovative, literacy-focused science education pedagogies and curricula through teacher-to-teacher professional development in partnership with university researchers and school districts.<sup>‡</sup> The node primarily works with teachers through the Lighthouse School project to enhance professional development of teachers and to translate the knowledge produced by the Centre to a broader community, but also includes earth science professional development opportunities for teachers-in-training. The node plans to establish a new Lighthouse School on Bowen Island in Year 4 as well as examining the potential for a theme school that focuses on technology and feature collaboration between education researchers and computer scientists.

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<sup>†</sup> Located in the Department of Curriculum and Instruction at the University of Victoria, the primary function of CETUS is to develop and encourage science education leadership in elementary and middle years schools by working with teachers in several school districts. The goal of CETUS is to assist these teachers to develop the expertise to be science leaders serving their districts by providing support for excellent science education in local schools. CETUS coordinates the development and support of the science education teacher-leaders, which is supported by a network of professional scientists at the University of Victoria willing and able to provide teachers with background information on science concepts (Source: CETUS Web site. Available online: <http://www.educ.uvic.ca/cetus/info.htm>).

<sup>‡</sup> Pacific Center for Scientific and Technological Literacy Proposal. October 20, 2004. p. 7.

## 4. Success and Impacts

This chapter presents the findings relating to the success and impacts of CRYSTAL to date, and progress toward the achievement of immediate and intermediate outcomes.

### 4.1 Collaborations

A central objective of the CRYSTAL Pilot Program is to establish effective research collaborations between education researchers with natural sciences and engineering (NSE) researchers to increase our understanding of how to improve the quality of K-12 science and mathematics education. Another key feature of CRYSTAL is to actively involve partners within the education community and science promotion community in the research, knowledge translation and outreach activities. This section presents findings on the nature and extent of the collaborations established by the Centres.

#### 4.1.1 Research Community

**Key Finding:** *The Pilot Program has established new and enhanced existing research collaborations among education researchers, and between education researchers and NSE researchers. However, evidence suggests that collaborations among education researchers are more common than collaborations between education researchers and scientists, with some scientists playing a limited role in Centre research activities.*

Findings from the case studies indicate that the Pilot Program has established and enhanced collaborations among education researchers conducting research on science and mathematics education. All Centres feature active collaborations between education researchers, and evidence indicates that these research collaborations are both active and productive, and examine a wide number of topics in the science and mathematics education research. Across all Centres, collaborations among education researchers are more common than collaborations between education researchers and NSE researchers.

While all Centres have either established or enhanced collaborations between education researchers and scientists or mathematicians, the number and extent of the collaborations vary both across and within the Centres. Case study findings show that all Centres have research projects that feature education researchers and NSE researchers; however, the nature of the collaborations range from limited participation to full participation by scientists and mathematicians in Centre research projects. For example, one researcher provides a first-hand account of the challenges associated with collaboration:

*Our worlds are on two totally different spectrums. We think differently, we see the world differently. All of a sudden we're trying to work together and speak the same languages. It is very challenging.*

Available evidence from the case studies indicates that the Program has established a limited number of active and ongoing collaborations between education researchers and NSE researchers, which feature active participation by scientists or mathematicians in research projects. For the most part, these collaborations tend to feature scientists with a "sensitivity" or affinity for science education and who have, in some cases, participated in science education outreach activities in the past. The following are specific examples of active and ongoing collaborations between education researchers and NSE researchers:

- ❑ CRYSTAL Atlantique: A chemist is working with education researchers on a Chemistry Camp project, and a physicist is working with education researchers on a project that examines informal learning among physics teachers.
- ❑ CREAS Sherbrooke: An engineer has collaborated with an education researcher from the Université de Sherbrooke on project analyzing the teaching of early algebra in Ontario and Québec as well as project examining Grade 7 and 8 textbooks in Ontario.
- ❑ CRYSTAL Manitoba: In addition to the strong linkage between the Director, from the Faculty of Science, and the Co-Director, from the Faculty of Education, the Centre has helped to foster several emerging partnerships between the education and science community for the purposes of teacher professional development.
- ❑ CRYSTAL Pacific: An earth scientist is collaborating with an education researcher to develop, implement and evaluate resources and professional development activities for pre-education, pre-service teachers and in-service teachers. Here, CRYSTAL funding “formalized” and enhanced prior interactions between the scientist and educator, both indicate they have learned about the others’ area of expertise -- earth sciences and constructivist learning strategies, respectively.
- ❑ CRYSTAL Alberta: An adapted-primary-literature project features a collaboration between a mathematician and an education researcher to develop a module (that can be accessed on-line) for high school students on the modeling of the West Nile Virus and how mathematics can be used to predict the spread of the virus. The researchers have worked together to adapt an original academic paper into an interactive, web-based document that can be used in high school mathematics courses yet maintains the canonical form of the academic paper and includes pedagogical tools. In addition to the researchers, the project involved a high school mathematics teacher as well as several undergraduate students at the (CRYSTAL Alberta) King’s Centre for Visualization in Science. One researcher notes that the collaboration between the researchers (who did not know each other prior to the project) was slow initially because it took a long time to “communicate” their different perspectives on mathematics education and it is a process that “can’t be forced,” but without a team composed of an education researcher, mathematics researcher and teacher (as required by the CRYSTAL Pilot Program) such a module could not have been created.

However, all Centres have experienced limited participation by some scientists and two Centres have had a natural sciences and engineering researcher withdraw from Centre research projects. Here, a number of reasons are cited for the withdrawal, or limited involvement, of science researchers, including: the partnership with education researchers was one-sided with scientists seen as the provider of content or opportunities for research; the demands of their science research programs; differing expectations and poor communication between science and education researchers regarding research projects; and a mutual lack of understanding and cynicism regarding each others’ approaches and methodologies.

In order to examine the nature of collaborations between education and science researchers, interviewees were asked to identify factors that either facilitate or inhibit such collaborations. Interviewees identified the funding and structure (i.e., the requirement for collaborations between education and science researchers) provided by the CRYSTAL Pilot Program as a key facilitating factor. The example from CRYSTAL Alberta illustrates how the requirement by CRYSTAL, which lead to a requirement by the Centre, has lead to the development of a research project that features an active, ongoing collaboration between an education researcher and mathematician. A scientist from this Centre indicates that the fact that CRYSTAL is an NSERC program has helped to legitimize such collaborations, the interviewee comments: “that this is an NSERC Centre has been enormously helpful. It has brought a stamp of credibility to the collaborations with

education researchers." In terms of inhibiting factors, case study findings identify the following: the distinct differences between the subject matter and activities of research in the natural sciences and research in education means that normally there is little interaction between the NSE research community and the education research community; the demands of the research programs for both education and science researchers, which limits the amount of time that can be devoted to establishing collaborations; the fact that participation in Centre projects is over and above the research and teaching responsibilities of science researchers; and the lack of recognition from faculties of science for participation in science education either in terms of service or performance (e.g., publications and tenure).

#### 4.1.2 Awareness of Needs and Concerns of User Community

**Key Finding:** *While difficult to accurately measure, available evidence from the case studies suggests that researchers actively involved in Centre activities are more aware of the needs and concerns of the education and science promotion communities. Interviewees attribute the increased awareness of researchers to interactions between researchers and teachers and science promotion professionals whereby researchers gain insight into the challenges related to teaching and promoting an interest in science.*

Findings from four case studies indicates that CRYSTAL has increased awareness of researchers involved in Centre projects to the needs and concerns of the user community, especially the education community. Overall, evidence indicates that Centre researchers are more aware of the needs and concerns of the user community than the typical researcher. The increased awareness is attributed to interactions between researchers and the user community, which are often built-in to Centre projects, via interviews, e-mail feedback, workshops, working sessions, consultations and conducting research. In terms of the education community, interview findings indicate that teachers feel that researchers are more aware of "what teachers face" and the "daily reality of teachers" because the researchers are "getting in the classroom." For example, a teacher from CREAS Sherbrooke provides an example of how researchers have gained an understanding of the needs of teachers:

*During the three [study] days, we brought them problems in mathematics. They brought us some solutions but the solutions were for Secondary V, and we're in Secondary II. Students would have been completely lost. We said to them, "Nice ideas, but we're living the reality and this won't work." So they went back, and found material that was more appropriate.*

In the case of CRYSTAL Manitoba, the Centre identified nine broad needs of the user community in the area of science and mathematics education as well as their responses to these needs, which were presented at the Second National CRYSTAL Conference.

As for the science promotion community, findings from all five case studies indicate that science promotion professionals are involved in Centre projects albeit to varying degrees. There are some examples of researchers working directly with science promotion professionals and their organizations who are more aware of the needs and concerns of this user community; however, the awareness appears to be more localized among these researchers than Centre-wide.

### 4.1.3 Relationship between Research Communities

**Key Finding:** *Overall, the findings for this issue are mixed. Some evidence indicates that the Pilot Program is having a small positive impact to establish connections between the education research community and the NSE research community. Other findings suggest that the relationship between the two communities may have been strained, or even damaged, as evidenced by instances of NSE researchers either withdrawing from, or not actively participating in, Centre activities.*

Evidence across case studies suggests that CRYSTAL has had a small yet detectable positive impact on the relationship between education and science communities. On this point, it is important to note that the relationship between these two communities is distant and collaborations between the two communities for the purposes of science and mathematics education are rare. For example, researcher and university administrators refer to the two communities as the “two solitudes” where “the norm is isolation with one or two exceptions.” The main reason cited for the limited interaction between the two communities is that each “speak a different language” and “have a different culture” than the other. In the words of one education researcher, “we speak different languages. Science and mathematics educators look at it [science education] from a different angle than science and mathematics experts.” That said, interviewees report that the Pilot Program’s requirement for collaborations between educators and scientists is very important because the collaborations established by the Centre represent a “start” or “progress” towards increased connections between the two communities in the areas of science and mathematics education.

On the other hand, there is evidence to indicate that in a few isolated instances, the collaborations between education researchers and NSE researchers have worked to reinforce the different perspectives held by the two communities. Here, differing agendas, poor communication and the nature of the role of scientists in Centre projects has led to the limited involvement or withdrawal of NSE researchers from Centre activities.

### 4.1.4 User Community

This section presents findings about the nature and extent of collaborations between Centre researchers and members of the user community.

#### 4.1.4.1 Education Community

**Key Finding:** *The mid-term review found that CRYSTAL is resulting in collaborations between Centre researchers (both education and NSE) and members of the education community. For the most part, the collaborations are between education researchers and members of the education community and take place at a local and provincial level rather than a regional or national level. Researchers from all Centres have established collaborations with in-service teachers in science, mathematics or technology; however, the nature of these collaborations varies across Centres and Centre projects. Some Centres have developed strong, ongoing partnerships with provincial ministries of education while other Centres are beginning to initiate contact with ministries. Some Centres are working with school district representatives to access schools in order to implement research activities.*

CRYSTAL Centres collaborate with the following three groups within education community: in-service teachers; school districts or boards; and provincial ministries of education. Overall, the bulk of the

collaborations between Centres and the education community are collaborations between Centre researchers, especially education researchers and in-service teachers.

Across Centres, the collaborations between researchers and in-service teachers have taken a number of forms; however, the purpose of the collaborations has typically focused on the professional development of teachers. The following provides an indication of the types of collaborations between the Centres and in-service teachers:

- ❑ Research collaborations between researchers and teachers: The collaborations involve the teacher as an active member of the research team. The teachers assist the researchers in the design (e.g., development instruments such as interview guides), conduct (e.g., data collection such as interviews) and reporting (e.g., data analysis and co-author research articles) of research projects. In addition to the research skills acquired, the participating teachers gain skills and knowledge on how to improve their teaching of science and mathematics. This type of collaboration is less common than the following forms of collaboration.
- ❑ Professional development collaborations within the context of research projects: Teachers participate in ongoing professional development activities (e.g., implementation of teaching strategies, development of lessons and teaching resources) that are part of a research project to assess the impact of the professional development activities on the learning of science and mathematics. While teachers do not participate in the design of the research project, they implement the professional development activities in the classroom and provide feedback on the implementation and design of the professional development activities.
- ❑ Professional development collaborations: Teachers participate in professional development activities such as workshops and presentations to in-service teachers at teacher association meetings and professional development days.

For the most part, collaborations between Centres and school districts or boards have taken the form of partnerships for the purposes of research in the schools within the district and to raise awareness of Centre resources that can be used by the school district's teachers. For example, for some Centres, school districts have been important partners providing in-kind support, in the form of teacher release (i.e., covering the cost of substitute teachers), to enable the participation of in-service teachers in Centre activities. Also for a few Centres, representatives from school districts are active participants in Centre research projects; providing assistance with, and feedback on, professional development activities and resources.

The extent to which Centres have collaborated with provincial ministries of education varies from limited involvement to active participant. There are a number of reasons for the differing levels of involvement with ministries of education, including: the focus and nature of the Centre's research program and its relevance to provincial K-12 science and mathematics curricula; the nature and status of the curriculum change process within the province; and the need to scale up, test and package the results of research projects before approaching ministries of education. For example, the relevant ministry of education for one Centre recently completed the revision of K-12 math curriculum and the K-10 science curriculum, which is a two-year process completed every ten years. Two Centres have limited involvement with ministries of education and one Centre has maintained regular contact with the ministry of education and with ministry officials participating in Centre knowledge translation events. The following are two examples of active collaborations between Centres and ministries of education:

- ❑ CREAS Sherbrooke: In the context of a major reform within the Québec school system<sup>4</sup>, the Centre has become an important partner to Éducation Québec to assist with the implementation of the reform. In particular, the Centre has worked to enhance the science, mathematics and technology teaching competencies of in-service teachers to ensure the effective ongoing implementation of the new primary, elementary and secondary curriculum in the province. Given the number of school districts in Quebec (72) and the capacity of Éducation Québec, the Centre is regarded a key mechanism to enhance the professional development of teachers.
- ❑ CRYSTAL Manitoba: The Centre has become a close partner with the Manitoba Ministry of Education, Youth and Citizenship (MECY) and a key source of research for the Ministry to influence curriculum and policy. In addition, the Centre and the Ministry co-host a series of research forums with the Manitoba Education Research Network (MERN)<sup>5</sup> to present the findings of Centre research, with MERN acting as a key source of education research for MECY since the inception of the Centre.

#### 4.1.4.2 Science Promotion Community

**Key Finding:** *CRYSTAL Centre researchers have established, as well as enhanced existing, collaborations with science promotion organizations. To date, researchers are collaborating with a variety of organizations including science centres, marine conservation organizations, local businesses and not-for-profit organizations active in the area of science and environmental education. The nature of the partnerships vary across the Centres and projects, with some active collaborations to develop resources for partner organization programs, revise and enhance existing programs, or assess the impact of projects that focus on the learning of science and mathematics by children.*

Science promotion organizations are actively participating in Centre activities, and all Centres have representatives from science promotion organizations as members of Centre governance structures. To date, Centres have collaborated with science promotion organizations to: develop and deliver science and mathematic education projects and resources; enhance the delivery and effectiveness of organizations' existing programming, including the evaluation of education and outreach activities; and provide organizations and their audiences with information on Centre research projects. Findings from interviews with representatives from science promotion organizations indicate that they are positive about their involvement with Centres. For partnerships established as a result of the Centre, science promotion professionals report that they have gained a better understanding of science education and that the partnerships have supported the organizations to increase the educational aspects of their organizations' programming. In one case where partnerships with Centre researchers existed prior to the Pilot Program, respondents indicated that CRYSTAL has worked to make the partnerships more formal and assisted the

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<sup>4</sup> The Centre began at the same time as a major reform in the school system in Québec was underway. Since 2000, Éducation Québec has undertaken its broadest reform in the last 30 years. At the heart of this reform has been the elimination of grades, which have been replaced by cycles. Under Québec's new education program, Cycle One includes kindergarten and Grades 1 and 2; Cycle Two includes Grades 3 and 4; Cycle Three includes Grades 5 and 6; Cycle Four will consist of Secondary I, II, III, and Cycle Five will include Secondary IV and V. Cycle One was implemented in 2000-2001, Cycle Two was implemented in 2001-2002, and Cycle Three was implemented over the 2002-2003 school year. Implementation of the secondary program, Cycles Four and Five, was scheduled to be completed by 2006.

<sup>5</sup> The Manitoba Education Research Network (MERN) works to improve the quality of education in Manitoba's schools by establishing partnerships for research studies, collecting and analyzing data and supporting other forms of research activities. The network is a collaborative effort on the part of Manitoba's five Faculties of Education and Manitoba Education, Citizenship and Youth (MECY). Available online: <http://www.mern.ca/>.

organizations to develop, as well as provided, resources to enhance their programming (e.g., books, media and CDs). In two cases, partnerships with science promotion organizations are in the early stages of development because Centre projects that involve science promotion partners are still in the research and validation stages, and have not yet reached the knowledge translation and outreach stage.

The collaboration between CRYSTAL Alberta and the Edmonton Telus World of Science (TWS) is an example of an effective collaboration between a Centre and a science promotion organization. The TWS<sup>6</sup> has been working with Centre researchers on a project examining how visualizations can be used to help students to understand science. The collaboration has focused on using the results of a Centre project focused on creating visualizations of the particulate model of matter for grade 5 students to revise TWS' Cauldron Brew program to include visualizations of molecular chemistry. The visualizations on molecular chemistry are able to show students how molecules behave, which the previous version of the Cauldron Brew Program was not able to do. As a result of the revisions, the TWS representative expects that teachers will like the Program more and students will learn more from it. The pilot testing of the new Program, with the visualization component, began on February 29, 2008, with four elementary school classes.

#### 4.1.4.3 Awareness of Resources, Skills and Knowledge of Research Community

**Key Finding:** *Case study findings indicate that the awareness of the resources, skills and knowledge available at universities for improving science education has increased among teachers and partners involved in Centre projects. As with research awareness of the needs and concerns of the user community, the awareness of the user community of researchers' resources, skills and knowledge stems from interactions and collaborations with Centre researchers.*

Findings from four of the case studies indicate that the awareness of Centre teachers and partners to the resources, skills and knowledge available at universities for improving science education has increased; with little evidence of increased awareness in the fifth case study. Interviewees attribute the increased awareness to interactions and partnerships with Centre researchers. Interviewees report that they are more aware of resources (e.g., National Geographic Theme Sets™), skills (e.g., new teaching strategies) and knowledge (e.g., the use of visualizations in teaching science). For some teachers, the experience of working with university researchers has been a new and exciting experience. For instance, one science teachers commented: "It [CRYSTAL Manitoba] is the only [research] connection I can remember in 25 years of teaching." For other teachers and partners, the Pilot Program has had limited impact as they were already aware of, and in some cases, working with Centre researchers. In addition, there is some evidence to suggest that the Centres have increased awareness among the broader education and science promotion communities through presentations to, and by, members of these communities (e.g., regional and provincial teacher association conferences, science centre meetings, and community events).

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<sup>6</sup> The TWS, formerly the Odysium, is a private, non-profit organization operated by the Edmonton Space and Science Foundation that delivers programs and services aimed at the following community outcomes: increasing science and technology literacy; increasing support for science and technology education; increasing students' academic performance in the science curriculum; and increasing the number of individuals who pursue post-secondary education in science and technology related disciplines.



## 4.2 Training of Highly Qualified Personnel

This section presents the findings of the review which pertain to the training of highly qualified personnel (HQP). At the end of the third year, CRYSTAL Centres have involved an estimated 304 HQP either full- or part-time in Centre research activities, including students, teachers and community partners. The majority of individuals trained by Centres have been undergraduate and graduate students in education or in-service teachers. Of note, the review found that a unique characteristic of graduate study in education at the participating universities is a trend away from full-time study, with many students pursuing a master or doctoral degree in education on a part-time basis while continuing to teach. As a result, the categories for HQP, students and professionals are not mutually exclusive, with all Centres possessing graduate students in education who were also in-service teachers.

### 4.2.1 Students

**Key Finding:** *Case study findings indicate that the majority of students being trained by Centres are undergraduate or graduate students in education. Other students involved in Centre research projects, although to a lesser extent, are undergraduate students and graduate students in the natural sciences and engineering. For the most part, the review found that CRYSTAL is contributing to the training of students by enabling them to participate in the full range of educational research activities including design, planning, data collection and publication. In addition, students are also participating in Centre knowledge translation and outreach activities. Graduate students in faculties of education are more likely than graduates from faculties of science and engineering to be involved in projects that are related to their theses or dissertations and, as result, the Pilot Program is contributing to a greater extent to the training and development of education researchers and professional educators.*

At the graduate level, more master's level students are involved in Centre activities than doctoral students; by the end of the third year, an estimated 79 and 38 students, respectively. Among master's students, the degrees sought include: MEd, MA, and MSc. However, available evidence indicates that most students involved in Centre activities are students pursuing a MEd (either part-time or full-time). As discussed, often the part-time MEd students are in-service teachers. Though fewer in number, case study findings indicate that doctoral students in education are actively involved in Centre research projects. Among doctoral students, the vast majority involved are pursuing a PhD in education; however, two Centres feature the involvement of PhD students in the sciences in projects.

For the most part, graduate students have taken one of two roles within Centre projects, either assisting with the conduct, analysis and reporting of projects undertaken by Centre researchers or conducting research as part of a Centre research project that will contribute to a thesis or dissertation that is supervised by Centre researchers as well as other researchers. Across Centres, it appears that it is more common for graduate students, especially at the master's level, to be involved in the former capacity. Evidence indicates that graduate students involved in Centre activities are involved in all aspects of the research endeavor from helping develop data collection instruments, to conducting data collection, to analyzing and presenting research results, to co-authoring research articles; however, for most students this work will not contribute directly to their thesis. Findings from interviews with both researchers and students indicate that CRYSTAL has made a positive and, in some cases, significant contribution to the training of graduate students in education. For example, graduate students report the following impacts:

- ❑ CRYSTAL Alberta: A graduate education student indicates that her involvement in a Centre project has had a profound impact on her academic and professional training, and comments: "I have not learned as much at the professional level as I have since CRYSTAL."
- ❑ CRYSTAL Pacific: Through conducting research as part of a doctoral degree in education, a graduate student has "learned the process of a researcher" which provided a practical way to learn about qualitative methods. The student indicates that the research project is a "100 percent related to my PhD – it is my PhD."

An interesting unintended impact of the Program is that among the NSE graduate students who have been involved in Centre activities, either research or outreach, a few have developed an interest in the teaching of science and mathematics. For these individuals, the involvement in Centre projects has sparked an interest in pursuing either a teaching career or further study in the field of education. For example, at CREAS Sherbrooke an undergraduate student in engineering has decided to pursue a Master's in Science Education as a result of participating in a Centre project.

Case study findings indicate that undergraduate students in both education and the sciences are involved in Centre research projects, with a reported 82 students involved by the end of the third year. The degrees sought by undergraduate students include: BA, BSc, BEd, and BSoc Work. For the most part, undergraduate students in education (BEd) are participating in the same manner as graduate students in education (i.e., assisting with the conduct of Centre research projects) and, as a result, the Pilot Program is contributing directly to their training as future education professionals and/or educational researchers. In addition, evidence indicates that professional development activities, as well as resources and teaching methods developed for in-service teachers, are being extended to pre-service teachers (i.e., BEd students), thereby enhancing their training as future teachers. For undergraduate students in the NSE, available evidence indicates that the students tend to be more involved in either the technical processes associated with the design of resources for teachers or the delivery of outreach activities. To date, two Centres have been able to access NSERC Undergraduate Student Research Award (USRA) funding to support the participation of undergraduate NSE students in Centre projects. For example, at CRYSTAL Alberta, the King's Centre for Visualization in Science has trained 16 mathematics and science undergraduate students as part of the visualization projects using CRYSTAL grant funding and supplemented by other funding sources including USRA funding for three students. Most of the students are pursuing degrees in chemistry, biology, computer science or environmental science and work in the structure of a formal research group with research teams and weekly research meetings. A Centre researcher involved in the projects indicates that, through working in a team environment with other students and researchers to develop visualization modules, the students develop important technical and analytical skills, learn that they can tackle a difficult problem, practice their presentation and facilitation skills, and, more generally, increase their confidence.

Consistent with the case study findings, findings from the peer review indicate that Centres have contributed to the training of HQP; however, report insufficient information to assess the quality of the training activities.

#### 4.2.2 Professionals

**Key Finding:** *The Centres have focused mainly on training to enhance the teaching practices and methods of in-service teachers through a variety of mechanisms, including: involvement of in-service teachers in the*

*conduct of research projects; presentations at professional development days; workshops; development of lessons and curricular resources; lesson study and professional learning groups; targeted training and mentorship; and the use of technologies in the classroom. As of the end of Year 3, Centres report that approximately 5,093 teachers have participated in various science and mathematics education training activities. Findings indicate that CRYSTAL has had a limited impact on the training of science promotion professionals; however, some professionals indicated that participating in Centre research and knowledge translation activities has enhanced their knowledge of how to improve and assess the impact of science organization programs.*

Evidence from all case studies indicates that CRYSTAL is contributing to the training of education professionals (i.e., in-service teachers). As discussed in Section 4.2.1, the trend toward part-time study at the graduate level in education by in-service teachers has meant that there is overlap between education students and education professionals, with some individuals involved in both capacities in Centres' activities. As noted in Section 4.1.2.1, Centres have enhanced the training of teachers through research collaborations (often in action research projects) and/or participation in professional development activities.

The participation of teachers in research collaborations enhances their professional development in two ways: first, the teachers are involved in the development of the curricular resources or teaching methods to be tested; and second, they implement the intervention in the classroom and, as a result, have a first-hand account of the efficacy of the resource or teaching strategy. Through working with researchers, teachers report that they not only acquire knowledge of novel approaches to teaching science and mathematics, but also a better understanding of the educational research and theories of learning behind the resources and teaching methods. The following are examples of how research collaborations have enhanced the training of in-service teachers:

- CREAS Sherbrooke: Centre researchers have access to teachers as "research subjects", which has increased the researchers' understanding and knowledge about how science, mathematics and technology is currently taught in the school system. At the same time, researchers and teachers also work together prior to, during and after the work-study days, to develop competencies and understanding of different approaches, which is essentially a professional development activity for the teachers. There are also examples of teachers who have been involved in the study days, and then returned to university to pursue a post-graduate degree.
- CRYSTAL Alberta: A teacher involved in research collaboration reported that the involvement in the Centre has resulted in a "big change" in his teaching, with more time spent on teaching practical work in mathematics and less time spent on teaching out of the textbook. This is corroborated by the collaborating researcher who reports that "it [the project] is having major effects" on the teacher. As a result, the teacher has changed his approach to teaching the topic from less of a procedural, quantitative approach to more of a conceptual and qualitative approach, and also increased the precision of his language when teaching the terms related to differential equations.

The second way in which Centres are enhancing the professional development of in-service teachers is through knowledge translation activities that share resources and knowledge on how to improve the teaching of science and mathematics. Centres have undertaken a wide variety of activities to date, including: presentations at professional development days; workshops; development of lessons and curricular resources; lesson study and professional learning groups; targeted training and mentorship; and

the use of technologies in the classroom. The following provides some specific examples of professional development activities:

- CRYSTAL Manitoba: Using a collaborative approach, one Centre project has involved the conduct of nine professional development sessions over three years on chemistry education with in-service teachers that cover nearly all the curricular outcomes in the Grades 11 and 12 chemistry courses. The project has attracted both new and veteran teachers and the number of teachers participating has increased each year to a total of 78 chemistry teachers in Year 3; half of the teachers have been in attendance since the project's inception.
- CRYSTAL Pacific: A Centre project features workshops and meetings between education researchers and teachers to introduce specific scientific literacy strategies to the teachers, and then the teachers use these strategies with their classes. Teachers interviewed indicated that the access to the expertise of the education research and learning about various scientific literacy strategies has had a very positive impact on their training as teachers because it has provided them with knowledge of what strategies to use as well as the resources to implement these strategies. As a result, one teacher involved in the project observed: "It has brought to the forefront the importance of using literacy strategies in science as a way to get kids to access the text and gain information."

Findings from four cases studies indicate that CRYSTAL has contributed to the training of science promotion professionals. For the fifth case study, the involvement of science promotion professionals has been limited to date because the Centre projects that involve science promotion partners are still in the early stages. Through participating in Centre research projects, members of the science promotion community have increased their knowledge of educational research methods, approaches to improve the educational aspects of their organizations' programming, and resources and approaches to evaluate the impact of science education and outreach activities. For example, one science professional involved in Centre projects indicated that through working with education researchers they have gained a better understanding of what students like about science, which helps to tailor their programs. The interviewee made the following observation: "You think this is what kids want, and you can be really surprised by what the kids say. They're not necessarily interested in the things you think they are going to be interested in."

### 4.3 Research and Knowledge Translation

#### 4.3.1 Research Activities

**Key Finding:** *Findings suggest that CRYSTAL has increased the scale and changed the nature of research activities in science, mathematics and technology education. The majority of Centres (four of five) have surpassed their third projected targets for scientific publications; however, it is difficult to assess the impact of these publications as well as extent to which it has increased research activities in science and mathematics education (i.e., the incremental impact) given the prior existence of research funding and projects undertaken by Centre researchers and available information on Centre research projects. In terms of the nature of research activities, available evidence indicates that CRYSTAL has resulted in more collaborative and participatory research in the area of science and mathematics education, with more involvement of the user community, especially in-service teachers, as well as the science researchers.*

The mid-term review found that Centres have performed well in the area of research results, with four of five Centre surpassing both third year projected targets for scientific and education publications, and

communication of these results at national and international conferences. Here, it should be noted that there is little information upon which to base an assessment of the impact of these publications and communications of research results. The following provides an indication of the specific fields in which Centres report publications to date: chemistry education, science education, education measurement and testing, educational psychology, reading education and literacy, the philosophy of education, science, mathematics and technology education, research methods, cognition and the sociology of science. Further, by end of the third year, Centres reported a total of 29 completed theses pertaining to a specific aspect of a Centre research program in a number of different fields, including: chemistry education, environmental science, Aboriginal science education, science education, and sustainability education.

Interview findings indicate that the impact of CRYSTAL funding on research activities has been different for education researchers than for NSE researchers. For some education researchers, the Pilot Program has increased their research activities by providing an opportunity to pursue projects that specifically address science and mathematics education research and enable them to conduct research with teachers in school settings. For other education researchers, CRYSTAL has had less of an impact on increasing research activities, as they are already actively conducting science education research, but instead, has increased the collaborative nature of their research. For instance, these education researchers indicate that they would likely be undertaking similar research in the absence of CRYSTAL, but would not be partnering with NSE researchers or with the education community to the same extent. Centre projects have enabled researchers to partner with teachers to conduct research and professional development activities to understand how science and mathematics is taught. Here, it is important to note that CRYSTAL funding represents one source of funding among a number of other funding sources for education research and, although it is supporting new research projects, the projects necessarily build on previous research conducted by Centre researchers in the area of science and mathematics education.

With respect to NSE researchers participating in Centres, for most of those interviewed, CRYSTAL has increased their activities in the science and mathematics education. Scientists and engineers indicated that prior to the participation in a CRYSTAL Centre they tended to be more involved in science education outreach activities as opposed to research activities, and their involvement was tended to be in a more ad hoc manner. One scientist, indicated that the CRYSTAL Centre has had a huge impact on his ability to work in the area of science education because it has made resources available in Canada to engage in these types of activities; without having to collaborate with researchers in other countries (who have access to funding for this type of research). Related to this, a few NSE researchers indicated that CRYSTAL funding has provided a formal mechanism through which to participate in science education research. Findings from one case study indicates that CRYSTAL has enabled a scientist to be more active in the area of science education because it has been "legitimized" by NSERC funding, which essentially equates to "NSERC has said that it is 'okay' to do research in science education." On the other hand, for a few NSE researchers, CRYSTAL has not increased their involvement in science education research activities because of their limited participation in the Centre activities (see Section 4.1.1).

#### 4.3.2 Increased Understanding of Ways to Improve Science, Mathematics and Technology Education

**Key Finding:** *Available findings indicate that CRYSTAL is increasing the understanding of ways to improve science, mathematics and technology education for both researchers and teachers. Collaborations between researchers and teachers have increased understanding of the need, and how best, to improve*

*the teaching of science and mathematics, as well as providing the context to further this understanding through research to examine and test approaches to improve science and mathematics education.*

By the end of the third year, evidence indicates that research being conducted by CRYSTAL Centres is contributing to an increased understanding of ways to improve the teaching and learning of science, mathematics and technology. In addition, researchers and teachers are partnering to develop, implement and assess resources and teaching strategies for teachers that will enhance the teaching of science and mathematics. The following provide specific examples of how research conducted by the Centres is contributing to the knowledge base for improving science education:

- ❑ CRYSTAL Pacific: Through an ongoing collaboration with middle school teachers, education researchers have gained a better understanding of how science literacy strategies including visual approaches, word categorization activities and reading strategies can be best used to improve the teaching of science and mathematics.
- ❑ CRYSTAL Alberta: The Centre's visualization projects have developed a series of visualization modules that address common misconceptions made by students of key concepts in the subjects of climate change, modern physics and chemistry (e.g., differentiating between climate change and ozone depletion). The projects have increased understanding by engaging teachers in the process of changing how science is taught, but also providing the evidence to demonstrate the need for change.
- ❑ CRYSTAL Manitoba: The Centre's research has identified a wide number of risk and protective factors that affect the teaching and learning of science, mathematics and technology. For example, findings from a study examining student learning suggest that high school mathematics students need to focus on the content and on their learning processes rather than on the credential they hope to gain by taking the course—moving from mathematics as a gateway for further education to mathematics as an area of interest in and of itself.
- ❑ CREAS Sherbrooke: Centre research has increased understanding of ways to improve the teaching of science through a literature review carried out on project-based learning and interdisciplinary teaching strategies. Through accessing and communicating the significant research in other parts of the world on these strategies, it has increase teacher's understanding of how to better teach science.

Based on the information made available, the Peer Review Committee found it very difficult to assess the quality of Centre research or the impact the research will have on how to improve science, mathematics and technology education.

#### 4.3.3 Knowledge Translation Activities

**Key Findings:** *Overall, CRYSTAL has increased knowledge translation and outreach activities, with Centres undertaking a wide variety of knowledge translation and outreach activities. Across the Centres, the knowledge translation and outreach activities can be grouped into four types: publications or academic conference presentations; professional development workshops or training sessions; development and dissemination of teaching resources and materials; and meetings and conferences. To date, Centres have conducted an estimated 677 knowledge translation activities targeting teachers and developed approximately 479 knowledge translation tools for teachers. While the reach of the Centres' knowledge translation activities is impressive, there is limited information to assess the extent to which the user community has accessed and used the knowledge produced by the Centres. Furthermore, available*

*evidence indicates that it is too early to fully assess the extent to which Centre research has been translated to the user community.*

As discussed in Section 4.3.1, the Centres have been active in the publication and communication of research results through academic journals and conference presentations. Of note, the October 2007 issue of the *Canadian Journal of Science, Mathematics and Technology Education* (CJSMTE), was fully dedicated to CRYSTAL Manitoba research. Also, education researchers from CRYSTAL Pacific and CRYSTAL Alberta were Guest Editors of the December 2007 special issue of the *International Journal of Science and Mathematics Education* entitled *Language - An End and a Means to Mathematical Literacy and Scientific Literacy*. Further, research from Centres have been presented at local, provincial, national and international conferences in a wide range of disciplines, including: science and mathematics education, chemistry education, educational administration, educational psychology, computer science, environmental science, and Aboriginal science and technology. In addition to academic conferences, Centre researchers, students and partners have presented on research projects and Centre activities at teacher association conferences, ministry of education meetings, and science promotion conferences.

CRYSTAL Centres have either organized or participated in many workshops and meetings as a means to translate knowledge and provide professional development to in-service teachers and the education community. In addition, these activities provide Centre researchers with an opportunity to disseminate and demonstrate the utility of learning resources designed to enhance the teaching of science and mathematics.

To date, the Centres have produced an extensive collection of teaching resources and materials, many of which have been posted on, or can be accessed through, Centre Web sites. In addition to the production of the resources, researchers from all Centres provide professional development activities to better support the uptake and use of the resources by teachers. The following findings provide specific examples of resources produced by Centre projects:

- ❑ CRYSTAL Pacific: With the guidance of an educational researcher, teachers at the first Lighthouse School have developed 11 exemplary unit plans and teaching materials. Unit plans and teaching materials include: Habitats and Watersheds (Grades K-1); Air, Water and Soil (Grade 2); Plant Growth and Changes (Grade 3); Weather (Grade 4); and Oil and Watersheds (Grade 5).
- ❑ CRYSTAL Alberta: The King's University College Centre for Visualization in Science has a Web site that allows for the free download of 28 visualization modules that describe, explain and predict scientific phenomena in the areas of modern physics, chemistry, climate change and elementary science.
- ❑ CRYSTAL Manitoba: A Centre project has developed over 200 "Resources for Chemistry Teachers" that include labs, activities, answer keys, and links to simulations and other resources, addressing most of the Grades 11 and 12 curriculum outcomes, and are available on the Centre Web site, supported by three PD days per year and by ongoing access to the researchers by e-mail.

These findings are consistent with the findings of the Peer Review Committee which report the Centres are disseminating research results and, in the case of a few Centres, recommend increased dissemination of resources and materials for teachers.

#### 4.3.4 Use of Research Results by the Education Community

**Key Finding:** *The mid-term review found that knowledge, and to a lesser extent the research results, produced by the Centres, are being transferred to and used by the education community. Specifically, knowledge regarding teaching strategies and pedagogies as well as curricular resources and teaching materials are being developed by researchers, often in collaboration with teachers, and used by teachers in their classrooms. At present, there is evidence that the use of Centre resources and teaching strategies by teachers are contributing to revision of teaching methods and the improved quality of science, mathematics and technology educations; however, many Centre projects are either in the earlier stages of evaluating research results or are still implementing research activities. Further, findings show that two Centres are making some progress towards contributing to the revision of curricula.*

There is evidence that resources, teaching strategies and research results are being used to improve the quality of science, mathematics and technology education. To date, findings suggest that resources and teaching strategies transferred from Centres to in-service teachers are being more readily used by the education community than the results of Centre research. This is due, in part, to the fact that many Centre research studies are still in progress, and the evaluation and testing components of the research projects are either not started or in the early stages. As a result, it is difficult to determine the extent of the use of Centre resources among in-service teachers.

Case study findings show that, among in-service teachers involved in Centre research and professional development activities, the use of resources and teaching strategies is very high. Teachers report that their involvement in Centre projects, as well as their use of new teaching resources and methods, has increased both their knowledge of, and comfort teaching, science and mathematics, especially among “generalist” teachers at the elementary and middle school levels who do not have a background in science or mathematics. Available statistics on traffic to Centre Web sites indicate increasing access, and use, of teaching resources and activities produced by Centres. For example,

- CRYSTAL Alberta: The King’s University College Centre for Visualization in Science Web site, that allows for the download of visualization modules that describe, explain and predict scientific phenomena, reports steadily increasing traffic during the first nine months of operation, reaching 3,800 visits (105,000 hits) in April 2008.
- CRYSTAL Atlantique: The Communauté d’apprentissages scientifiques et mathématiques interactifs (CASMI) Web site aims to develop scientific and mathematical literacy through problem solving using a collaborative virtual environment in mathematics and science education. There are now 10,000 members who have logins and passwords for the site. Of these, 7,000 are students in primary and elementary school and approximately 1000 are teachers in the school system. In a six-month period to the end of March 2008, 30,000 visitors visited 285,000 pages.

Further, findings from the CRYSTAL Manitoba case study indicate that culturally-responsive science units developed for Oikiqtani and Beaufort schools are being used territory-wide by Nunavut and Northwest Territories teachers and are likely to provide the foundation for the elementary science curriculum in Nunavut. In addition, chemistry resources for Grades 11 and 12, developed by the Centre, are being used in 24 school divisions in Manitoba.

To date, there is limited evidence to indicate that knowledge produced by the Centres is contributing to the revision of provincial science and mathematics curricula. Findings from the CREAS Sherbrooke case study



indicate that Centre is working closely with Éducation Québec to assist with the effective implementation of the new curricula. Specifically, the research on integrative teaching approaches (e.g., project-based learning, multidisciplinary approaches) has been useful for teachers who are increasingly expected to understand and use such approaches in the classroom. For example, one teacher indicated how the collaboration with Centre researchers has enhanced the teaching of technology within the integrated curriculum. CRYSTAL Manitoba has an ongoing collaboration with Manitoba Education, Citizenship and Youth and is regarded as a key source of science and mathematics education research by the Ministry. To date, Centre projects have contributed to changes to the Manitoba Science Curriculum in chemistry (Grades 11 and 12); science and social studies units with a historical perspective (Grades 4 and 5); Francophone resources for rural schools; and sustainability resources for middle and secondary school science courses.

## 5. Delivery and Design

This chapter of the report presents findings related to the delivery and design of the CRYSTAL Pilot Program.

### 5.1 Delivery of CRYSTAL Pilot Program

**Key Finding:** *Findings indicate that CRYSTAL has been largely delivered as designed, with each Centre implementing research, knowledge translation and outreach activities as planned in their proposals. Some projects within Centres have experienced delays or changes in the focus resulting from the withdrawal of researchers, challenges associated with conducting education research in schools and communities, or opportunities that have resulted in new projects.*

While the approach taken by the CRYSTAL Centres differ in both the scale and focus of activities, the Centres are examining distinct yet related aspects of science, mathematics and technology education. In general, the Centres have delivered their research, knowledge translation and outreach programs as proposed in their original applications to NSERC. The Peer Review Committee indicates that research, knowledge translation and outreach programs have been implemented as planned for all Centres, with the exception of CRYSTAL Pacific. Here, the Peer Review Committee recommended the continued funding for all Centres, with the exception of one conditional funding recommendation for CRYSTAL Pacific. As with any project, Centres have experienced some unexpected events that have resulted in a change of focus or scope of projects, but for the most part, these changes have been minor in nature. For example, CRYSTAL Alberta initially intended to create a Journal for School Science and Mathematics, which would be available on-line and contain reports by scientists and mathematicians on their research that would be complemented by lessons, outcomes and tools for use with students; however, it has evolved to become the CRYSTAL-Alberta Outreach Web site keeping the same content of the proposed Journal. This Web site presents the created prototypes for promoting mathematics and scientific reasoning through text and visuals; the visuals are accessed via a link to the King's Centre for Visualization in Science Web site. In some cases, such as CRYSTAL Alberta, CRYSTAL Manitoba and CREAS Sherbrooke, the early findings of some projects have worked to influence or inform the design and delivery of other Centre projects; it would appear that this process has been facilitated by the use of an explicit structure or theoretical model to design, and guide the delivery of, Centre programs.

Findings from the CRYSTAL Pacific case study indicate that the departure of the initial Centre Director and Node 1 leader in Year 2 affected the delivery of some Centre projects. Further, this event affected not only those directly involved but other members of the Centre, have hindered collaborations between Centre participants and created confusion regarding the objectives of the Centre, and, more generally, negatively affected the morale and team spirit of the Centre. Although work on Centre projects continued, the operations of the Centre (e.g., Web site updates) as well as team activities (e.g., meetings) of the Centre were disrupted and delayed. Evidence indicates that the Centre has taken steps to attempt to overcome this event, including the appointment of a new Co-Director, new Co-applicants within Node 1, and the development and implementation of a contingency plan for this node.

### 5.1.1 Integration of Centre Activities with Centre Objectives

**Key Finding:** *The level of integration of Centre research, knowledge translation and outreach activities varies across Centres, with the majority of Centres exhibiting a high level of integration.*

Findings suggest that three Centres exhibit a high level of integration between activities and main objectives, while the level of integration for the remaining two Centres is fair. The following design and delivery features were seen as facilitating a high level of integration:

- ❑ The use of a sound conceptual or theoretical structure with cross-cutting themes and approaches in the design and delivery of Centre programs;
- ❑ The establishment of one overarching Centre objective supported by a series of sub-objectives; and
- ❑ Strong communication and collaboration between Centre participants involved in research, knowledge translation and outreach activities to ensure that each area's activities align with one another and the objectives of the Centre.

In terms of factors that inhibit integration, the mid-term review found the following:

- ❑ A wide array of projects without established links;
- ❑ Lack of clarity regarding the development and evolution of the Centre; and
- ❑ The presences of "silos" between either Centre projects or Centre activity areas.

### 5.1.2 Challenges

**Key Finding:** *Centres have encountered three key challenges in the delivery of research, knowledge translation and outreach projects: conducting education research with schools and communities; involvement of researchers and students from the NSE; and geographical location of universities and schools involved in Centres.*

All Centres have experienced difficulties relating to the challenge of conducting education research in schools with in-service teachers, and communities. The key challenges are:

- ❑ Access to Teachers: Researchers and teachers interviewed indicate that it is difficult for teachers to find the time to participate in Centre projects on an ongoing basis. Reasons cited for this difficulty include: busy schedules of teachers; teachers are loathe to be away from their classrooms for an extended period of time; teachers lack the time and energy to participate; difficulties associated with finding substitute teachers; and difficulties keeping teachers involved due to turnover, changing positions and changes to teachers' timetables or teaching schedules.
- ❑ Labour relations issues in the education community: Three Centres experienced delays accessing schools and teachers due to labour relations issues (e.g., work action, contract negotiations) between teacher unions and school boards. These labour issues delayed the implementation and data collection activities of Centre projects.
- ❑ Time required for establishing research partnerships with user communities: Findings from two case studies indicate that Centre researchers have had to invest significant amounts of time to establish relationships, build trust and receive necessary approvals in order to be able to conduct research in schools and communities.

As discussed in Section 4.1.1, all Centres have experienced challenges involving researchers and students from the NSE in activities and projects. This is perceived as a challenge to the delivery of Centre programs because the participation of scientists and engineers, and to a lesser extent students, provides subject matter expertise and first hand accounts and examples of the process of scientific inquiry, which are regarded as critical to improving how science and mathematics is taught. Here, interviewees attribute the different cultures between education and natural sciences, the demands of the research programs and a lack of recognition or reward for participating in science education projects for the limited involvement of researchers and students in Centre projects.

For three Centres, CRYSTAL Manitoba, CREAS Sherbrooke and CRYSTAL Atlantique, the geography of institutions participating in the Centre has posed a challenge for project development and communication among participants. In terms of conducting research, the location of some participating universities and communities has meant that researchers must travel long distances to conduct research or meet with other researchers. While the Centre participants communicate via telephone and e-mail, some report feeling isolated from Centre activities because they are not located near or at the host university. To overcome this challenge, Centres hold annual, in-person meetings between researchers to provide an opportunity for face-to-face interaction between Centre participants.

### 5.1.3 Strengths, Weaknesses and Improvements

**Key Finding:** *Evidence from the case studies revealed three key strengths of CRYSTAL Centres and two areas for improvement to address areas of weaknesses.*

Findings reveal three key strengths of CRYSTAL Centres. First, Centres have established ongoing collaborations between education researchers, science researchers and teachers, which is building common ground between these three communities to address science education. Although the overall involvement of science researchers is limited, evidence indicates that the science researchers that are involved tend to be actively engaged in Centre projects. Second, the dedication and commitment of Centre participants is regarded as a key strength of the Centres, especially among scientists and teachers who participate in Centre projects in addition to their full-time workload. Third, interviewees report that the enhanced profile of science education within faculties of education, education communities, and local and regional communities that has been brought about by CRYSTAL Centres is a key strength.

Findings from all case studies indicate that Centre researchers and partners feel that a key area for improvement for CRYSTAL Centres is to increase the level, as well as improve the nature, of participation of researchers in the NSE. On this point, respondents had very few suggestions on how best to address this weakness of the Centres to-date. A few interviewees indicated that their Centre needs to re-engage some scientists through continued communication. A few others indicated that scientists and engineers need to be involved in a more meaningful and participatory manner in research collaborations rather than be regarded as a provider of scientific knowledge or expertise. Although it is too early to tell, a potential best practice or mechanism for engaging scientists and engineers in Centre research is finding projects that have a common research foci for education researchers and science researchers, such as the adapted-primary-literature projects undertaken by CRYSTAL Alberta. On this point, CRYSTAL Alberta researchers report that the adapted-primary-literature projects may prove to be a fruitful collaborative focus for education researchers and NSE researchers (i.e., the research interests and primary literature of scientists becomes a focus of research on classroom resources and instruction).

Another weakness of Centre delivery to date, and hence an area for improvement, is the integration of Centre projects with both Centre objectives and the Pilot Program's intended outcomes. For three Centres, findings from case studies indicate that there is a need to better integrate research, knowledge translation and outreach activities across Centre projects. For these Centres, the presence of "silos" between projects and activity areas, as well as the implementation of too many unconnected projects, have resulted in the lack of integration between Centre activities and objectives. Here, suggested improvements include increased communication between Centre management and participants as well as better articulation of the Centre's objectives to both Centre participants and NSERC.

## 5.2 Design of CRYSTAL Pilot Program

**Key Finding:** *Overall, case study findings reveal that the approach taken by CRYSTAL is considered appropriate by Program participants.*

Findings from four case studies indicate that the approach taken by CRYSTAL is considered appropriate to achieve its objectives; findings were mixed for the other case study. In particular, interviewees from all Centres indicate that the key design features of the program which make it appropriate are:

- ❑ The requirement of collaborations between education researchers, science researchers, the education community, especially in-service teachers, and the science promotion community; and
- ❑ The network structure of centres used by the Pilot Program because it allows for regional representation and a national focus.

In terms of the optimal number of Centres, few interviewees felt able to provide an informed opinion. For those who were able, most indicated that five Centres is a good start.

While deemed appropriate, interviewees feel that the approach taken by CRYSTAL faces a number of constraints and challenges associated with educational research in Canada that can limit the achievement of intended outcomes. For example, interviewees identify the following challenges:

- ❑ The fact that education is under provincial jurisdiction, which can limit the extent of the impact of the Pilot Program across provinces;
- ❑ The long timeframe required to conduct education research, as well as the long cycles for curriculum change – as one education researcher commented "Education changes at glacial speeds and is very resistant to change.";
- ❑ The level of the funding provided by the Pilot Program, given the scope of the objectives; and
- ❑ The fact that teacher release, which is an extremely important consideration when conducting education research, is not an eligible Centre expense.

### 5.2.1 Strengths, Weaknesses and Improvements

**Key Finding:** *Key design strengths of CRYSTAL identified by key informants were the establishment of an NSERC program to address science education and the objective to establish and support collaborations between education researchers, NSE researchers, education professionals and science promotion professionals. In terms of weaknesses, findings indicate the following three weaknesses with the design of CRYSTAL: the mechanisms and incentives in place given the level and nature of involvement of NSE*

*researchers; the lack of funding for teacher release to participate in Centre projects; and the timeframe and resources dedicated to CRYSTAL in light of its expected outcomes.*

Findings from the mid-term review reveal two key strengths of the Pilot Program. First, the establishment of a program by NSERC to improve the teaching and learning of science and mathematics is regarded as a very important strength and applauded by interviewees. Interviewees indicate that the presence of NSERC in the area of science education research has enhanced the profile of science and mathematics education research. For example, interviewees' comments indicate the importance of this decision by NSERC:

*It says a lot to science teachers that NSERC takes seriously the education of students who are not in university.*

*NSERC was ahead of the curve on this. They took a lot of criticism about CRYSTAL, such as for taking money away from other things, but it is an outstanding example of leadership on their part and was very forward thinking.*

Second, the objective to establish and support collaborations between education researchers, NSE researchers, education professionals and science promotion professionals is considered a key strength because these collaborations are perceived as essential to the improvement of science and mathematics education. In particular, interviewees indicated that the approach taken by CRYSTAL enables the development of a common ground among the participants and the capacity to address the objective of how to improve science and mathematics education from the required perspectives of those involved in science and mathematics education, including: pedagogy and education research (education researchers); content knowledge of science and engineering (NSE researchers); participation in, and feedback on, the design and implementation of projects in the classroom (teachers); and opportunities to promote science and mathematics education experiences and resources to teachers and students both in and out of the classroom (science promotion organizations).

Findings indicate two key weaknesses with the design of CRYSTAL. First, the lack of funding for teacher release is perceived as a key oversight by the Pilot Program because it is regarded as the critical factor for ongoing, active participation of in-service teachers in Centre projects. Also, the extent to which Centres have been able to secure funding for teacher release from ministries of education, school districts or schools varies significantly across Centres.

Second, the timeframe and funding for CRYSTAL in relation to its expected outcomes is considered a weakness. Education researchers and members of the education community indicate that it is unrealistic for the Pilot Program to achieve its intended objectives within its five-year timeframe. Here, education researchers indicated that it can take up to ten years to conduct and assess the effectiveness of education research. It is also noted that the process of curriculum change within the education system can take a similar timeframe. As one Partner commented:

*To effect change in the education system, where change in curriculum and implementation sometimes takes a decade to do, the funding is problematic. ... you don't just develop a resource, you might want to show the teachers how to implement it, but also follow the students to see if it is sustainable. You cannot do that in the short time that you have....*

In addition, the level of funding for CRYSTAL is small in comparison to the sum of investments made in the area of science education research, education research more broadly, and the education system. Given the scale of investment and the fact that CRYSTAL is not the only program supporting science education research, the impacts of the Pilot Program will tend to be limited and localized in a nature.

For the most part, improvements to the design of CRYSTAL are related to actions to address the identified weaknesses. For example, the following improvements were identified:

- ❑ Increase the involvement of science researchers in Centre projects by the development of mechanisms to recognize and reward scientists that participate in science education research;
- ❑ Funding for teacher release to increase the participation of in-service teachers in Centre research and professional development activities.

In addition, some key informants indicated that the involvement of the Social Science and Humanities Research Council (SSHRC) as a partner, and potential source of funding, would improve the design of CRYSTAL given that the research conducted by the Centres is education research, albeit with a focus on the learning of science and mathematics.

#### 5.2.2 National Networking and Leadership

**Key Finding:** *Findings indicate an ongoing need for a national networking and leadership role within CRYSTAL, especially in light of the lack of national forums for education policy in Canada.*

Representatives from Centre management were asked to what extent there was a need for a national networking and leadership role within the Pilot Program. In general, interviewees indicated a need to bring members of the Centres together to share research findings, identify commonalities, and explore opportunities for collaborations between Centres. Case study findings indicate that, to date, the two annual national conferences have provided a forum for approximately 80-90 participants including education researchers, science and mathematics researchers, representatives from ministries of education and school districts, teachers, representatives from science promotion organizations, and students to interact, network and learn about the projects undertaken by the Centres. In particular, interviewees feel that that the national meetings provide a structure for education researchers and NSE researchers to come together at a national level; a structure that Canada lacked until CRYSTAL, due to the absence of an active national forum for discussions regarding science and mathematics education policy.

While the annual national conference is perceived as an important aspect of the networking and leadership role, there is evidence to indicate that the effectiveness of this role has been limited by available resources and the lack of focused, ongoing interactions among Centres between conferences. The review found that a significant portion of the funding received by CRYSTAL Alberta to perform the national networking and leadership role is used to deliver the annual national conference. Travel costs, materials and supplies and interpretation for the first national conference represent 75 percent of the grant for national leadership and coordination, which leaves little funding to pursue other networking or coordination activities. Perhaps as a result, interviewees report that “not much has come out of” the four working groups established at the first annual meeting to address four priority issues in the area of science and mathematics education: marginalized populations; teacher education; use of language in science and mathematics; and outreach. Interviewees attributed the lack of “follow through” between conference to little ongoing support, a lack of a problem-based approach with explicit deliverables, and difficulties assigning responsibility and maintaining

momentum to produce working group reports. One respondent suggested that, rather than exchanging information at the conference (which can be done by e-mail), consideration might be given to having a more focused agenda. For example, a topic might be selected (e.g., the Canadian science, mathematics and technology curriculum) and researchers could be asked to submit papers beforehand, with the objective that the papers would be discussed and debated at the conference, and eventually published as a book that presents the findings of the papers.

### 5.3 Alternatives to the CRYSTAL Pilot Program

**Key Finding:** *Findings from the case studies indicate that CRYSTAL is a unique program with few comparable programs or potential alternatives in Canada. Findings from the Internet-based review of comparable science education programs provide some evidence of initiatives in other jurisdictions that are related to CRYSTAL.*

Overall, the vast majority of interviewees indicate that CRYSTAL is unique and are not aware of alternative approaches or programs that could achieve the same or similar results. At the national level, a program identified as similar to CRYSTAL was the *Imperial Oil Centres for Mathematics, Science and Technology Education*. Here, interviewees noted that there are two important differences between approach taken by CRYSTAL and the various approaches taken by the Imperial Oil Centres. First, unlike CRYSTAL, most Imperial Oil Centres focused solely on the dissemination of existing research in the area of science education for the professional development of in-service teachers rather than conducting science education research. For Imperial Centres that fund science education research, the funding tends to be for a series of smaller grants for research projects pursued by one or two researchers rather than to support an integrated, Centre-based research program. Second, the Imperial Oil Centres did not focus on establishing research collaborations between education researchers, science researchers and the education community to address science and mathematics education. In addition, interviewees indicated that the *Let's Talk Science* organization undertakes some outreach and professional development opportunities that are similar to the activities of some Centres. A non-profit organization, *Let's Talk Science* receives support from a number of organizations including the Royal Bank of Canada and the Canadian Imperial Bank of Commerce.

Internationally, a number of programs and initiatives exist; however, the scale and focus of these programs tend to differ substantially from that of CRYSTAL. The following are a few examples of science education initiatives in other jurisdictions:

- ❑ National Science Learning Centres, United Kingdom: The National Network of Science Learning Centres is a joint initiative by the Department for Education and Skills and the Wellcome Trust. The network consists of ten Science Learning Centres, including a National Centre, that deliver courses and programs in continuing professional development for science teachers at primary and secondary levels.
- ❑ National Science Foundation (NSF), United States of America: The NSF has a number of programs that focus on different aspects of science education ranging from funding for research and evaluation on science education (e.g., Research and Evaluation on Education in Science and Engineering Program) to programs to address the projected shortages of science, mathematics, engineering and technology professionals (e.g., Innovative Technology Experiences for Students and Teachers Program) to programs that seek to recognize faculty that bring the excitement and



richness of scientific discovery to a broad spectrum of students (e.g., Director's Award for Distinguished Teaching Scholars).

- ❑ Merck Institute for Science Education, United States of America: This initiative featured a partnership between the Merck Institute and the school districts of Linden, Rahway and Readington Township in New Jersey and North Penn in Pennsylvania through a five-year grant awarded in 1995 as part of NSF's Local Systemic Change initiative. The initiative focused on teacher professional development by providing teachers with opportunities to build a strong foundation of science knowledge and teaching skills.

### 5.3.1 Absence of CRYSTAL Pilot Program

**Key Finding:** *Evidence indicates that the absence of CRYSTAL would have direct negative impact on both the nature and extent of research and knowledge translation activities in the area of science and mathematic education.*

Centre participants were asked what the impact of the absence of CRYSTAL would have had on them. Almost all interviewees indicate that the absence of CRYSTAL would have a direct negative impact on both the quantity and quality of research, knowledge translation and outreach activities in the area of science education. Here, interviewees note that the Pilot Program has been an important initiative to both establish and catalyze activity, and in the absence of the Pilot Program these activities would likely have been pursued in a slower, more ad hoc manner or not at all. The following findings provide an indication of the impact of the absence of the Pilot Program on Centre participants:

- ❑ Education researchers: The impact would vary, with some researchers indicating that they would continue to conduct science education research and others indicating they would pursue other areas of research. Here, education researchers indicate that they would likely not have the same level of interaction and collaboration with science researchers and in-service teachers as they have had under CRYSTAL, or the same level of excitement about science education in their faculties of education.
- ❑ NSE researchers: The impact would vary from little to no impact for scientists and engineers not actively involved, to a significant impact for scientists and engineers actively collaborating on Centre projects. For the latter, without CRYSTAL they would be pursuing science education outreach in more limited fashion and likely not in collaboration with education researchers.
- ❑ Teachers: The impact would be fewer professional development activities (within the scope of Centre activities) relating to science, math and engineering, and fewer opportunities to access the knowledge, resources and expertise of science education researchers.
- ❑ Science promotion professionals: The impact would be little to no collaboration with education researchers and less knowledge about how to enhance the science education aspects of their programming and assess the impact of their programs.
- ❑ Students: The impact would be significant on education students, with respect to research opportunities in science education. The impact would less on NSE students, but the absence would mean that fewer NSE students would be exposed to science education research or participate in science education outreach activities.

Findings from interviews with unfunded applicants are consistent with case study findings. For five of the nine unfunded applicants interviewed, the activities proposed in their full applications have not been

pursued at all in the absence of CRYSTAL funding. In the remaining four cases, applicants reported that some of the activities have been pursued, but in a very limited fashion.

## 6. Conclusions

**Conclusion #1: The CRYSTAL Pilot Program is making progress toward the achievement of immediate outcomes.**

Available evidence from the mid-term review indicates that the Pilot Program is making progress toward the achievement of immediate outcomes. The Centres have established effective collaborations between researchers from education, natural sciences, mathematics and engineering; however, the number of collaborations between the education community and the NSE community has been limited to date. Active, ongoing collaborations are more common among education researchers than between education researchers and NSE researchers, with a few NSE researchers either having withdrawn from or involved in a limited capacity in Centre activities. All Centres have either established or enhanced collaborations with the education community, primarily in-service teachers, as well as the science promotion community.

To date, CRYSTAL Centres have involved an estimated 304 HQP, either full- or part-time, in Centre research activities. The majority of individuals trained by Centres have been undergraduate and graduate students in education or in-service teachers. Findings from interviews with both researchers and students indicate that participation in Centre activities has made a positive, and in some cases a significant, contribution to the training of graduate students in education. For the limited number of NSE students participating in Centre activities, evidence indicates that their involvement has enhanced the development of their technical skills or contributed to their knowledge of, and interest in, science education.

CRYSTAL has increased research and knowledge translation activities in science, mathematics and technology education, but it is difficult to determine the exact extent of this increase. Findings suggest that the CRYSTAL Pilot Program has increased the scale and changed the nature of research activities in science, mathematics and technology education. The majority of Centres (four of five) have surpassed their third year projected targets for scientific publications; however, it is difficult to assess the impact of these publications as well as the extent to which it has increased research activities in science and mathematic education given the prior existence of research funding and projects undertaken by Centre researchers and available information on Centre research projects. CRYSTAL has increased knowledge translation and outreach activities; with Centres having undertaken a wide variety of activities, most of which have focused on reaching in-service teachers. To date, Centres have conducted an estimated 677 knowledge translation activities targeting teachers and developed approximately 479 knowledge translation tools for teachers.

Findings indicate that Centre researchers are more aware of the needs and concerns of the education and science promotion communities and, in turn, members of the education and science community involved in Centre activities are more aware of the resources, knowledge and skills of Centre researchers. There is little evidence to assess the extent to which the Centres have increased the communication, collaborations and networks between the key players in science, mathematics research and practice in Canada. There is some evidence to suggest that the user community is influencing the research agenda of some Centres.

**Conclusion #2: The Centres are increasing the understanding of the skills and resources needed to improve the quality of sciences and mathematics, and the best ways to enrich the preparation of young Canadians in these foundation subjects.**

Findings indicate that the Centres are increasing the understanding of ways to improve science, mathematics and technology education for both researchers and teachers. Collaborations between researchers and teachers have increased the understanding of the need for, and how to best to improve, the teaching of science and mathematics, as well as providing the context to further this understanding through research to examine and test the best ways to improve science and mathematics education. Resources, teaching strategies and research results are being used to improve the quality of science, mathematics and technology education. To date, the resources and teaching strategies transferred from Centres to in-service teachers are being more readily used by the education community than the results of Centre research. This is due, in part, to the fact that many Centre research studies are still in progress and the evaluation and testing components of the research projects are either not started or in the early stages. As a result, it is difficult to determine the extent of the use of Centre resources among in-service teachers. Given the time required to establish research partnerships with schools and teachers, it is a noteworthy accomplishment that the Centres have been able to conduct research, produce results and begin to translate these results by the end of the third year.

**Conclusion #3: The CRYSTAL Pilot Program has enhanced the capacity of education researchers to conduct science, mathematics and technology education research.**

CRYSTAL has had a positive impact on both the extent and nature of their science, mathematics and technology education research. For some education researchers, the Pilot Program has increased their research activities by providing an opportunity to pursue projects that specifically address science and mathematics education research and enable them to conduct research with teachers in school settings. For other education researchers, CRYSTAL has had less of an impact on increasing research activities, as they were already actively conducting science education research, but instead, has increased the collaborative nature of their research. In particular, the Pilot Program has played an important role as a catalyst in establishing partnerships and collaborations between education researchers and the education community, especially in-service teachers. Findings from interviews with both education researchers and teachers indicate that the collaborations have enhanced the capacity of education researchers by increasing their awareness of the needs and concerns of teachers as well as how science and mathematics is currently being taught in K-12 classrooms. On this point, it is important to understand that the impacts of CRYSTAL tend to be localized in nature and need to be understood within the context of other investments made in science education in Canada.

**Conclusion #4: There is limited involvement of scientists and students from the natural sciences and engineering in Centre research, knowledge translation and outreach activities.**

The midterm review found that across all Centres there is limited involvement of NSE researchers in Centre activities, with only a few examples of effective collaborations established between researchers in education with those in the NSE. As discussed in Section 4.1.1, findings indicate that a number of factors have inhibited the continued, active participation of science researchers in Centre activities and research collaborations with education researchers. In general, there is little interaction between the education research community and the NSE research community. However, evidence indicates that CRYSTAL has

helped to facilitate the interactions and collaboration between education researchers and NSE researchers by supporting and legitimizing these collaborations.

There are a limited number of students from the NSE actively participating in Centre research and outreach activities. At the graduate level, a few NSE students are involved in Centre projects, with the limited involvement attributed to heavy workloads and busy schedules. At the undergraduate level, a few projects at a few Centres have been able to actively involve students in research and outreach activities. Typically, NSE students have been involved in the development of resources for teachers or outreach activities with in-service teacher and their students.

**Conclusion #5: Given the nature of the research being funded and the level of the involvement of natural sciences and engineering community, the continued funding and administration of the CRYSTAL Pilot Program solely by NSERC should be discussed by Council.**

The improvement of the teaching and learning of science, mathematics and technology has important bearing on the mandate of NSERC. The improvement of science literacy and numeracy of K-12 students in Canada will help to increase the supply of students interested in, and qualified for, university science, mathematics and engineering programs. This supply would, in turn, support the development of a pool of highly qualified science and technology graduates capable of conducting natural science and engineering research in either academia, the private sector or the public sector for the benefit of Canada. Within the context of supporting the “pipeline” of natural sciences and engineering graduates and the promotion of science literacy within Canada, the aims and objectives of CRYSTAL are consistent with NSERC’s function to “promote and assist research in the natural sciences and engineering.”<sup>7</sup> Further, the involvement of researchers in the natural sciences and engineering in Centre activities is critical to the Pilot Program’s relevance to the function of NSERC.

While within NSERC’s mandate, the findings of the mid-term review reveal that a substantial portion of the Centre activities supported by CRYSTAL necessarily pertain to education research and the training of future educational researchers and education professionals. Under CRYSTAL, these activities are intended to be focused on improving the teaching and learning of science and mathematics, but more broadly these activities are more consistent within the function of SSHRC to “promote and assist research and scholarship in the social sciences and humanities.”<sup>8</sup> That said, findings indicate the Pilot Program is a unique funding mechanism for supporting science education research that has attracted a lot of interest from the education research community. Here, education researchers report that funding for science and mathematics research in Canada is limited and represents a small proportion of the overall funding for education research. It is believed that NSERC has demonstrated leadership and raised the profile of science education through the Pilot Program.

It can be concluded that both the activities supported by, and the outcomes of, the CRYSTAL Pilot Program cut across the mandates of NSERC and SSHRC to varying degrees. At the level of activities and immediate outcomes, findings from the mid-term review indicate that most of the research, knowledge translation and outreach activities are being undertaken by education researchers and, in general, the

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<sup>7</sup> Natural Sciences and Engineering Research Council Act. 1976-77, c. 24, s. 27.

<sup>8</sup> Social Sciences and Humanities Research Council Act. 1976-77, c. 24, s. 5.

outcomes associated with these activities are accruing to researchers in education, students in education and in-service teachers. At the intermediate and final outcome levels, the nature of the outcomes more directly benefits NSERC and the natural sciences and engineering community (e.g., increase in students qualified for and interested in science, mathematics and engineering programs at the university level). The limited involvement of researchers and students from the NSE and the focus on education research activities indicate that the continued administration of the program solely by NSERC beyond the pilot phase would not be sustainable. Further, given the split of the activities and outcomes funded by the Pilot Program between the mandates of NSERC and SSHRC, the continuation of the Program beyond the pilot phase would require the joint administration of the program by NSERC and SSHRC. As a result, the continued role of NSERC as the sole agency responsible for funding and administering CRYSTAL beyond the pilot phase requires careful consideration.