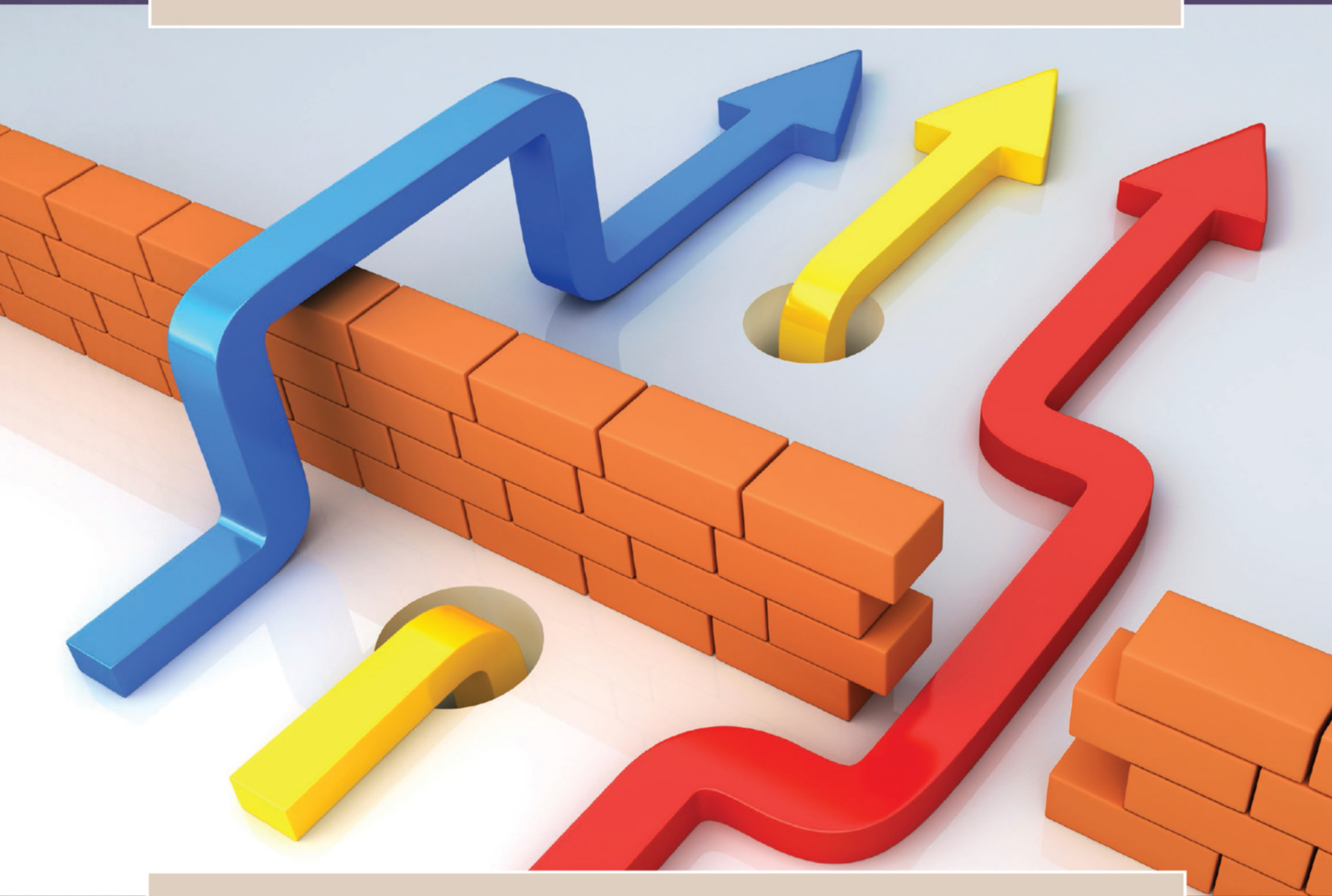
BOLD VISIONS IN EDUCATIONAL RESEARCH

New Ground

Pushing the Boundaries of Studying Informal Learning in Science, Mathematics, and Technology

Karen S. Sullenger and R. Steven Turner (Eds.)

Foreword by Jrène Rahm



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New Ground

Bold Visions in Educational Research

Volume 46

Scope:
Bold Visions in Educational Research is international in scope and includes books from two areas: *teaching and learning to teach* and *research methods in education*. Each area contains multi-authored handbooks of approximately 200,000 words and monographs (authored and edited collections) of approximately 130,000 words. All books are scholarly, written to engage specified readers and catalyze changes in policies and practices. Defining characteristics of books in the series are their explicit uses of theory and associated methodologies to address important problems. We invite books from across a theoretical and methodological spectrum from scholars employing quantitative, statistical, experimental, ethnographic, semiotic, hermeneutic, historical, ethnomethodological, phenomenological, case studies, action, cultural studies, content analysis, rhetorical, deconstructive, critical, literary, aesthetic and other research methods.

Books on *teaching and learning to teach* focus on any of the curriculum areas (e.g., literacy, science, mathematics, social science), in and out of school settings, and points along the age continuum (pre K to adult). The purpose of books on *research methods in education* is **not** to present generalized and abstract procedures but to show how research is undertaken, highlighting the particulars that pertain to a study. Each book brings to the foreground those details that must be considered at every step on the way to doing a good study. The goal is **not** to show how generalizable methods are but to present rich descriptions to show how research is enacted. The books focus on methodology, within a context of substantive results so that methods, theory, and the processes leading to empirical analyses and outcomes are juxtaposed. In this way method is not reified, but is explored within well-described contexts and the emergent research outcomes. Three illustrative examples of books are those that allow proponents of particular perspectives to interact and debate, comprehensive handbooks where leading scholars explore particular genres of inquiry in detail, and introductory texts to particular educational research methods/issues of interest to novice researchers.

New Ground

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Foreword by Jrène Rahm

Edited by

Karen S. Sullenger and R. Steven Turner
University of New Brunswick, Canada

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JRÈNE RAHM

FOREWORD

CRYSTAL Atlantique: Stories about Creating Possibilities, Releasing the Imagination, and Learning to Learn

This book about CRYSTAL Atlantique is a rich story about "*creating possibilities*" and "*releasing the imagination*" (Greene, 1995). In doing so, it moves the discourse towards new meanings of science education and engagement with STEM and its study by giving voice to all its participants. The centre was a product of the then new and temporary venturing into and funding of kindergarten to grade 12 science and mathematics education by Canada's national funding body for scientific research, the Natural Sciences and Engineering Research Council of Canada (NSERC). CRYSTAL Atlantique, one of the five centres in Canada at the time, was charged with the task to "increase our understanding of the skills and resources needed to improve the quality of science and mathematics education (K-12)" (NSERC, 2005). Transdisciplinary research, innovation, and collaboration among educators, scientists, mathematicians, researchers, teaching professionals, and practitioners supportive of life-long learning in science was sought. As such, the stories in this book attest to the kinds of possibilities such a complex mandate gave rise to among a set of very diverse authors and stakeholders who came together, initially maybe with some doubts and hesitation, and over time, became a community of practice committed to the study of informal science education.

The results of that partnership are told through rich stories that embody what Ingold (2013) refers to as *learning to learn* and as such, each story "aims not so much to provide us with facts *about* the world as to enable us to be taught *by* it" (p. 2, emphasis in original). In essence, the book engages the reader in a journey of learning about the Atlantic region and the kind of STEM research and possibilities that emerged through the NSERC-funded partnership over time, grounded in a complex spatial and temporal fabric and disciplinary boundary work most scholars still shy away from today. Some of the themes being discussed across the chapters address what it means to collaborate, what research methods matter, or why informal science might be particularly good at introducing children to the world of science and offering them the time to tinker with science and mathematics and get hooked, both through physical or virtual social interactions. What science matters, to whom, and when are issues central to the book. While engagement with mathematics or science might be driven by common sense and necessity for the Mi'kmaw, for others it is the passion of scientists that gets them in. For teachers, engagement in science clubs after school is an empowering means to try out new pedagogy and activities without accountability pressures, whereas for scientists and graduate students, engagement led to the practice of communicating science. For computer scientists engaged in the design of learning environments, the project became a means to learn about and become part of the STEM educational community.

What distinguishes CRYSTAL Atlantique from the other centres is its focus on informal learning in STEM, a neglected area of research in Canada and not addressed in this manner by any of the other CRYSTAL centres. In fact, this book makes evident in what ways misalignment among funding resources, goals, local practice (in terms of science and its infrastructure; formal and informal science), and issues tied to current accountability measures (increased focus on school science over informal science) undermined and seriously challenged the centre and the recognition of its achievements. Yet, we know so little about informal STEM learning in Canada, and even less about rural informal STEM education. There are also few studies that have taken seriously what STEM implies once conceptualized as stretched across time and space; emergent from and embedded in a complex system of repertoires of practices, formal and informal, among which children, youth, and adults navigate; and constituting ways of knowing and being in science. Still fewer initiatives have explored the richness in scholarship the bringing together of scientists with educators and practitioners brings about. This book begins these conversations.

Given that grounding, which I wish would be taken up further by NSERC and other funding resources in Canada through new initiatives given its pertinence to STEM education for the next century (Rahm, 2014), the work by CRYSTAL Atlantique led to some important messages. I briefly highlight five but many more would be worth noting. First, it led to a community of innovation and shows well that trans-disciplinary work and the bringing together of science and technology (i.e., computer science; distance education) with education is key to STEM, and possible. Second, the project got members of STEM together from New Brunswick and Nova Scotia in ways without precedence, and in ways that have much to teach us about the development of partnerships and collaborations that transcend spatial, temporal, and epistemological boundaries. Third, the book starts with a focus on culture and the place of science in youth culture and community in the Atlantic Canada region. As such, STEM was located and looked for at the interface of the formal and informal and explored in terms of their synchronicity and its meaning in place. It led to the recognition of some key features, such as its social nature and grounding in interactivity, time being an asset rather than barrier to learning, and the importance of learning and its activities being practical and relevant. The team developed activities that offered learners opportunities to become members of the world of science, at the elbows of scientists, online or through the asking of questions and the development of a disposition of curiosity. The book goes beyond the idea that learning is a solo act and leads to the accumulation of facts. Fourth, the second section of the book addresses the challenge of developing rich and solid research driven by methods that work in informal practices and that go beyond looking inside one specific program. What this may imply in practice was picked up well in the chapter on ethnomathematics and the Mi'kmaw community for instance, exploring the complex dialectic between culture and positioning of individuals, leading the authors to argue for the importance of community agency in STEM. It would make STEM learning locally relevant and empowering to the communities that still too often find themselves at the margin of science despite their rich local ways of knowing and being. Fifth, the project repositioned the different stakeholders by offering them opportunities to border cross into new identity work. For instance, teachers became "science people," then learners, and then facilitators. The project also led to the creation of new social networks and the making of the familiar unfamiliar given its longitudinal research design (four-year project). That the centre was not sustainable beyond the funding cycle is rather unfortunate, however, yet also hints at the need for further creativity and imaginations and actions at that level.

In closing, this book about CRYSTAL Atlantique offers a rich set of stories *about creating possibilities, learning to learn*, and a vivid illustration of what the "*releasing of imagination*" in STEM might imply—let's learn from it! How can we now get such centres going and make them sustainable, a priority for research and funding agencies, and mobilize findings like the ones reported here in ways to ensure equity driven STEM education in Canada and elsewhere?

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All those involved in CRYSTAL Atlantique want to thank the Natural Sciences and Engineering Research Council of Canada for having the foresight to create the CRYSTAL Project and commit to studying the potential, and the challenges, of learning and understanding science, mathematics and technology. We celebrate and recognize the steps NSERC has taken to bridge the gap between education and the sciences.

The papers in this book began as a special journal issue, but that approach to presenting our findings was abandoned when it became clear that a special issue was insufficient to capture the full range of new ground broken in the work of CRYSTAL Atlantique. We also want to acknowledge the three researchers who took their time to read and write a critical commentary on those articles for that special issue. It was from their responses we realized the need to undertake a larger work. Thank you Leonie Rennie, John Falk, and Jrène Rahm.

We also want to recognize the contributions of the organizations and people who supported our research in so many ways. Some supported our work financially with matching funds, with in-service time for teachers to participate, and with additional resources both technical and material. Some organizations allowed members to work with and/or on our research teams. They contributed time and funds to allow participants to travel for meetings, conduct data analysis, and engage in further study. These people and organizations were essential in our success; we are grateful for their belief in our studies. Thank you to the University of New Brunswick, Université de Moncton, Mount Allison University, St. Francis Xavier University, New Brunswick Department of Education (francophone and anglophone sectors), New Brunswick Teachers' Association, New Brunswick Innovation Foundation, New Brunswick Environmental Trust, Huntsman Marine Science Centre, Groupe d'éducation et d'écosurveillance de l'eau, Science East, CCNB Bathurst, Agence universitaire de la Francophonie, Nova Scotia Agricultural College, Groupe de Développement Durable du Pays de Cocagne, Environment Canada's EcoAction program, Toon Pronk with the New Brunswick Department of Natural Resources, David Lentz (UNB), Social Sciences and Humanities Research Council, Fisheries and Oceans Canada, NSERC's PromoScience program, and Biosphère de Montréal.

We are most grateful to the children, teachers, parents, and community members who participated in our research studies, who were interested in the programs we developed, responded to our questions, and allowed us to explore their experiences. Their enthusiasm and co-operation were indispensable and integral to any insights or successes we attained. We want to thank everyone who allowed us into their lives.

Finally, we want to acknowledge Ellen Rose, Essie Lom, and Alex Cogswell for their time and energy in editing and proofreading the chapters, and preparing this volume for publication.

Part One

CRYSTAL Atlantique—The Story

KAREN S. SULLENGER & R. STEVEN TURNER

CRYSTAL ATLANTIQUE—THE STORY

> *But actually coming in to CRYSTAL was a very similar experience for me. I had no experience of working with educators and people in education faculties. Very different. Different styles of research, different integration of theoretical and practical problems in schools, all very new to me. I must say very valuable. I've sometimes felt like an anthropologist looking at a different tribe since I've been here. (CRYSTAL Atlantique researcher)*

> *But when we had our conferences, I felt that that was really a great learning opportunity for me. And it certainly exposed me to a whole new area of research and discourse that was totally unfamiliar to me. And it did move me serendipitously to some really interesting research projects, which I probably wouldn't have done if it weren't for CRYSTAL. (CRYSTAL Atlantique researcher)*

> *What I like also is that in the CRYSTAL, we were allowed always to make a link between our research and outreach. And I liked that, because before I was doing both of them, and I was not sure it was okay to do that. But now, with CRYSTAL, I know that other people are doing the same thing and that it was important. (CRYSTAL Atlantique researcher)*

Canada's Natural Sciences and Engineering Research Council (NSERC) launched its CRYSTAL program in 2004 in an effort to promote research into science and math teaching at the K12 level. Educators were invited to form regional collaborations, often with practicing scientists, in order to compete for five funding streams ($200,000 yearly for five years). NSERC shared the widespread concern of the STEM community that too few Canadian students were choosing science as a career. NSERC thought that having scientists and educators conduct joint research would provide some insights into the situation and perhaps result in possible solutions. Our collaboration, CRYSTAL Atlantique, represented the Canadian Maritime provinces in the eastern part of the country. As one of the five final research sites chosen, CRYSTAL Atlantique has become a prototype, not only for demonstrating ways in which scientists and educators could work together, but for more effective and insightful research into informal learning. Table 1 lists each of the five national sites and their research focus or theme.

There are a number of firsts associated with the project CRYSTAL Atlantique. NSERC is one of Canadian federal granting councils charged with distributing

K. S. Sullenger & S. Turner (Eds.), New Ground, 3–35.

Table 1. National CRYSTAL centre themes

National CRYSTAl Centres	*Theme*
Pacific CRYSTAL University of Victoria	To promote scientific, technological, engineering, and mathematical literacy for responsible citizenship and ecological sustainability through university and community research partnerships.
CRYSTAL Alberta University of Alberta	To provide guidance to improve students' interest in and engagement with science and mathematics.
CRYSTAL Manitoba University of Manitoba	To increase students' resiliency by, first, recognizing risk and protective factors and second, minimizing risk factors and optimizing protective factors.
CREAS Sherbrooke Université de Sherbrooke	Contribuer à l'avancement des connaissances en lien avec les problématiques éducatives interpellées par les disciplines scientifiques à l'école et favoriser la formation à la recherche dans le domaine. Développer des partenariats et des collaborations permettant de réaliser des recherches collaboratives dans les milieux de l'enseignement et de la formation et favoriser la mobilisation, dans ces milieux, des savoirs issus de la recherche.
CRYSTAL Atlantique University of New Brunswick	To study the culture of science, mathematics, and technology within Atlantic Canada through informal learning.

federal research funding for science. The CRYSTAL (Centres for Research in Youth, Science Teaching, and Learning) was the first time NSERC had ever funded science education research. Education is a provincial responsibility in Canada and as such only indirectly influenced federally through the distribution of grant monies. The NSERC mandate was for five CRYSTAL research centres across the country, each with a different theme associated with science, mathematics, and technology.

The grant required that the research teams consist of both scientists and educators. It turned out this was the most difficult aspect of the program to develop for most groups; CRYSTAL Atlantique was the exception.

Other firsts within CRYSTAL Atlantique are that this project represented the first time francophone and anglophone educational researchers from the region had collaborated on a major project. It was the first time community colleges had served as members of a university-based research team in New Brunswick or Nova Scotia. It was the first time members of the science, mathematics, and computer science faculties from different universities had worked with science, mathematics, and technology educators. CRYSTAL Atlantique was the first time educators from New Brunswick and Nova Scotia universities had partnered in a science education research grant. Finally, it was the first time members of the informal science community partnered with universities in a research project. One of the things members of the research team noted in reflecting on CRYSTAL Atlantique's achievements was the significance of these firsts.

In this book, we explain who we are and how we came to be working together; we trace the nature of our interactions, encounters, and collective activities; and we interrogate our collective experiences with the project and reveal what we learned about informal learning in science, mathematics and technology. Equally importantly, we show how our work pushes the boundaries of informal learning research in ways that could re-vision the significance of informal learning and pose new approaches to studying informal learning contexts.

In addition to reflections on the CRYSTAL experience, this book contains chapters illustrating the kinds of research and research projects undertaken by members of our research community. During the development of this volume, each research chapter was reviewed by two outside peers. In addition, the set of drafts was then submitted to three internationally-recognized informal learning researchers, who wrote critical commentaries about the set of research pieces as a way of beginning a conversation—extending the ideas and findings. We are grateful to all those who took time to review the original research pieces and to the three authors who took time to read the entire set of research pieces and write a review. Their feedback and critique helped shape our work into a book. We do not refer to the reviewers by name here, but we do use the pieces they wrote as data/insight and refer to their feedback and the ideas they proposed. In preparation for the book and as a final responsibility/celebration of our work together, the CRYSTAL Atlantique research team met one last time in 2011 to reflect on who we were, what we had accomplished, and where we thought informal learning research needed to go. We came to refer to this gathering as the Reflection on Research meeting; the reflections came to inform much of what appears in this book.

WHO ARE WE AND HOW DID WE COME TO BE WORKING TOGETHER?

One could say, as we did in our original grant application, that we were a multidisciplinary group of researchers with a common interest in science, mathematics, and technology research who chose to study informal learning. In retrospect, that description so understates our work and accomplishments. The story of how we evolved into a community of researchers and how that common interest was identified and forged is much more complex and revealing.

We began as a group of relative strangers brought together by the opportunity of being awarded a national and prestigious grant. CRYSTAL Atlantique has a core of 13 principal researchers who formed research teams comprised of other researchers—members of community-based science organizations, instructors from community colleges, teachers, and undergraduate and graduate students. We were all from the Maritime region of Atlantic Canada, and we represent two language groups, English and French, though both of these are second languages for two of the researchers. We work at four different universities in two different provinces, four of us have science education as a background, one is an historian of science, three are scientists, two are mathematics educators, one has an interest in educational technology and instructional design, and two are computer scientists; and we engage in different research approaches ranging over quantitative, qualitative, constructivist, and critical theory.

How was such a disparate group able to work together, to find common interest, to move beyond being only a collection of researchers in one region? That is the story we want to share.

We came to the project with our own questions: questions that emerged from our own concerns, experiences—professional and personal, philosophies, and theories. For example, Steven Turner is an historian of science; his interest in science education and learning science grew from his concern and frustration with the lifeless science programs offered to his daughter in middle school and beyond. Chadia Moghrabi, a computer scientist, wondered what would happen if software development targeted for schools was developed for the learners, using their feedback. Bob Hawkes, who began his career as a teacher but was now an eminent physicist, believed that more high school students would pursue science careers if they had a more realistic understanding of what being a scientist, of what doing science, entailed. Each of us who joined the CRYSTAL Atlantique project contributed elements of what was to become a rich and complex landscape.

Each of us has a story—a set of experiences that led us to take advantage of this opportunity, to take a detour from our primary studies to explore these questions. In retrospect we realized that even this kind of detour is itself about informal learning. When we as researchers wander—step outside the structure, form, context of our carefully constructed and restrictive disciplinary research programs in order to look at new areas of study—we engage in border crossing. We push our own boundaries, our own learning. Often confined by our own area of expertise, we don't often get the opportunity to border cross. The CRYSTAL project was a chance and, in part, this book is about what it is for a group of researchers to wander outside their normal areas of study.

There were also external factors that impacted/shaped who we were and how we came to be working together. One was the application requirements. Another was the Maritime context, the region where we live and work. Three external criteria were imposed upon us by the requirements of the grant-proposal: one, we had to choose a theme; two, assemble a multidisciplinary team, not merely a collection of researchers, that included educators and scientists; and three, we were not allowed to change/shift our research direction/program throughout the five years. We welcomed these requirements, but whether out of naivety or eagerness, we did not recognize at the outset the challenges these requirements were going to place on our work and our relationship with NSERC.

During the Letter of Intent stage we selected our theme, invited science, mathematics, and technology educators, members of the science and arts faculties, community colleges, and members of the community-based science organizations across the Atlantic Provinces to join the research team. So limited is the size of the science, mathematics, and technology community in the Atlantic region that possibly everyone associated with the academic pursuit of these fields within the region was contacted by one or more of the three lead university research teams and invited to participate. We thought it essential to build a research team that included researchers from more than one province, from both the education and science communities, from First Nation groups, from the community colleges, and, especially, within New Brunswick, which is the only bilingual province in Canada, from the francophone and anglophone research community. At the Letter of Intent stage, our research team included most of those elements. Even at this stage though, we were still a group, a collection of principal researchers, collaborators, and partners proposing individual research studies connected by a common theme: studying informal learning as a way to explore the culture of science, mathematics, and technology in the Atlantic provinces.

Regional circumstances created immediate hurdles for our participation in the national CRYSTAL program. The Atlantic provinces of Canada—New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland—are mostly rural, economically struggling, and socially conservative. Universities are small in number and size by national comparison. The outcome is that there are few sources of matching funding or resources outside the provincial government and university systems. The University of New Brunswick is one of the largest employers in the province—the five New Brunswick universities are the second largest if you consider number of employees.

Planning for CRYSTAL Atlantique began almost a year before the actual announcement for the proposals. The New Brunswick Department of Education approached the University of New Brunswick to see if there was an interest in partnering to develop a regional proposal. While the government and university agreed to the partnership, they were unable to establish a regional agreement to one shared proposal. In the end, Karen Sullenger, a science educator, and Steven Turner, an historian of science, both researchers at UNB, agreed to lead the development of a Letter of Intent. The two of us favoured a theme that would see CRYSTAL Atlantique focus on the "culture of science" in the region, and explore informal science learning as a principle means of enhancing that culture. We posed the theme and contacted colleagues in other universities to see if there was shared interest in that theme. At the same time, we shared our thinking with scientists, engineers, and educators across the university campus to determine if there were others who would like to participate. We also identified a group of principal researchers and initial projects. After a joint meeting of all those interested to shape the proposal and levels of commitment, we wrote, shared drafts, and finally, submitted a Letter of Intent to NSERC. At the full proposal stage, we were selected as one of 16 proposals across Canada to be invited to compete. Shifting from the Letter of Intent stage to the Full Proposal allowed us to include other key researchers. At that point, we expanded our team to include two research teams from the francophone Université de Moncton.

NSERC was insistent from the start that its CRYSTAL collaborations focus on a single theme pursued by a multidisciplinary team of researchers and avoid working merely as a collection of discrete projects. The extent to which we at CRYSTAL Atlantique met this requirement was intermittently controversial throughout the lifetime of the collaboration. For example, outside reviewers hired by NSERC to review the CRYSTAL programs in the third year described CRYSTAL Atlantique's program as "separate silos" of research rather than a "team" undertaking. We, in turn, regarded this critique as unappreciative of the ambitions and scope of our "cultures of science, mathematics, and technology" focus, and as failing to recognize the unifying interest in informal learning, in all its many guises, that ran as a common theme through the projects that our collaboration pursued. The nature of larger interdisciplinary groups is that they can be construed as disjointed or multifaceted—depending on the experiences and perspective of the viewer. The larger concern we raise is who gets to determine whether a group of researchers are disjointed, working in silos, or a multifaceted research community—who is the authority?

Finally, we contend who gets to decide "what is going on" is an important question because there are consequences. In our case, despite how we framed our work, how we saw ourselves, others with more power decided differently. The concern over who should "have the say" (that is, be the authority) is the same kind of concern researchers in our group are raising about informal learning research, as you will see in the following sections.

Table 2 describes each of the principal research areas pursued by the principal CRYSTAL Atlantique researchers and notes the way in which each addressed the principal theme and five subthemes of our work:

- Examining children's understandings of science and scientists
- Exploring teachers' understandings of science, mathematics, and conducting research
- Understanding the use and impact of technology
- Using and developing resources and curriculum
- Investigating children's problem-solving and critical thinking abilities

In addition, we provide a brief overview of the research aims and goals of the each of the projects. Looking across the next few tables will give you an idea of the scope and complexity of each of these research projects.

Finally, at this early stage, we also agreed on an administrative structure. Karen Sullenger served as Director; Steven Turner and Dennis Tokaryk, a UNB physicist, served as the Management Committee and headed the Advisory and Program Committees respectively; and we hired an administrative assistant. A CRYSTAL Atlantique website was developed and maintained by the Community College at Bathurst. Diagram 1 depicts our administrative structure.

Table 2. CRYSTAL Atlantique research studies

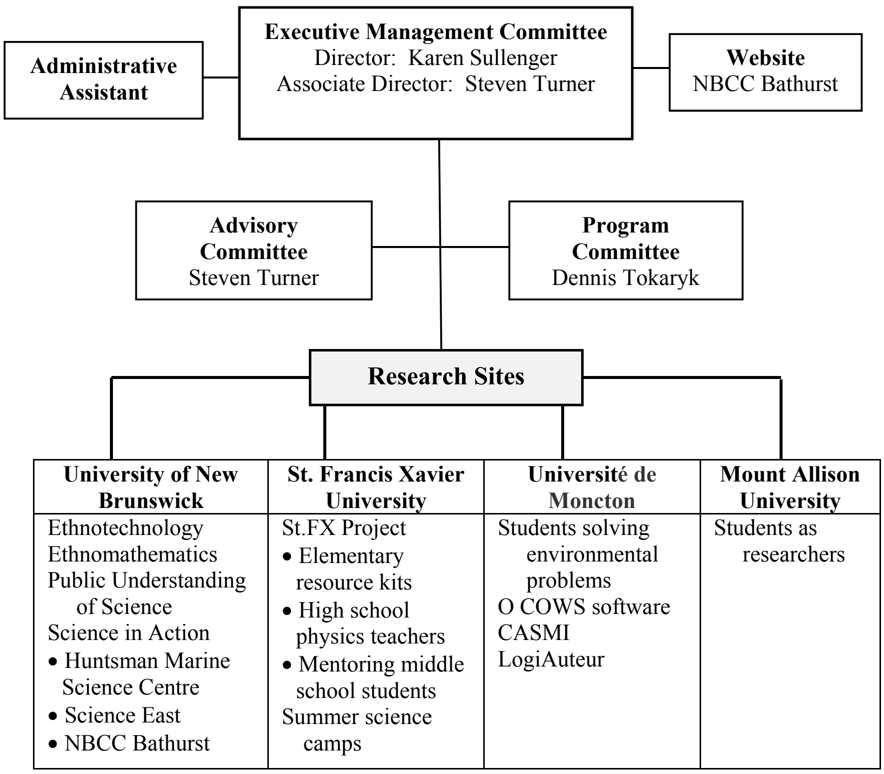
	Children's Understandings	Teachers' Understandings	Use and Impact of Technology	Resources and Curriculum	Problem Solving & Critical Thinking
CASMI The aim of this project was to develop a genuine problem solving community that unifies schoolchildren (K-12), teachers, and prospective teachers. CASMI (Communauté d'Apprentissages Scientifiques et Mathématiques Interactifs) is an online, interactive, multidisciplinary learning community. Members submit solutions to the challenging, open-ended problems, and receive personalized feedback.	●		●		●
Ethnomathematics Recognizing the need for community-appropriate, equitable mathematics education, researchers in this project conversed with members of dis-enfranchised communities about the mathematics practices associated with their cultures. Connec-tions were made between these practices and the mathematics done in academic settings. As part of this research, the "Show Me Your Math" program invites Aboriginal students to explore the mathematics evident in their own community, and share their learning at an annual math fair.	●	●			
Ethnotechnology This project investigated the informal instructional design practices of K-12 science and math teachers, as compared to the formal approach known as instructional systems design (ISD). Researchers interviewed teachers about their intuitive beliefs regarding learning and teaching, and how these beliefs inform their development of instructional activities and materials.		●		●	
LogiAuteur Traditional e-learning systems are not responsive to the needs and preferences of individuals. LogiAuteur was created as an adaptive hypermedia system, meaning that it personalizes its approach to better fit the learner. This Web-based course management system applies the theories of multiple intelligences and learning styles to adapt to the individual user.			●		

	Children's Understandings	Teachers' Understandings	Use and Impact of Technology	Resources and Curriculum	Problem Solving & Critical Thinking
OCOWS Software Can problem-based learning be adapted to software? Will software that is developed with users be more effective than software developed for users? For this project, researchers created OCOWS (Online Co-operative Working System), as a series of problems offered through software. OCOWS was designed to engage high school level learners in collaborative problem solving.			●		●
Public Understanding of Science This study examined teachers' thinking about the nature of science and its role in public decision making. What do teachers understand science-technology to be? What role do they see science and technology playing in the resolution of problems facing humankind?	●	●			
Science in Action What can young and middle level learners understand about scientists and their work through informal learning? An afterschool science program for upper elementary and middle school students was created where learners interact with real scientists and work on long-term projects. In the three-year elementary program, called the Whooo Club, learners investigated a different aspect of animals each year. In the middle school program, EcoAction, learners conducted in-depth studies of a piece of land. Learners not only grappled with questions and ideas scientists explore, they also studied skills scientists need to conduct their work.	●			●	

	Children's Understandings	Teachers' Understandings	Use and Impact of Technology	Resources and Curriculum	Problem Solving & Critical Thinking
St. Francis Xavier Project Researchers considered the relationship between scientists and non-scientists, and how informal learning might occur when these groups collaborate. In one study, science professor mentors partnered with middle and high school students; the students were then interviewed about their perspective on this mentoring relationship. In another, scientists developed kits for use in the elementary classroom, working closely with teachers to examine the value of such kits as a professional development tool. Another study paired physicists with high school teachers to adapt and develop classroom resources.		●		●	
Students as Researchers In the program Go Global: Science Research, high school students worked intensively as part of a university research group for about 10 days. These groups included other high school students, university student mentors and faculty. Students were exposed to the ways scientists actually work, live and interact. Researchers considered how such authentic experiences affect student engagement in and perceptions about science.	●				
Students Solving Environmental Problems This multinational, multi-phase project looked at how students pose and solve environmental problems, and how particular educational strategies might affect these skills. In the first phase, students spontaneously posed and solved problems. In subsequent phases, researchers introduced creativity and problem-solving strategies, including visual representation. One goal was to develop a model explaining problem solving.	●				●
Summer Science Camps What kinds of understandings of doing science do children engaged in science activities develop? At these week-long camps, children aged 5-14 years participate in scientific activities in an actual science laboratory setting. Under the guidance of science undergraduates, children dress and act the	●				

	Children's Understandings	Teachers' Understandings	Use and Impact of Technology	Resources and Curriculum	Problem Solving & Critical Thinking
part of real scientists, learning through role-play. Camp activities are designed to be hands-on and exciting, and are usually inquiry based.					

Diagram 1. CRYSTAL Atlantique management structure



As part of the negotiations leading the formation of CRYSTAL Atlantique, we worked together with all the principal researchers and partners who were associated with the original Letter of Intent and those who joined us from Université de Moncton to decide if we could amalgamate into one full proposal guided by one theme. We blended easily, and found ways of tweaking our theme, various research projects, and the growing number of researchers and partners into a unified vision. Table 3 lists the principal researchers, key research questions they explored, and the composition of their research teams. One outcome of the blending process was our name: “CRYSTAL Atlantique,” using the French spelling for Atlantic to reflect the two linguistic cultures that made up our research team. Another outcome was that every researcher committed him or herself to remain connected to the overall project. These governing positions, commitments, and connections were critical as the project matured and became the framework for our shifting from a collection of projects to a research network.

Table 3. Research Project Summary

Principal Researcher(s)	*Primary Research Area*	*Research Projects and Key Questions*	*Research Team*
Mount Allison			
Robert Hawkes Khashayar Ghandi	Physics Chemistry	Students as Researchers •What role does early research experience have for high school students on their perception of the nature of science and scientists?	Scientist (3) Research asst (1)
St. FX			
Leo MacDonald Ann Sherman (UNB)	Science Ed Early Childhood	St. Francis Xavier Project •How can the science curriculum be enhanced for students through action-rich experiences, and in what ways can teachers be supported to develop these experiences? •In what ways can teachers become involved in adapting existing resources and developing and utilizing new classroom resources? •In what ways might the mentorship of a science professor affect students’ understanding of and interest in science?	Scientist (3) Engineer (1)
Truis Smith-Palmer	Chemistry	Summer Science Camps •How might an informal science camp program foster student engagement in the learning of science? •In what ways might participating in such camps impact how undergraduate students understand and communicate science?	Grad Student (1) Undergrad science student (20)
U de Moncton			
Diane Pruneau	Science Ed	Students Solving Environmental Problems	Scientist (5) Educator (5)

Principal Researcher(s)	*Primary Research Area*	*Research Projects and Key Questions*	*Research Team*
		•How could we help students to better pose environmental problems? •Could creativity strategies help students to find more creative solutions to environmental problems? •Could students learn to make more sustainable decisions when we teach them a structured and reflective decision making process?	Engineer (1) Community group (3) Grad student (9) Research associate (3)
Chadia Moghrabi	Computer Science	LogiAuteur •How might the theories of multiple intelligences and learning styles be applied in an adaptive hypermedia learning management system?	Grad student (5)
Victor Freiman	Math Ed	CASMI—An Interactive Virtual Learning Community •Is it possible to develop a strong, sustainable community of online learners? In what ways can such a community be encouraged? •What informal problem solving activities can be organized in a virtual space? •How can learning be guided in a pedagogically meaningful and still informal way?	Math/Scientist (3) Grad student (6) Undergrad research asst (1)
Tang-Ho Lê	Computer Science	O COWS Problem-Based Learning Software •How might this approach affect the roles of teachers and learners? •Can this software facilitate co-operative and collaborative learning? •With skilful preparations, is it possible to avoid the "time consumption" issues commonly associated with the problem-based learning approach?	Grad student (4)
Univ of NB			
Ellen Rose	Instructional Design and Tech	Ethnotechnology •What are the "folk pedagogies" of science teachers—that is, what are their tacit beliefs about how people learn and how best to teach them? •Can the folk pedagogies of science teachers inform a new or revised instructional design process?	Grad student (3)

Principal Researcher(s)	*Primary Research Area*	*Research Projects and Key Questions*	*Research Team*
Dave Wagner	Math Ed	Ethnomathematics •What conflicts exist between the everyday mathematics in disenfranchised cultures and Western school mathematics? •How can this mathematical knowledge be incorporated into the learning and teaching of mathematics?	Grad student (1)
Steven Turner	History of Science	Public Understanding of Science •What factors shape public attitudes toward technology and science, as well as public readiness for civic participation in technical issues? •What are science educators' attitudes toward science and technology, and the special challenges of teaching science in the Atlantic Region?	Grad student (1)
Karen Sullenger	Science Ed	Science in Action •What do elementary and middle school students believe about science, scientists, and the work of scientists? •In what ways can afterschool programs be designed to help students develop more complex understandings of science and scientists? •What benefits might result when young learners interact with scientists and educators from community-based science organizations?	University educator (1) Teacher (20) Librarian (1) Grad student (4) Undergrad (8) Community group (4)
		Huntsman Marine Science Centre •Do the long-term education programs at Huntsman have any impact on the students' attitudes and interests toward science? •Does the students' experience at the Huntsman have any impact on their postsecondary decisions?	
		Science East •Do the education programs at Science East have any impact on students' attitudes towards science, or their abilities to learn science content? • Does visiting Science East and other science centres have any impact on what subjects undergraduate students choose to study at university?	

OUR COLLECTIVE ACTIVITIES, ENCOUNTERS, AND COMMUNITY

Turner and Sullenger had collaborated on research before undertaking/organizing this grant initiative. Consequently, we brought experiences and beliefs with us about how partnerships and group research work successfully. While Turner's research is grounded in the history of science with an interest in science education and the public understanding of science, Sullenger's research focus on science education included an interest in collaborative, participatory research. Early on in her doctoral studies she was introduced to Reason's (1989) notion of co-operative inquiry, which became a career-long research interest. Both Sullenger and Turner believe in the social nature of groups as the key to understanding meaning-making, though as a radical/social constructivist, Sullenger is more interested in the interactions as learning contexts. Reason argues participatory-style research should be inclusive, be driven by the group, not the individual, allow participants to choose their roles, and be responsive to the life circumstances and events in which researchers find themselves. We tried to realize Reason's concept of inquiry within our own research by inviting everyone who participated in the research to be part of the research team, allowing participants to choose the role they wanted to undertake, having research move forward at a pace the group set, and working with participants as they needed to step back or wanted to be more active depending on what was happening in their lives. Our intent was to bring this same dynamic to the CRYSTAL planning process.

While Sullenger and Turner proposed the theme of looking at the culture of science in science, mathematics, and technology through a focus on informal learning, they opened up that theme to approval and critique by everyone who wanted to participate. They introduced the proposed theme to other researchers to see if they were interested—was this an area of study they would like to undertake? Final approval came when we had discussed the idea face to face in an initial meeting and we all committed to that as our theme. Reason (1989) contends that co-operative inquiry is a process of different individuals making proposals but the group acting as decision-makers. The crux of any group is the give and take of the decision-making process. Reason's model, however, poses dilemmas that we would face later as the CRYSTAL research progressed. When does a group's decision make it impossible for an individual to continue? When does overall commitment to a project override individual preferences? How to establish a forum where people feel they can express themselves, feel heard, without alienating or silencing one another? All are questions that arise in such discussions and group undertakings; all have the potential to strengthen and/or constrain/reshape the work of those involved.

Turner and Sullenger found that at the beginning of the CRYSTAL project, no matter how many times people met to discuss and plan the research study, the group remained a set of quasi-strangers, each with their own reasons for participating and committing to the project. The initial realities of CRYSTAL Atlantique clashed with the rhetoric of NSERC and its expectations that, from the beginning, a unified team of collaborative researchers would be present. Their experience with CRYSTAL Atlantique, as well as their previous experience, led Sullenger and Turner to agree with researchers like Etienne Wenger, who argue that groups or teams evolve from the inside and cannot be mandated (Wenger, 1998; Wenger & Snyder, 2000; Smith, 2009). Only gradually, and with considerable effort, did the collective activities and encounters pursued by CRYSTAL Atlantique help shape the group into a research community.

Collective Activities

Throughout the six years of the project (2005-2011), there were activities we undertook collectively. That is, all of the research teams worked together to contribute to these events and tasks. Perhaps the most important activity was that we agreed to meet bi-annually. Also important was that we shifted the meeting site among the three universities in New Brunswick. The goal was to share the demands and driving distances across the research space. We were committed to shared ownership, shared responsibility for hosting and connecting. This collective endeavour was the foundation underlying our sense of being a research community.

In the spring of each year, we held a Colloquium series where everyone shared their research with one another. Invitations were also sent to the Department of Education and other educational organizations in both provinces. In Year Two, we invited the lead researcher from CRYSTAL Manitoba to be the major speaker. Each year thereafter, we chose members of our research team to be lead speakers and placed these talks on our website.

The Colloquium was held over two days, with day one and half of day two being a sharing of one another's research; the last afternoon was set aside for general business and updates from NSERC. Since these were works in progress, researchers presented updates, early findings, and asked for insights and feedback. It was during this process that researchers from the different fields began to gather ideas that could be applied to their studies and ask for assistance in using the strategies. The level of trust that emerged during this process is noteworthy. Research teams were open with the challenges they faced and the feedback they received. The questions asked fueled self-reflection and in some cases became the impetus for change and/or expansion. We combined lively exchanges with mutual respect for the ideas and research expertise each researcher brought to their project.

In the fall of each year, we held a second meeting aimed at updating and reconnecting with one another. This meeting was used to discuss our annual report and the presentation of our results to NSERC. We also used the time to review budgets and allocate funds for the upcoming year. Finally, we used the time to discuss and ask the bigger questions of interest to the group such as what counted as informal learning, the threads or patterns emerging across our work, and what were we learning about students' understandings of science, mathematics, and technology. We also discussed a growing tension between CRYSTAL Atlantique and our main funding body, NSERC. By Year Two, NSERC had begun to emphasize research of direct relevance to curricular matters and school-based results. That emphasis, however, clashed with the philosophy and practice of informal education that CRYSTAL Atlantique was committed to investigating.

Prior to the annual Fall meeting, the Board and Director met to review the budget and discuss any situations or issues that arose. In most cases issues and situations were considered by the entire research team but in some cases decisions were made by the Board. During any research project as extended as ours and as complex things are going to happen that impact the group. For example, we had researchers who left the project as they made career moves to other universities. Rules put in place by NSERC said they could no longer continue with the project. In other cases research teams wanted to divide and continue with separate studies. These kinds of situations have implications for the research—what can be accomplished by the remaining team members? Should we consider possible redistribution of funding if the studies cannot continue as planned? There were also deaths of family members that required time away from the studies and possibly a leave of absence. The leadership team had to consider the best course based on the requests of those impacted. Sabbaticals were another interruption in the research that the leadership group had to consider. In some cases the sabbatical opportunities were in areas outside the CRYSTAL research. Most research approaches consider such experiences—e.g. change in team composition, personal loss or crisis, or other research opportunities—to be disruptions, distractions, or annoyances. We tried to adhere to Reason's co-operative inquiry approach, in which these occurrences are regarded as part of the ebb and flow of the research process, embedded in the research life itself.

The mid-project review was conducted on behalf of NSERC by an outside consulting firm. An evaluation team was sent to each of the five projects to interview members of the research team, partners, teachers, and others engaged in various aspects of the research. This process was another activity we undertook as a collective. When the final report was received the entire research team met to consider the feedback and determine our response. The report praised our work, especially those projects that fit within the traditional view of informal learning such as outreach, or that provided an extension of or connection to schools and projects that were more practice-based. But we were reminded that we looked like a collection of projects rather than a collaboration, and that the new direction of the overall CRYSTAL program was that our work have an impact on schools. Did we want to change our direction or work? The group decided to stay the course, and insisted that there was as much value in the research not cited by the reviewers as in what they did highlight.

Each year, five researchers from each CRYSTAL were invited to an annual meeting hosted by one regional CRYSTAL and funded by NSERC. The three-day meeting allowed different members of the research teams to share their work and helped create an overall sense of the kinds of questions and issues being tackled by the five CRYSTAL groups. While there were attempts to connect the research of the five groups, in the end there was no lasting document to record the groups' accomplishments or conference to analyze and compare the results. Fruitful as the national CRYSTAL initiative proved to be, we regretted the absence of integration