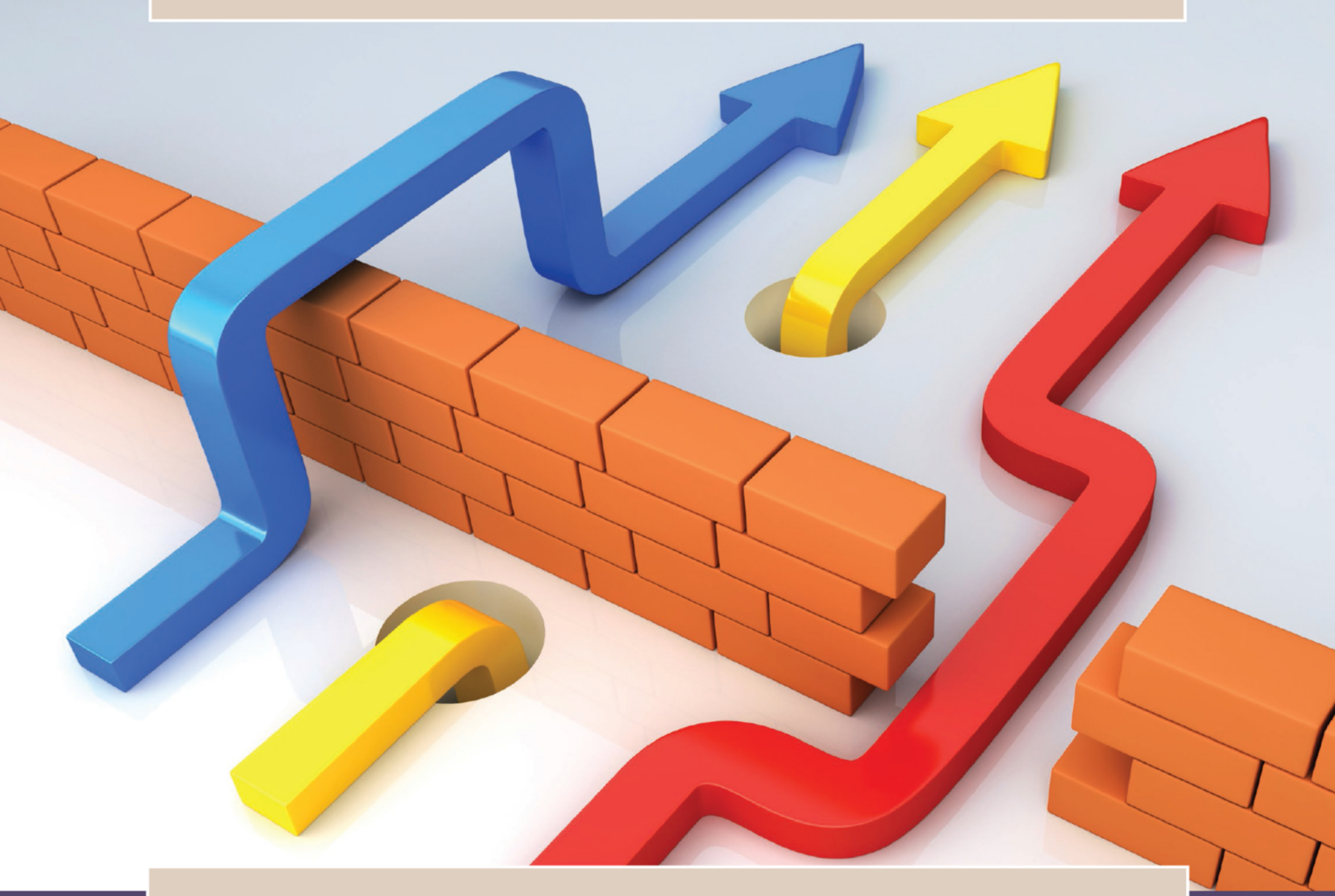
BOLD VISIONS IN EDUCATIONAL RESEARCH

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.

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

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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

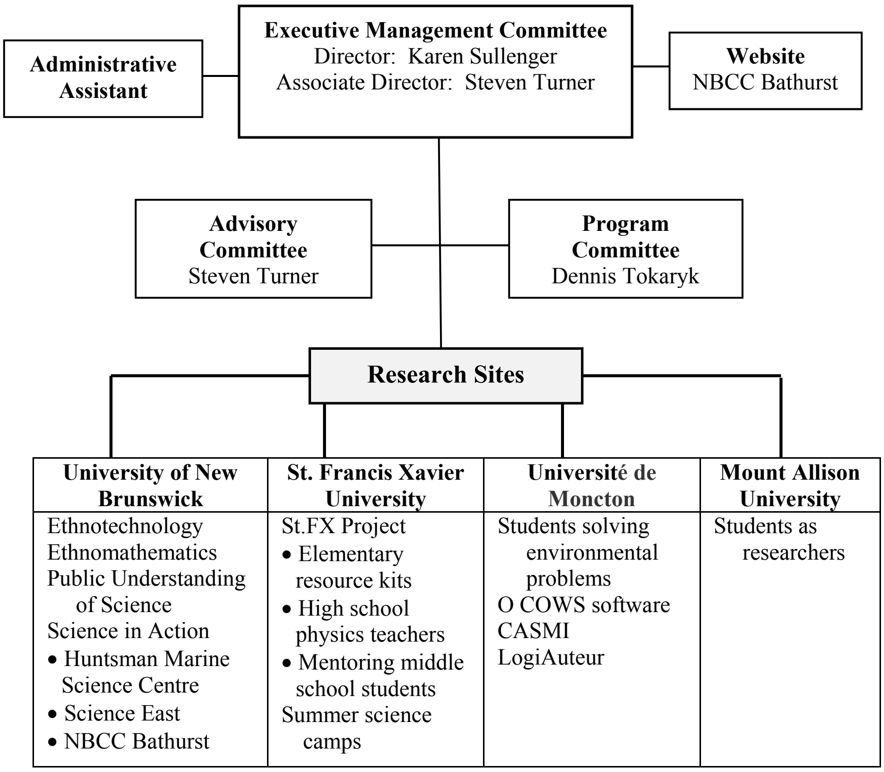
	Children's Understandings	Teachers' Understandings	Use and Impact of Technology	Resources and Curriculum	Problem Solving & Critical Thinking
CASMI The aim of this project was to develop a genuine problem solving community that unifies schoolchildren (K-12), teachers, and prospective teachers. CASMI (Communauté 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 disenfranchised communities about the mathematics practices associated with their cultures. Connections 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



University of New Brunswick	St. Francis Xavier University	Université de Moncton	Mount Allison University
Ethnotechnology Ethnomathematics Public Understanding of Science Science in Action • Huntsman Marine Science Centre • Science East • NBCC Bathurst	St.FX Project • Elementary resource kits • High school physics teachers • Mentoring middle school students Summer science camps	Students solving environmental problems O COWS software CASMI LogiAuteur	Students as researchers

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 or the attempts to provide it, and we regard the need for integration as a challenge for any such future national initiatives.

In Year Six, we held our final collective activity—what we refer to as the Reflection on Research meeting (also just the Reflection meeting). The activity was divided into five discussion sessions. The first was a general get-caught-up followed by a discussion of the fundamental question, “What do we mean by informal learning?” While this had been an issue of discussion throughout the project, the meeting represented our last opportunity to consider our responses in retrospect of our studies. In Session Two we were divided into groups across research institutions as much as possible. For Session Three, groups were determined by issues that had arisen during the project: the experiences of those outside education; those who had grappled with the limits of informal learning research; and those who studied learning science in versus outside the school. The research interests overlapped but people participated in the discussion most central to their interest. Session Four saw the groups formed according to areas of study: science, mathematics, and technology. The final Session Five involved the entire group in considering the questions, “What is the place of informal learning research in Canada?” and “What did we learn that might be of interest to others?” The outcomes of these reflections are described and addressed throughout the volume that follows.

Encounters

Building on these collective activities and group interactions, various members of the CRYSTAL Atlantique research team worked with one another, dare we say it, “informally.” In some ways it was these informal kinds of encounters that strengthened the network and the friendships throughout the years and helped to forge a shared sense of community. Even in Year One, people began to see connections among their work and research interests. By Year Three, researchers were conferring with one another about the research strategies they had developed and/or the activities they were using with their projects. Unlike classroom-based research, informal learning programs and activities have to be designed, developed, and implemented either prior to or as part of the research itself. In one case, the Department of Education became interested in one particular CRYSTAL Atlantique study that offered money for professional development and implementation of the project with teachers in schools; however, the funding could not be used to fund any research. We encountered other funding groups that would fund the learning experiences but not the research and vice versa. In the field of informal learning, designing and conducting the learning experience and the research are often inseparable, but it was difficult to find agencies and groups who would fund both.

Mostly, the researchers outside education began to implement research strategies and activities they learned from others in CRYSTAL Atlantique. In other cases, researchers saw connections and decided to co-author papers and presentations on aspects of their work that overlapped. Towards the end of the project, as well as in preparation for this book, researchers worked together in reading and providing feedback on one another's articles. As the research began to evolve, some members of the team saw connections with other projects and activities in which they were involved. CRYSTAL Atlantique also became an opportunity to reach out to and connect with other groups outside the actual research teams.

Some examples might be helpful in seeing the full implications and significance of these encounters. Those unfamiliar with qualitative research tended to utilize and rely more on survey instruments. However, once they saw the potential of the interview, observation, and other research strategies being used, they asked for help in developing their own instruments, especially interviews. One group shifted its entire data collection strategy in Year Three to focus on interviews and journals. In a different case, one scientist liked the ideas presented by a francophone colleague on how to use writing as a way of allowing students to explore and explain their understandings. He worked with her to see how he could implement something like that in his courses. This ability to mentor one another and share expertise was also evident when educational researchers hit the limits of their understanding of certain science concepts. Scientists and computer scientists across the project were willing to share their expertise.

Two researchers co-authored a paper and co-presented at an international conference. There were other instances where researchers from different studies co-authored presentations at conferences. It was the initial connections among our work that led Viktor Freiman to suggest that CRYSTAL Atlantique and the Atlantic Canada Association of Science Educators (ACASE) join with the Mathematics and its Connections to the Arts and Sciences (MACAS) group in hosting and presenting the three-day conference held May 12-15, 2009 in Moncton, New Brunswick at the Université de Moncton. During the three days, presentations representing each of the groups were attended by anglophone and francophone teachers, scientists, mathematicians, members of community-based science organizations, and educators from several provinces. One of the CRYSTAL Atlantique researchers was invited to give a keynote presentation.

We also wanted to reach out to the education community across the province and share what we were learning. Several researchers conducted workshops for teachers and district school personnel throughout the project. To promote science in the schools CRYSTAL Atlantique collaborated with the anglophone and francophone school districts and the francophone group within the Department of Education to arrange for two teachers from each district to attend the National Science Teachers Association annual meeting, which was being held in Boston, Massachusetts.

Community

As this summary of our activities suggests, the project and the CRYSTAL Atlantique research team were never stagnant—we evolved, emerged from changes, transitioned to new phases, developed networks, collaborated, worked through life events, and flourished. We became what can best be described as a research community much in keeping with Wenger's (2000, 2011) notion of a "community of practice." Like Wenger's, our experience suggests that research communities must grow rather than merely be assembled, and that any discussion of interdisciplinary or collaborative team research that does not foreground the processes of growth must minimize the work and accomplishments of its participants. What Wenger notes as a paradox is perhaps the key factor in promoting communities of practice: you have to give up control.

The Reflection on Research meeting played an important role in describing who we were—who we had become. We considered the question, Would you describe us as a collaboration, a unified structure as NSERC expected? Almost everyone said "No." They felt a collaboration meant working together more closely and on a more continuous basis than had been possible during the CRYSTAL experience. For them a collaboration was more what one person described as "systematically working together, helping one another." Another person added, "Maybe not a lot of collaboration, but a lot of connections." Some admitted to doubts that the group would ever "come together," but everyone agreed something like collaboration had happened, that there was an "emerging quality" to the project. There was a definite sense during the discussion that mandating people to co-operate would never work, especially if doing so did not interest them.

One person was willing to entertain the view that CRYSTAL had moved toward the status of a legitimate collaboration:

> And I will say that certainly by the end of CRYSTAL, I felt that I was a part of a collaboration. I guess one of the things that I found remarkable about the way CRYSTAL developed over the years was how it did develop as a collaboration. I'll be honest, there were so many of us, we were so diverse, different linguistic groups, different disciplines, different areas, different school backgrounds, that I wasn't sure that CRYSTAL would come together. That was one of my doubts. (CRYSTAL Atlantique researcher)

Another person added that at the beginning some projects did not even get started and others "petered out." Most agreed that it took us a couple of years for the final projects to become established or as this researcher put it, "After a couple of years, what was a good fit stayed."

One person commented that CRYSTAL's formation had been "an unusual way to form a team." He said that he usually met people at conferences or some other meeting and got talking with them, found common interests, and from there began to explore the possibility of shared research. In contrast, CRYSTAL Atlantique was more top down beginning with the call for proposals. However, the "top down" analogy ends there. While there were two researchers who initiated the idea of studying informal learning, joining the project was open to anyone who was interested. Information about the proposal was sent widely to all universities in the Atlantic provinces.

So, we asked, if "collaboration" in its usual sense fails to describe CRYSTAL Atlantique and how we came to work together, what term is more appropriate? One person suggested we were more a “network,” another suggested “a community,” and still another said that “a centre means many people who are neighbouring in their interest.” Building on this notion, someone noted, “Yes, we have neighbouring interests so that we could also be described as ‘intellectual neighbours’ or ‘theoretical neighbours.’” Continuing the conversation, another person said, “Neighbours, maybe, but a professional community”; “meeting may have been periodic but it influenced us to try new things.”

Finally, the point was made that time was important in creating the relationships that emerged. “Having support and independence is a luxury, it’s getting harder and harder to get funding,” one person commented. It was also pointed out that time was an issue in other ways. One person said, “All the sharing we did this morning, we could have spent the entire day.” In later discussions, the importance of time continued to be expressed—first, in terms of how often we met and, secondly, in terms of the length of the project.

We drew important conclusions from this discussion. For research groups created/generated by multidisciplinary grants to become synergistic, interactive, and establish links beyond their individual work, they must embrace/recognize that research is a social process that is context specific. Groups of people work within that social context to establish, first, an understanding of one another’s research projects and research skills/processes, and from there, second, identify common interests, possible solutions to research challenges and/or ideas of personal benefit. The synergy must come from within at a pace set by those involved in the conversation, in the studies and work being undertaken. Multidisciplinary research groups must be open to change and accept responsibility for both making and critiquing policy and guidelines. While the day-to-day workings of the project can be left to a Director and the Board, individual members of the team cannot relinquish their responsibility for the overall welfare of the group.

Our collective experience with CRYSTAL Atlantique was the halting journey of moving from being a group of quasi-strangers with vaguely similar interests, toward becoming a true research community, one continually more conscious of the commitments and interests that drew us together. Our experience, we believe, is common to multidisciplinary projects that pull together researchers with many diverse interests and scattered over a large region. Funding decisions and top-down mandates can call such groups into existence, but forging the synergies necessary to achieve their goals must come from within, and most existing models of research practice and research collaborations offer little practical advice on how that is to be done. The CRYSTAL Atlantique experience, however, suggests that Reason’s notion of co-operative inquiry and Wenger’s (1998) model of communities of practice provide us with the best insight on how groups of people shift from groups of academic strangers to establish interactions, collaborations, networks, communities.

In the book *Research Collaboration: Relationships and Praxis* (2007), Stephen M. Ritchie makes the argument that collaborations are the current research policy-fad of funding agencies. Governments feel groups of researchers are more productive, can tackle more complex questions, and they reward groups which undertake collaborative research projects. Ritchie also argues that there is little research on what makes an effective collaboration or whether assumptions made about them are valid. An extension of the collaborative research group is the multidisciplinary research collaboration, which is currently in vogue here in Canada. Again, there is little research supporting the claims that such teams are more productive and/or the results more insightful. In addition to there being little research evidence, we argue that policy decisions like the required or preferred use of multidisciplinary collaborative research teams, mixed methods research, and/or commercialization of research by funding agencies impact and can limit research direction and design.

However, our experience also suggests that interdisciplinary research groups may be the most effective context/vehicle for exploring research areas like informal learning. In our case, none of us studied informal learning as our primary research focus; in fact, one outside reviewer for the special journal issue contended that having informal learning as your research focus was not currently possible in Canada. Having a variety of researchers with differing research backgrounds allowed us to share expertise and offer new research perspectives with one another. In our case as well, we were studying informal learning contexts and aspects of informal learning that had little precedent in the research literature. So, perhaps, in cases where researchers want to venture outside their primary area of study, want to explore new research approaches, and want to extend the field of current study, interdisciplinary research communities may be the most effective context.

INTERROGATING OUR WORK: WHAT WE LEARNED ABOUT INFORMAL LEARNING

The Reflections meeting, like this chapter itself, presented us with the opportunity to draw together what we had learned about informal learning over the life of CRYSTAL Atlantique. That experience had been deeply self-reflective. In ways more than metaphorical, the researchers of CRYSTAL Atlantique found themselves unexpectedly engaged in a collective experience of informal learning not unlike those they designed for their own learners. This section recounts that experience and the journey of discovery it represented.

As noted already, the early proponents of CRYSTAL Atlantique began with a focus on culture. They wanted to know the place of science in the youth-cultures of Canada's Atlantic region—how science as a concept, an enterprise, and a field of study was perceived by young learners, and how it fitted into their identities and aspirations. A cultural focus seemed especially appropriate for a region marked by economic under-development, a strong Aboriginal presence, the existence of francophone and anglophone populations, and the relative absence in most communities of science-related role models and science-based careers for young people.

All of us were well aware of the large body of literature showing that cultural perceptions of science, in both children and adults, are not shaped primarily by school science, but by a diversity of other kinds of encounters beyond the constraints of formal schooling. In this way, our original cultural focus fitted perfectly with the concept of *informal learning*—with all the many ways in which young people acquire their information, attitudes, and aspirations about science from sources outside the formal science curriculum. CRYSTAL Atlantique's research focus on informal learning was to grow and intensify as the years went by and our engagement deepened and became more theoretical. The focus never excluded school-based studies, but it led us repeatedly to projects at the interface of the formal and the informal, and to the questions of their relationships and how the two could be best synchronized for the best outcomes.

What arose for us was the fundamental question, what constitutes "informal science education" and sets it apart from the formal? We quickly realized, as other researchers have observed, that even the advocates of informal science education usually define it in terms of what it is not, namely school classroom practices and curriculums. In lieu of definitions, discussants typically give lists of examples of kinds of informal science education, and these are often of sweeping scope. For example, in discussing the ways in which Americans get scientific information (other than in schools), John H. Falk listed libraries, museums (a generic term that includes natural history museums, science centres, zoos, aquariums, botanical gardens, arboretums, and nature centres), television programming (public, network, and cable), film and video, newspapers, radio, books, magazines, the Internet, community-based organizations (also a generic term meant to include organizations such as the YWCA, Boys and Girls Clubs, Scouts, 4-H, health-related organizations, and environmental organizations), and conversations with friends and family (Falk, 2001, p. 4). Similarly inflationary concepts of informal science education are encountered in the massive and highly regarded study of the American National Research Council, *Learning Science in Informal Environments* (2009), which includes hunting, nature-walks, and visiting one's physician among the sites for informal science learning (NRC, 2009).

We found such ostensive definitions of informal science learning, especially such sweeping ones, suggestive but impractical for guiding the work of CRYSTAL Atlantique. But should we use the term? John H. Falk and Lynn Dierking have long advocated replacing the term, "informal learning" with the term "free-choice learning." There is no evidence, they argue, that formal and informal educations represent fundamentally different types of learning. "Free choice" therefore emerges as the better term, since it captures what is personally and experientially unique about informal learning: it is (usually) nonsequential, self-paced, and voluntary. As much as we sympathized with this argument, CRYSTAL Atlantique chose not to follow the Falk-Dierking terminology. We view the formal-informal distinction as perhaps end points describing a continuum of learning contexts with the "other initiated/directed" contexts at one extreme and "self-initiated/directed" contexts at the other, with innumerable contexts between.

Practitioners and advocates of informal science learning have traditionally drawn sharp distinctions between the formal and the informal, together with occasionally invidious comparisons between the two. Canadian Jrène Rahm notes that in North America, informal science learning was originally associated with particular institutions, such as science museums, science centres, aquariums, parks, and television and radio programming. Studies of and writings on display-type institutions, especially science centres, still occupy an arguably disproportionate part of the research literature on informal science education. The identification of informal science education with institutions of this kind heightened and exaggerated the perceived dichotomy between informal science learning and school science, often to the advantage of the former. "Their educational role," Rahm writes, "was often conceptualized in opposition to schooling. They could offer low-risk experiences and self-motivated participation while also compensating … for lack of meaningful hands-on science activities in school …" (Rahm, 2010, p. 1). More recently a research literature on informal science learning environments, such as university outreach programs and after-school and community programs, has developed that blurs the formal-informal distinction. Nevertheless, Rahm argues, the "dichotomy between formal and informal learning … has been rather unproductive for the field …. Too often, all the good was relegated to out-of-school contexts and that which is repressive to schools" (Rahm, 2010, p. 1).

Navigating the political waters of informal science learning offered CRYSTAL Atlantique one additional challenge. In 2006, Zvi Bekerman, Nicholas Burbules, and Diana Silberman-Keller wrote formally what most educators already know: that formal education has long been the preferred daughter of educational theorizing while non-formal education has been relegated to the position of an exotic or poor relative. For the most part, policymakers who approach the subject regard much of non-formal education as supplemental, marginal, or recreational, i.e. not centrally important (Beckerman et al., 2006, p. 2).

While the notion of what counts as informal learning remained unchanged throughout the project, our internal discussions shifted from defining informal learning to considering its potential to do more than increase awareness, interest, and attitudes. At the final Reflection on Research meeting we asked ourselves, Does studying science in informal contexts work? Is it effective in developing more comprehensive, more complex understandings of science?

During our conversations, we discussed five aspects of informal learning that make it work and be effective. One aspect is that informal learning has the potential to provide a more interactive learning context. Two, time becomes an asset instead of a barrier to learning in informal contexts. Three, learning activities tend to be more practical, more relevant. Four, the context provides a model for what could be done, how students could grapple with ideas. Five, the social nature of informal contexts is normally more conducive to learning than formal contexts

Informal learning contexts work because they allow learners more interaction with objects, scientists, and people who are interested in science. As one researcher said, "Students are more involved in doing things and are allowed to touch things. With practice participants became more willing to write more, to explain, to share ideas, to disagree, to support their thinking, defend their thinking, to have information to support their ideas—ours also argued they were more willing to write when they figured out why they would need the information." There was a sense that students learned faster in this interactive environment as well.

Time in schools is carefully measured and so many things cannot be undertaken because of time. Everyone agreed that time, having more time to consider ideas, to reflect, and to redo activities, was another factor that made learning in informal contexts effective. One person's comments captured the sentiment of the group: "Well, I think the fact that you don't have to have something fit within a 50-minute period or whatever, that when you're a classroom teacher, you have a whole group of students that have to some degree reach a certain goal. You're largely free for that, and they are able to be somewhat self-directed." And another said, "It is important that they look at something but that they also have time to reflect—in class there is usually not time for that—experiential learning should include time for reflection—what did you learn, what do you think, do you have any new ideas, etc." Not only were people able to choose which times to work together, they could work on projects and activities over a longer period of time. Furthermore, not only was there more opportunity for face-to-face time, time could be extended virtually.

Informal learning offers more flexibility in terms of time as well, especially when one needed to attend to the needs of different kinds of learners. "Different kids need different mediums to express their understandings—they have different preferences and informal learning allows them more flexibility," pointed out one researcher. The argument is that being able to provide these alternative formats or mediums for learning take time, and flexibility—different learners need different amounts of time to accomplish the same tasks.

Some types of informal learning activities pursued by CRYSTAL Atlantique researchers offered greater practicality and relevance than activities usually pursued in formal contexts like schools, or even some kinds of informal contexts, such as museums and science centres. One person used this example: "Doing something that has a practical goal like Diane's environmental problem solving. It seems to me that's an important side of this as well, that the classroom learning is too often regarded as not relevant for that reason." Another gave the example of teachers working on informal learning projects that showed them what their students could do and grapple with: "And that working with the activities suggests in a way that there is kind of a revolutionary informal learning for teachers in classrooms where there is no professional development or support person." He went on to argue that in such practical contexts the students and teachers accomplish more by teaching themselves.

It was noted that the programs and activities the various teams developed modelled the ways in which students could learn. They also modelled how scientists work. Each of the programs considered a different approach to working with learners. As such, each provided a different model for how to learn in an informal context/setting. In the online math program called CASMI students of any age had access to different levels of math, chess, or science questions. They chose which questions they wanted to answer and how often. The program was shut down during the summer when there were not enough people to respond to the student's solutions. However, some students became so attached, so engaged in the activities, that when the program was activated for five days as part of a summer course, they found out and submitted solutions to problems. Students who participated in these programs were enthusiastic, they kept returning, and they developed learning skills. They also gained insight into how mathematicians and scientists work. One researcher said,

> Students gained a much deeper understanding of what science is really like—those that participated in working with scientists—you could see that when we read their journals. For example, things like realizing that, unlike science labs that you do that have been kind of pre-set up to work, at least most of the time, hopefully, or perhaps not hopefully, in research, much of the time you spend huge hours in something that doesn't work out. And it was clear that that was very obvious to them. Also, just how much work science was. You put huge amounts of work into a tiny, tiny, little issue, and then a huge range of skills and people you need to make something work, and many other things.

The longest conversation of the Reflections meeting was held about the social nature of informal learning. Students want to be engaged with other people in learning. In the online mathematics program, CASMI, there was no place for students to do more than submit solutions to problems at first and get a response from someone associated with the project. At one point, a "Contact Us" page was activated. Participants quickly began to ask questions of those "faceless" people who were responding to their submissions. They asked questions like, what is your favourite colour and who is your favourite singer? The research team ended up disconnecting the page because they did not have the capacity to keep responding to all the questions and conduct the rest of the research. However, the episode illustrated for us how learners crave interaction or connection, and how that need can often be met effectively in informal learning contexts.

It was also pointed out that the social nature of these informal contexts promotes risk taking. One researcher put it this way:

> Informal learning allows learners to take risks—to be risk takers—doing new things is intimidating but seeing other people around you in informal learning trying and taking the same steps—the social context of learning is encouraging and they are one another's role models—I use the metaphor of stepping…on the top floor of the CN Tower, there's a glass floor, and it's—I forget how many stories down, a hundred stories down maybe, it's a long way down. It's intimidating, right? And so, in order to take that step from the solid floor out onto that glassed-in area where it looks like you're stepping out into nothing, it takes a lot of courage to make that step. But it gets easier when you see those people around you in that same area enjoying themselves and doing that.

Besides encouraging people to take risks the social nature of informal learning is "contagious," as one person put it. Learners see other people involved and that makes them want to participate as well. Another person argued that "learning together is more successful than learning alone—by learning the process of something like problem solving or how scientists work, studying things helps them remember things more effectively and to make connections—it puts the scientists' ideas in perspective, context." This same person also argued, "they also learned much faster." Finally, the point was made that, "the boundaries between who is teaching and who is learning become more blurry. It is more okay in some sense for teachers/leaders to learn from the participants." The social nature of informal learning, for our group of researchers, was more about learners having a shared interest than increasing interest.

We pushed the discussion further and asked, if informal learning is effective, "What kinds of understandings of science and mathematics do they develop?" One person contended that,

> They (learners) understand who scientists are more complexly. They understand scientists' work better. They probably can tell you a lot of things about what scientists have learned about insects from their research, but they can also tell you about why they write, about how they come up with their questions or what kinds of things they study about insects—which was a shift from just coming in here and learning all you can about an insect.

Another person added, "They learned some of the processes like collecting data, the importance of making careful observations—both the teachers and the students—the idea that there is not one right answer—that making mistakes is part of the process—learning the processes helps them take more risks when they encounter ideas they don't know much about. They learned decision making, how to solve problems they could apply to new situations."

The notion of habits of mind—keeping records, sharing ideas, explaining, the need to write—was noted by a number of people. "They are not just learning vocabulary but the concepts behind them." One person described an example of a project which elementary level learners performed in which they applied ideas and experiences they studied as a group to studying an animal with a single partner. There were no grades, no marks. The students invited guests to a "fair" where they shared their projects. It was the expectation that they would need to know, to be able to explain, that was more compelling than a mark. Each group carefully constructed a poster or diorama to show to those who visited their display. For many of these young learners it would be the first time they were expected to be the "knowers." They learned about the animals from the work of scientists, what would scientists want to know? How would they study them?

Another area of discussion was about learning online, one of the more promising contexts for informal learning. There was a growing sense that learners acted, and learned, differently online than face to face. For example, there was "some evidence that students work differently when they solve problems using the computer than without—online they mix with an 'audience' and interact in social ways like saying 'hello' or Happy St. Valentine's Day—how many would do that on a paper and pencil activity?"

Among those studying online and face-to-face learning there was general agreement that learners were more willing to ask for help and try different problems than if they were merely using a textbook. One person noted, “Well, one thing they probably learn is that they can enjoy interacting with others on mathematics problems, which is something that you don’t feel in school usually.” People suggested the online learning experience was more interactive. The students did more initiating the experience and controlling the direction it took. However, it was also noted that students often get caught up in the colours and style and don’t focus on the activity. Even so, one person suggested that “students are much more adept with technology outside the schools than most adults.” Taking the conversation in another direction, those studying technology-based learning found it more difficult to determine what students’ reactions to the experience were. They were either anonymous, you did not know who you were interacting with, or they often did not want to hurt the researchers’ feelings with negative comments.

Studies of informal learning have often contrasted it favourably with school science or classroom science, noting the capacity of the latter for promoting disengagement, passivity, and rote memorization. Few members of CRYSTAL Atlantique accepted this critique of school science without reservation, or engaged with it directly. But all of us were aware of it, and that awareness underlined for us the unique potential of informal learning projects to promote and preserve learners’ interest in science, to hold open the prospect of science-based careers, and to encourage an engagement with learning science that students would carry back with them into their classrooms and daily lives. Engagement—how to encourage it, recognize it, and assess it—became the guiding concept that pulled together our diverse projects and unified our common journey toward a deeper understanding of informal science education and what it could offer our students and ourselves. The diversity of strategies for promoting and assessing engagement are displayed in the collection of research reports in this volume.

PUSHING THE BOUNDARIES OF INFORMAL LEARNING

The Reflection on Research conference held at the conclusion of CRYSTAL Atlantique not only gave us a collective opportunity to look back on our experience, it also gave us an opportunity to look forward to the future of informal science learning and research into the field. We argue in this book that the borders of informal learning are too restrictive, especially in what is considered informal learning research. We also argue that our work represents what that kind of research might look like, and as such, what we learned about such an undertaking, what we accomplished.

Accomplishments

So, after our review of how CRYSTAL Atlantique came to be, how it evolved, and what we learned, both about informal learning itself and how to do research into informal learning, what can we look back on as some of our specific achievements? As we have already noted, within the informal or free choice learning community we are outsiders. None of the lead researchers had previously worked or conducted research with science centres, museums, afterschool or outreach programs—the mainstream activities of informal science learning and research. However, we believe that our status as outsiders was valuable in allowing us to push the boundaries of informal learning studies. Within the few years of our work we achieved a number of modest though significant accomplishments.

As researchers and scholars, we crossed academic and research boundaries ourselves—an accomplishment in itself. But the real accomplishment was the number of new researchers we introduced to research and mentored in investigations of informal learning. Throughout the project we problem-solved, introduced new research approaches to one another, and developed new research strategies. During this process we also introduced an array of teachers, members of community-based science organizations, community colleges, and graduate students to the research process. Across our studies 16 teachers and one district science education specialist worked with us as researchers, with three of them going on to pursue Master's degrees, though not associated with the project. Most of these teachers helped to develop and deliver the programs in addition to participating in research activities from interviewing to data collection and analysis. A number of the teachers also presented findings at international and regional conferences and wrote articles for local newsletters. Six educators from community college and community-based science groups also participated as researchers and were especially helpful in developing program curriculum, data collection and analysis, and sharing our findings at conference presentations and in articles. The district science education specialist and one educator from the local Science East centre began Master's degrees as a result of their participation in the research and program development.

Eighteen undergraduate students, some pursuing careers in education and others in science, chose to participate in the research as well. Most of the prospective teachers worked to develop curriculum, undertaking tasks like acquiring and organizing tools and equipment, critiquing books and reading materials, and working with teacher-researchers in the schools. Another 18 Master's students participated in research design, data collection and analysis; presented findings at regional, national, and international conferences; and co-authored articles. In addition, 16 graduate students pursued Doctoral degrees as part of the various studies. They also oversaw parts of the research, collected and analyzed data, made conference presentations, and authored research articles. Of these graduate students who participated as researchers, nine completed a Master's degree and four completed their Doctoral degree.

Another accomplishment was the spectrum of ways we shared and communicated what we learned. Over the years, we shared our work with local and regional educators, including teachers and district personnel, in non-research settings. Online we established scientific cafes, in person we conducted workshops for hundreds of teachers. One team prepared seven CDs of educational guides that were available to district personnel and teachers. Another group developed science kits that were given to teachers and left for them to use as they wanted. Other researchers conducted public lectures. Several of the teams established websites to accompany their programs that were available to other educators and the public as well. CRYSTAL Atlantique itself developed a website for the project.

Many teachers and other educators agreed to participate in our research projects, including the high school teachers and students who learned to use and critique problem-based learning software working while working with Tang Ho Lê, and who studied the impact of considering multiple intelligence and software development with Chadia Moghrabi. Other teachers participated with Steven Turner in exploring the question of middle-school disengagement from science, and shared their personal perceptions of science and technology in its relationship to society. Teachers took time to share their ideas about being introduced to and using technology with Ellen Rose. Teachers, students, and leaders from First Nation communities helped Dave Wagner to understand their perception of mathematics in their community. There are too many to thank individually but across the projects, thousands of students locally, nationally, and internationally participated. Hundreds of teachers gave us their insights and time as well. We owe no small measure of appreciation for their participation and the success of our work.

Our accomplishments included the number of the researchers and their teams who participated in local, regional, and international conferences, and in Year Four, the joint conference among CRYSTAL Atlantique, the international mathematics association MACAS (Mathematics and its Connections to the Arts and Sciences), and ACASE (Atlantic Canada Association of Science Educators). University, school-based, and science-organization-based researchers presented their work to those attending. Earlier in Year Two, Sullenger had proposed to the Departments of Education in New Brunswick, Nova Scotia, and Prince Edward Island that they collaborate to send a group of teachers to the National Science Teachers Annual Conference to be held in Boston. A busload of more than 50 anglophone and francophone teachers from the three provinces attended the conference.

In addition, researchers developed programs and shared their work with students/learners across New Brunswick and Nova Scotia. From annual classroom visits made by Truis Palmer to share chemistry with students, to Victor Freiman's CASMI website on mathematics, science and chess problem solving, our work impacted the science, mathematics, and technology understandings of those who participated. Science camps drew more than 5000 students over the six years. An after school program we instituted called Science in Action had more than 500 participants of upper elementary and middle school age. Thousands of students worked with L'Affaire Climate and used educational CDs developed by Diane Pruneau and her team. Bob Hawkes and Khashayar Ghandi and their team of scientists mentored over 40 high school students attending the summer residence science program at Acadia University. Hundreds of students worked with the science kits developed by Leo MacDonald and Ann Sherman and hundreds more tried out physics problems developed with their teachers and physicists. The Show

Me Your Math program, led by Dave Wagner, drew hundreds of students, teachers, and members of First Nation communities. These programs, and the research results based upon them, are described in more detail in the chapters that follow.

These informal and out-of-school programs we implemented and studied clearly show that when informal learning experiences are provided, students are drawn to them. If the programs were provided on a consistent basis, we argue that interest would grow, strengthening and enriching the culture of science, mathematics, and technology that currently exists in the region. We also note that these kinds of programs need continued involvement of those who create them. However, the example of CRYSTAL Atlantique shows that while research programs may be valuable means to create and launch informal learning initiatives for science, they may not be useful instruments for sustaining or perpetuating them. Of the over 20 programs and projects we initiated and studied, only four of them extended beyond the life of the grant. One had been initiated before the grant but on a much smaller scale but it continued and expanded after the grant period. Another project continued as part of other research grants with international partners—whether it will continue beyond these additional grants is unknown. Still another project was continued by one of the key researchers who took it over for that research team and continues it as part of her current research. The fourth and most successful program expanded to tens of thousands of students and other learning areas beyond science and mathematics. Even so, the continued oversight of the program was taken over by other researchers, as the original researcher's research interests shifted.

At the same time, we also communicated and shared our work in the more academically traditional ways through conferences and publishing. As a group, we presented at just over 20 regional conferences, almost 50 national conferences, and over 100 international conferences. This is accompanied by 30 publications in conference proceedings. Team members contributed three book chapters, 14 reports, and 44 refereed publications in addition to the works in this book. The network of new researchers we met in this process is still another aspect of our accomplishments. Some of these connections led to invitations to attend conferences, and requests to be guest speakers and critics. In two cases, the networking led to extending research studies by partnering with other scholars on new grants. Networking is a silent, unrecognized aspect of research that deserves more attention.

As you will note in the chapters that follow, we learned a number of things about children's understandings of science, mathematics, and technology. For example, we learned that interest is the key to students' success and wanting to stay in the programs. This shared interest resulted in students who may never have interacted with one another in the course of a school day, working closely together and forming friendships that wouldn't have been precipitated or possible in the school context. We also learned that children are capable of learning far more than we expect in current curriculums. Even young learners are capable of critical thinking, learning to solve problems, and grappling with complex issues. In a last example, we learned that students want to be engaged in programs that are intellectually engaging and in which they have choices. They prefer tasks and problems that engage them personally and emotionally. We found that students become attached to the place they study as much as to the ideas they study and the people they study with. As one reviewer of the journal chapters noted, our work looks beyond the more traditional questions such as learner attitudes and level of interest.

These findings are consistent with the notion of engagement put forward by researchers like Appleton et al. (2008) and Reschly and Christenson (2012). Student engagement is defined by them as having subcomponents requiring learners to have an intellectual, behavioural, and emotional connection to academic ideas and concepts. Others, such as Axelson and Flick (2011), suggest all definitions surrounding engagement are insufficient, too vague, and need clarification. Researchers like Vadeboncoeur and Rahal (2014) argue that engagement in out-of-school activities is an outgrowth of the social relationships that form between youth and adults. They write that exploring these social relationships and the contexts in which they develop can help explain why youth continue to participate in certain activities—why activities become more meaningful. There are also researchers like Azevedo (2013) who believe that the study of engagement as an outcome of interest is flawed. Azevedo argues that the concept of interest lacks an adequate theoretical foundation. He goes on to say that explanations of both students' interest or lack of interest in certain activities cannot be explained by current theory.

Our work supports the need for more research and discussion of the notion of engagement. We found, for example, that another important aspect of engagement is attachment to place. For example, you will read in the articles ahead of how children became attached to the river they were studying and the effects motorized vehicles were having on it, and in another case the attachment middle school students felt to their piece of land when the question of it being developed was raised. In another instance, participants became attached to the online program where they could pose answers to various problems. The website was closed for the summer except for a two-week period when it was used as a learning activity for prospective teachers to develop questions. In that time period—even though they had been notified it was closed and had been closed for a month—learners found the site open and sent in their responses. The argument that students are under-challenged in schools is not new. Even students who struggle are often under- or inappropriately challenged. The students we worked with demonstrated high levels of interest, self direction, and a willingness to grapple with ideas even when they were not initially successful. What they want is connection—intellectually, personally, emotionally, and to place. Even if that place is a website.

To date engagement has been primarily considered as a psychological construct—that is, as a desired behaviour. However, we know that learning is as much a social construct and process as it is an individual endeavor. Learning in informal contexts acknowledges, more so embraces, the collaborative, social nature of learning. While schools eschew the social nature of learning in favour of individual efforts and accomplishments—foremost, in the assessment of such accomplishments—informal learning has the potential to explore other aspects of engagement such as its sociological, cultural, and educational nature.

But perhaps our most significant accomplishment is our questioning of the status quo in informal learning research. In Part Two of this book we offer stories from our research that represent examples of our exploration into informal learning. The chapters in this section were submitted by interested members of the project team on topics they wanted to share. Based on the conversation during our final Reflection on Research and the papers themselves, the three themes for these articles emerged.

The first theme is explored in Section I: we call it "Voices Outside Education." The papers there collect the contributions of researchers in the natural sciences and in computer science. They demonstrate the unique perspectives that researchers outside the field of educational research per se can bring to the study of informal science learning, and they illustrate the many opportunities that exist for collaboration with educators.

The second theme, explored in Section II, we call "Questions and Dilemmas Associated with Informal Learning Research." Their team members describe the issues and concerns encountered as they conducted their studies. These chapters also offer examples of new approaches developed to address or resolve outstanding problems posed by the context of informal learning itself, the needs of the learner-participants, and the research questions themselves.

Section III addresses the theme, "Alternatives to Science in School," and the studies presented there explore the potential of informal learning to better serve the development of more complex understandings of science than those of the formal classroom. They seek to shift the conversation from how informal learning can enhance school learning to how it can be a learning context in its own right.

Finally, in Part Three, we briefly address several proposed, new directions for informal learning research, and we bring participants in CRYSTAL Atlantique again to centre stage, to offer their own reflections about our story, our achievements, and the future of research into informal science learning.

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Part Two

Research Stories from CRYSTAL Atlantique

Section I: Voices Outside Education

R. STEVEN TURNER

INTRODUCTION

From its inception, CRYSTAL Atlantique sought to heavily involve researchers with academic specializations in fields other than education per se and those who held institutional positions outside faculties of education. Their involvement was considered crucial to the focus on informal science learning and the attention that was to be paid to regional science-culture.

This commitment was reflected from the start in the management structure of CRYSTAL Atlantique. The three-person team of co-directors, located at the University of New Brunswick in Fredericton, consisted of an educator from the Faculty of Education, a member of the Physics Department, and an historian of science from the Faculty of Arts. This management structure was sustained over the five-year life of the project. Participating researchers from universities and science centres across the Atlantic provinces included chemists, physicists, mathematicians, computer-scientists, science-centre managers, and outreach officers in non-university-based research facilities. Because researchers drifted into and out of the CRYSTAL family over the life of the project, and because collaborations between educators and other kinds of specialists were common, it is hard to calculate what proportion of the CRYSTAL research was actually carried out by specialists outside education. A safe estimate, however, is that at any point during the lifetime of CRYSTAL Atlantique, at least a third of those involved and a third of CRYSTAL research constituted "voices outside education." For example, in Year Three, out of the 70 researchers, 30 (or 43 percent) were scientists, computer scientists, historians, and non-education graduate and undergraduate students. Examples of the kinds of research those individuals conducted and the results they obtained are included in this section of our research stories.

Because we regarded this intense involvement by non-educators as very unusual among educational research collaborations in Canada, we encouraged individuals from the start to reflect upon the nature of their involvement—with teachers and schools, with other researchers from faculties of education, with each other, and with the field of informal learning research. At the end of the project, in April 2011, we invited our non-educators to a workshop in Fredericton, to discuss their involvement and what they had learned from it that might be valuable to other collaborations.

Predictably, our awkward language of "educators and others" produced merriment among the workshop group, all of whose members felt a strong professional identity with educational work and research. But on a more sober note, they expressed the traditional frustration that their involvement with

K. S. Sullenger & S. Turner (Eds.), New Ground, 41–45.

educational activities and educational research was not always respected in their academic departments and not always conducive to promotion and institutional rewards within the university. Several of the university scientists involved with CRYSTAL were also active in the university-focused "scholarship of teaching and learning" movement, and they regarded their activities with K-12 science learning as a natural extension of that commitment. During the workshop, those scientists expressed their frustration with NSERC funding rules that had sharply differentiated research with K-12 level students from research oriented toward teaching and learning among first-year university students. Scholars from outside the field of education, they suggested, have a role to play in overcoming those artificial, institutionally based dichotomies.

Asked to reflect on the differences between "informal learning" and "formal" learning, our Outside Voices found it difficult to arrive at precise definitions and distinctions. But they pointed to educational opportunities being opened up by the World Wide Web that embodied the essence of informal education, in being voluntary, pursued mainly for interest or pleasure, non-assessed, learner-focused, and operating outside the framework of schools and classrooms. Others pointed out that informal learning was bettered understood as "alternative" forms of learning, and noted that many of their specific projects, while clearly constituting informal education, had unfolded in close collaboration with teachers and schools. That remark prompted discussion of the rewards and frustrations of such collaboration. Teachers usually enjoy collaborating with scientists and others from outside the schools, but they have little free time, and with the best of intentions often expect outsiders to offer programs or opportunities that will somehow ease their classroom burdens. Principals worry that collaborating teachers will be diverted from their contractual teaching obligations, and they require outside researchers and would-be collaborators to financially reimburse schools for the time required of teachers. One computer scientist remarked that channels of collaboration, once opened, do not stay open long; every new project required a new round of persuasion that collaboration was important and valuable. The task of motivating others to collaborate had to be undertaken again and again.

Our Outside Voices considered the role that researchers outside education had to play in studying informal learning in science, mathematics, and technology. Here there was universal agreement that such specialists had much to offer, as well as some criticism of other research collaborations for excluding them. In their role as research scientists, individuals involving themselves in science camps or extra-classroom activities can offer students additional insight into science as an activity and counteract the impersonal or intimidating image that young people often have of science. Consider the following exchange between three Outside Voices:

> T.: We bring a different thing to the students … [They] look at you as an actual scientist. And I think the students respond to that in a certain way.
>
> B.: I think another possible role is surely that people who are doing scientific research day to day have to by its very nature bring a bit deeper view of the

> nature of how science is done, and I think that's an important contribution we can make.
>
> D.: Yes, it's funny, because that whole process can be so foreign to somebody in their younger years, that it's just a monstrous barrier that says, "whatever they're doing I don't understand it," end of the road, right? And I guess the talent or the trick in facilitating a camp or an activity like the outreach program … is to figure out a way to push through that barrier and to say look, you actually do have a fingerhold into what's going on here. You really can appreciate what's part of the process involved in doing science on a professional level.

Our Outside Voices also stressed a key role for themselves in the "translation" of research results and practical concerns from education into the "idiom" of other academic fields. Their participation in K-12 education, both in projects and research, facilitated the participation of others. Two stated,

> T.: So setting up some place or website or somewhere where people can join in, then you are facilitating a lot of people who would like to make a contribution, but don't want to set up the whole thing themselves. So there's a lot of people who are willing to make smaller contributions to that.
>
> D.: Even the half-step of taking a scientist or somebody from the university and having them do an hour presentation in the classroom … [is] a half step towards the kind of informal education we've been discussing. It is an important way to get people into that stream and into that mindset—okay, maybe I have to think of a different way to approach this group of people as opposed to what I've mastered in the university.

Are there problems in collaborating with educators in joint program-delivery/research projects like those pursued under CRYSTAL auspices? Several Outside Voices noted that the kinds of qualitative research common in educational circles are often unfamiliar to those outside the field. Informal education research is frequently done by individuals who develop and deliver a program, and simultaneously carry out research upon it and with its participants, both to assess its efficacy and to extract deeper learning principles. That kind of practitioner-research is often new to those outside the field of education. Adopting those methods (and adapting to them) constitutes another phase of the useful "translation" work non-educators can play in educational collaborations.

Our Outside Voices also recorded their impressions of the state of research in Canada on informal science learning. All agreed there was too little interest in the topic, with the possible exception of the science centre/museum community. Although NSERC provided limited funding for science enrichment programs (PromoScience was mentioned), it allocated little for the research necessary to determine whether those programs were effective. Several expressed disappointment that CRYSTAL Atlantique had attracted little attention from the regional media, in spite of its inclusive nature and heavy emphasis on outreach.

With technology and the new media rapidly breaking down the barriers between formal and informal science learning, educational research in general seemed to them weakly positioned to understand this change or contribute to new forms of science learning. Non-educators from many fields seemed better positioned to explore this change and its potential contribution to science learning than many educators themselves. The Outside Voices expressed the hope that the example of CRYSTAL Atlantique would inspire similar broad research collaborations in the future, and promote a willingness within the research community to better integrate other kinds of scholars into the study of informal learning.

What kinds of research did the Outside Voices in CRYSTAL Atlantique conduct? The three articles included in this section illustrate the very broad range and communicate some of their more significant results. In the first article, a team of chemists and physicists at Mount Allison University led by physicist R.L. Hawkes report on their Go Global: Science Research program. For several years this project provided high school students with the opportunity to work closely with university researchers on actual research projects for 10 days during the summer. In addition to the research involvement, that program provides many kinds of other opportunities for discussion, mentoring, and informal science learning. Information collected from participants in various forms demonstrates the success of the program in achieving its goals and provides a number of specific recommendations for establishing similar programs. Several unexpected results emerged from the research. One was the high and originally unintended "spillover effect" on professors, researchers, and undergraduate mentors in terms of their teaching style and confidence; another was the effective role that students showed themselves capable of playing in assisting program developers to refine and improve the program.

In the second article, chemists Truis Smith-Palmer and Sabine Schnepf, working with a team of educators, report on a program of summer science camps operated under the auspices of St. Francis Xavier University. Aimed at students ranging in age from five to 14, the camp program provides a series of one-week camps that allow younger students first-hand experience with chemistry-related phenomena, the guidance of university student-counselors, and the opportunity to "play scientist" in safe and supportive contexts. The authors note that such camps have begun to flourish everywhere, as a kind of informal learning experience designed to encourage interest, engagement, and confidence, as well as knowledge itself. However, they note, there has been relatively little assessment of science camps for their efficacy or real impact on children, in part because of the substantial methodological challenge of gathering useful data from very young participants. The authors review the methodological literature, introduce various techniques employed by themselves, and present some of the research data obtained through their use.

In the third article, computer scientist Tang-Ho Lê and educator Charline Godin from the Université de Moncton introduce their newly-developed, Web-based, didactical software system, OCOWS. Software of this kind has previously been developed mostly for informal learning among adults, they note, and when adapted for use with school-aged children it has notoriously failed to maintain student engagement. Online and computer-assisted learning too often "present students with an impoverished learning culture that fails to hold their interest." OCOWS meets this challenge by shifting the focus from the transmission to the construction of knowledge and building on several strains of advanced learning theory. The system, they demonstrate, combines a focus on problem-based learning with the creation of virtual learning communities. The authors go on to outline the research methods used to validate the system, and they present evidence that its use can enhance student engagement and achievement, within the context of informal learning systems.

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ENGAGEMENT: THE IMPORTANCE OF RESEARCH-INTENSIVE EXPERIENCES

We have started a program called Go Global: Science Research at Mount Allison University. It provides high school students with the opportunity to work intensively as part of a research group for about 10 days. This analysis is based on a three-year operation of the program, starting in summer 2007. Our goal was to examine the issue of fostering student engagement through short but intensive informal (out-of-class) experiences in science. In this paper, we describe the program, our research model, and an overview of some key results. The analysis shows that it is possible to have a significant positive impact on students in a short period of time (~10 days), both in changing their viewpoints about scientists and in providing a positive learning experience of authentic science.

INTRODUCTION

In a recent paper in *Cultural Studies in Science Education*, Rahm (2007) wrote:

> What would it take for youth to come to see science as a source of inspiration, as something intriguing and valuable, and as a world including them as active agents and legitimate members irrespective of who they are …

That summarizes perfectly the goals we set for development of an informal science experience for high school students. Our intention is to foster engagement through informal (out-of-class) experiences in science that incorporate direct participation in a research group. In this initial paper we describe the program, our research model, and an overview of some key results. In a later paper we will provide additional details on the research analysis, and a guide for application of these principles.

The main theme that emerges from our research is that experiences that truly engage must be authentic, and perceived by the participants to be authentic. Others have considered the importance and role of authenticity. For example, van Eijck and Roth (2009) write:

> Providing students with opportunities to experience how science really is enacted—i.e. authentic science—has been advocated as an important means to allow students to know and learn about science.

They go on to consider the questions of what constitutes authentic experiences, and why it is that authentic experiences are so critical. For the situation described in

K. S. Sullenger & S. Turner (Eds.), New Ground, 47–65.

their paper (an Aboriginal youth "Brad" who develops scientific interest and understanding through a variety of authentic, primarily environmental, scientific experiences), they argue that participation and perceived usefulness of results within an everyday life context are key elements of authenticity. A key element of our program is that students work on authentic research questions within a group, and they perceive that the results they obtain are important.

Nobel laureate Carl Wieman, a thoughtful advocate for effective science education, frequently recounts during public lectures how his voyage into science education started when he realized that graduate students entering his research laboratory did not think at all like scientists. He realized that after only a short period in a research environment the graduate students exhibited thought patterns and views consistent with professional scientists. It seemed remarkable that excellence in science courses during high school and undergraduate science did not translate into coming to "think like a scientist." The Colorado science education research group developed an instrument called CLASS (Colorado Learning Attitudes about Science Survey) (Adams et al., 2006) to differentiate novice and expert thought patterns and attitudes within physics (although the instrument has now been adapted to other settings in science). Tests conducted before and after introductory undergraduate courses in physics using CLASS indicated that students in most cases actually exhibited more novice thought patterns after the university course. A follow up study (Gray et al., 2008) suggested that students knew what physicists believed, but did not share those beliefs themselves. A driving force for the development of our Go Global: Science Research program was the possibility that intensive participation by high school students in a research environment, even for a limited time, might have a dramatic impact on their perceptions of science and scientists.

Guiding our research is the realization that student perceptions of the nature of science, and of scientists, will be central to their future decisions regarding scientific careers. While the experiences in our program are very different from those outlined by van Eijck and Roth (2009), in both cases participants come to look more positively upon science and science careers because they become insiders, and see that there is more congruence between the type of life they seek to live and a career as a scientist or a user of scientific expertise. We provide initial results both of pre-program views on the nature of science and scientists, and how working alongside scientists altered these views.

As we will outline in more detail below, participant feedback on the program has been used to evolve the program in each of the three years. One aspect that was added in years two and three was nightly discussion sessions, on topics such as communication and ethics in science, and this proved highly popular and successful. Science, technology, and society themes have, of course, been well studied in science education, and play a key role in some science curricula. While we recognized that science and society components were critical to scientific literacy objectives (in understanding science for everyday life contexts and for making informed decisions on science input-related questions in a democracy), we were surprised that high school participants in our program craved the opportunity to discuss these issues. We argue that a key part of engagement and authenticity is going beyond a narrow definition of science to the applications, implications, society influences, and ethical questions of the science.

THE GO GLOBAL: SCIENCE RESEARCH PROGRAM

Since 2007, Go Global: Science Research has operated as a program at Mount Allison University that provides high school students with the opportunity to work intensively as part of a research group for about 10 days. Placements in biology, biochemistry, chemistry, and physics research laboratories have been offered. This experience has a primary goal of introducing scientific research through direct participation as part of a research team. This is a selective program based on the students' credentials and their performance in a telephone interview based on a consistent set of questions (for each year of applicants) asked from a questionnaire prepared by authors.

Students choose their research preferences from a list of available projects. During the course of the program, students learn to use some of the tools and instruments of modern science, and are provided with the opportunity to develop their strengths in critical thinking, analysis, scientific creativity, and scientific communication. However, probably the most important aspect of this short but intensive program is the exposure students get to the way scientists work, live, and interact, with each other, with students, and with the public. In the first two years of the program most students worked individually on their research projects, but as a result of input from students, we have adapted the model so that whenever possible high school students are placed in each research lab in pairs, and work collaboratively on a common program. That means they work in a research group that includes another high school student, university students, and Mount Allison faculty. In all the years that we have run this program, the high school students have worked closely with Mount Allison undergraduate researchers after receiving safety training. This affected both the high school students and the undergraduate students as will be discussed later in the paper.

While each high school student spends most of the week in research activities with his or her group, each participant of the program also has an opportunity to tour other research labs at Mount Allison, explore science in the surrounding area, interact with university students, and make use of the fitness and athletic facilities at Mount Allison University so that they can experience different facets of university life.

During this period students stay at the Mount Allison campus and they are mentored by a senior Mount Allison student who also monitors their residence life during the program. This student mentor also provides teaching and research leadership and assistance to the high school students.

Each year, we arrange a seminar by scientists for Go Global students. In addition to formal activities, we usually start and finish the program by inviting all students to the house of one of the scientist mentors who is involved also as a PI in the program for a breakfast and supper. This is for several reasons, including giving the students a chance to observe to some degree how the scientists live.

Each night after dinner and other activities, all students, the undergraduate student, and scientist mentors take part in nightly discussions of different issues, from comparison of science with non-science, scientific collaborations, scientific communication, scientists and society, as well as controversial aspects of scientific research. Student participation has been vigorous, and the discussions have been a key element of the overall experience. This suggests that science educators may well be overlooking the importance of including discussion of cultural, ethical, economic, and social aspects of science as core parts of science programs.

LITERATURE REVIEW

Before outlining our educational research model, it is appropriate to consider the existing literature with respect to research-intensive science internship programs. We note that Barab and Hay (2001) have provided a comprehensive overview of much of the literature as part of their analysis of an internship experience for middle school students.

A number of studies have considered the impact of internship programs. For example, Knox et al. (2003) and Markowitz (2004) have evaluated short and long term impacts of a summer academy at the University of Rochester. That program concentrates on laboratory skills, whereas our Go Global program focuses on research. Not surprisingly, students expressed significant enhancement in various technical skills, and some improvement in understanding of the nature of science. Bell et al. (2003) used the VONS instrument to test the impact of an eight-week internship on student understanding of the nature of science. While there were some gains in the process of science, serious misconceptions about the nature of science were largely unchanged by the experience. On the other hand the research of Etkina et al. (2003) on a similar program showed significant gains in both success in the subject, and also in understanding of the nature of science, and showed that high school students can play an authentic role in scientific research.

It is perhaps not surprising that an experience, even of eight weeks, will have limited impact on the understanding of the nature of a subject as complex as science. Considering that, while having an interest in the degree to which we can enhance critical reasoning and deep understandings of science, we have developed the hypothesis that the main impact on internship programs might be in student perceptions of scientists, as opposed to the nature of science itself. Students choose careers at least partly according to how they view themselves fitting into their perception of that career. We will return to this point in the discussion section of the paper.

Applied research on how to fine-tune internship experiences to yield the most positive impact is relatively scarce. Grindstaff and Richmond (2008) have studied interactions between pairs of high school students involved in a seven-week internship experience. Their works suggests that optimal situations have student pairs share processes and techniques, but have results which leave scope for significantly different interpretations. In our program we have had a mix with some placements having a single high school student in a research lab, in other cases two students in the same lab but with individual projects, and in some cases two students working together on a single project. Richmond and Kurth (1999) show that internship experiences have significant positive impact on viewing science as an evolving body of knowledge supported by collaborative investigations, and much more modest gains in seeing the importance of creativity in science. They showed that guided reflection in individual journals played an important role in the gains achieved, and this suggests changes which we have implemented in our Go Global: Science Research program. The successful Rutgers program (Etkina et al., 2003) has a graduated system which moves from instruction and collaborative learning into authentic research participation. Templin et al. (1999) made a general study of some of the issues in making summer-long science research internship programs successful.

By their nature, research-intensive programs can only directly reach a modest number of high school students. Therefore, it is important to study the indirect outcomes on family members, students, and teachers at their home school, and others. This is called the “splashdown effect” and has been studied by Stake and Mates (2005).

The question of engagement and its definition is also key to this paper and we review that literature below. It was natural for science education researchers to consider definitions of engagement best suited to formal education settings. Early studies frequently counted time on task (Fisher et al., 1980; Brophy, 1983) as a major factor in the degree of student engagement. Natriello (1984) employed the term to describe students’ motivation to participate in the activities offered as part of the school program.

Definitions that are more recent focus on delicate cognitive, behavioural, and affective indicators of student engagement in learning tasks. For example, Newmann (1992) defines engagement as a circumstance when

> students make a psychological investment in learning. They try hard to learn what school offers. They take pride not simply in learning the formal indicators of success (such as grades), but in understanding the material and incorporating or internalizing it in their lives.

Skinner and Belmont (1993) also offer a cognitive-based definition:

> Children who are engaged show sustained behavioural involvement in learning activities accompanied by a positive emotional tone. They select tasks at the border of their competencies, initiate action when given the opportunity, and exert intense effort and concentration in the implementation of learning tasks; they show generally positive emotions during ongoing action, including enthusiasm, optimism, curiosity, and interest.

In the same school of thought, Bomia et al. (1997) define student engagement as a

> student's willingness, need, desire and compulsion to participate in, and be successful in, the learning process promoting higher level thinking for enduring understanding.

There are practical reasons for the increasing interest in engagement. Several studies noticed a decline in respect for educational institutions among students; one result, they suggest, is that students can no longer be counted on to value and adhere to the academic expectations imposed by an educational system (Modell & Elder, 2002). As portrayed in some popular books, students consider education as boring or as a simple grade game, in which they try to cope with as little effort as possible (Burkett, 2002). Student engagement is seen as a remedy to such signs of student disaffection. Recently, the concept of student engagement has attracted interest as a means to improve low levels of academic achievement and high dropout rates in schools and even in colleges. For example, Svanum and Bigatti (2009) have found that engagement during one semester forecasts college success and that engaged students are more likely to earn a degree.

In this paper, we wish to promote a definition of engagement that clearly bears some similarities to that of Bomia et al. (1997), but places particular emphasis on experiences that are authentic scientific investigation, and that are perceived by the student to be authentic. In our Go Global: Science Research program, we offer students a chance to be engaged in a short-term research project, and we study their responses to learn about the effects of this type of engagement on students' understanding of science, scientists, and on students' future interest.

PARTICIPANT PROFILE

In this study we analyze the Go Global: Science Research program with particular emphasis on how to increase engagement and to positively impact participant views on the nature of science and scientists. The details of our research model are presented in the following section. Before considering research results, it is important to have a profile of the participants.

This analysis is based on three years of operation of the program (2007–2009), with a total of 32 participants. Most of the participants took part in the program after grade 11 (78 percent), although several (9 percent) were after grade 12, and (13 percent) were after grade 10. Geographically while the majority of students came from Canada (91 percent), several students were from international settings (USA and two countries in the Middle East). From within Canada, students in the program came from a variety of provincial school programs (NS, NB, QC, ON, MB, BC). There was a good mix between students from large cities, towns and small cities, and rural settings. The acceptance ratio varied somewhat over the years of the program, from about 50 to 85 percent, although self-selection in those who apply makes the program more selective than the figures would suggest. There was a reasonable gender balance over the three years, with 56 percent male and 44 percent female.

Applicants were selected on the basis of academic record, previous science experiences and accomplishment, a letter of reference, and a telephone (or in some cases in-person) interview. We placed considerably more emphasis on this interview, and in particular the attitudes of the applicant and expectations for the program, than we did on academic records. Therefore, while some of the students had truly exceptional academic programs, overall on average they are not dissimilar to a typical academic high school student. While a few of the students had unusually extensive prior participation in science-related informal science experiences (e.g. science fairs or competitions, internship opportunities, or visits to scientific centres and museums), overall the group is probably not strongly different from average students in this regard.

This should be considered a group of self-selected students with positive attitudes toward science and solid academic credentials, but not in general with particular prior scientific accomplishment or unusual academic strength.

EDUCATIONAL RESEARCH DESIGN

We employed a multi-modal science education research design that included both quantitative and qualitative components. Prior to the on-campus experience each participant completed a written survey (WIAS—What Is A Scientist?[1]) that explored existing views about such questions of similarities of scientists to other professions, the reasons to engage in science, the nature of scientists, and the student's view toward future science plans. In addition, the WIAS instruments asked students to identify scientists by name.

Before developing the WIAS tool we considered several existing survey instruments. Existing survey instruments possibly relevant to our study include CLASS, VASS, and VNOS. CLASS, the Colorado Learning Attitudes about Science Survey (Adams et al., 2006), is intended more for an early university setting and is largely specific to the physical sciences. The nature of our program required an instrument that is applicable to all sciences. The VASS, Views About Science Survey, and VNOS, Views of the Nature of Science (Lederman et al., 2002), did not have a focus on the nature of students' understanding of scientists, as well as science itself, and therefore we developed WIAS. The WIAS provided a valuable glimpse into the attitudes toward science and scientists from a group of high school students who self-identified with particular interests in science. In Year One of the program, recorded audio interviews were also done prior to the program as part of the research design.

In all three years a focus group was held near the end of the program to specifically inquire both about design of an optimal research-intensive program, and to reflect on how the program had changed their views of science, scientists, and science career options. Participants were both perceptive and reflective, and directly asking for opinions on how to design an optimal program is perhaps a research tool that is underutilized in science education research.

In Year One, follow-up investigations (by telephone or email) were conducted individually. These were used both to inform program design and to assess the impact of the program in changing student attitudes.

In Years Two and Three of the program, we had nightly discussion groups, and in Year Three part of the research design included analysis of student written reflections at the end of each discussion group. Also in Year Three, each student maintained logs throughout the experience, typically reflecting once per day on their experiences. These reflections formed a particularly valuable resource for the research reported here.

IMPORTANCE OF AUTHENTIC RESEARCH EXPERIENCES

During group discussions, as well as at the final focus group, and in their individual written reflections, participants made it clear that one of the most absorbing parts of the program was the opportunity to do authentic science research. Even in the initial interviews, it was clear from student comments that high school lab experiences were not perceived as authentic—they realized that they were just following a set of procedures to demonstrate a process in most cases. In this section we will consider several aspects that differentiate truly authentic science experiences, drawing most heavily on the student written reflections from Year Three of the program.

Authentic science will not always work out the way that was expected or intended. The majority of the student experiences resulted (without being planned to demonstrate failure) in this aspect of authentic science. As one student participant wrote in their daily reflections:

> Today the projects that we had been helping out with didn't work out the way we wanted it to. I discovered that scientific research consists of lots of failures and that most experiments don't work out the way we want it to. Also that is what makes it fun …. It is like problem solving and I like how stimulating it is. Now I can appreciate the hard work scientists put into research. I am still enjoying everything about research and love it.

The last part of this quote demonstrates that scientific experiences do not have to be smooth in order for students to remain positive. As one participant wrote:

> Even though the DSC trial seemed to fail, I still enjoyed prepping and performing the trial.

Authentic science research cannot be planned in detail and will usually divert from intended directions. Depending on their settings, different students commented at times on a developing sense of how science works, and the nature of science. There were frequent comments about how much work science was (but this was viewed as a positive), and the nature of trying different things was stressed in several reflections. For example, one nightly reflection included the following statement:

> Research is a lot like solving a puzzle, you keep trying different pieces until it fits.

In the ideal settings *participants gradually took on more independence and responsibility* as the week progressed. As one student wrote in her reflections for one day:

> I'm increasingly getting to do more stuff by myself now which I'm really enjoying because I think I like having the responsibility of doing work by myself and completing it properly even if they are minor tasks.

For a variety of reasons it is usually difficult for students to be given this same level of independence and responsibility in formal classroom settings.

Another aspect of authenticity is that there be understanding of the "big picture" of the research effort, and the feeling that the work done by the participants plays a part, even if a small one, in that total research effort. In most cases the permanent members of the research group were effective in providing this complete picture background, often in a spiral way with increasing sophistication and detail as the week progressed. As one student participant wrote in his reflection:

> I didn't expect to discover anything revolutionary. I just hoped that I helped at least a little bit.

It was true that in our pre-experience applicant interviews there were cases where the high school student had unrealistic expectations regarding what might be possible. It was reassuring that the week, in general, showed how much work and effort was required for even minor progress, but that students did not seem at all discouraged by that realization.

We want to stress that *authentic does not in any way imply lack of fun*. The overall tone of the week is that science can be enjoyable (as well as challenging and at times frustrating). As one student wrote in his daily reflection:

> Today was such a FUN day. No, really it was a fun day.

Program participants come to realize that scientists are interesting, friendly people, and we will comment on collaborative experiences more fully in a later section.

A key question is whether nine or 10 days are enough in order for students to experience a reasonably comprehensive and authentic experience. The first year experience was slightly shorter (seven days) and in the first focus group participants suggested a longer experience for the future, so we extended the experience by about two days. At the end of the experience students present their research results and these presentations make it clear that high school students can have a significant experience in a short but intensive period. As one participant wrote in his reflections following the last research day of the week:

> I am also quite amazed at how much everyone learned in just one week … It was great to see how research worked in a professional setting. It was definitely different from learning in a classroom setting … It was great interacting with actual researchers and students …

VIEWS OF SCIENTISTS

Science education research is rich in various techniques to assess student perceptions of scientists. Most studies have supported the view that student views of scientists are inaccurate, and that these views are one roadblock to students viewing themselves in a science career. Lederman (1992) has provided an interesting review on this literature.

Probably the best way to provide accurate views of scientists is to have students work directly with scientists. During the Go Global: Science Research program not only do students work with scientists in a lab setting, but also interact with scientists and university science students in other environments including social ones. Participants in the program frequently noted that they were surprised that scientists were so “normal” and “friendly.” Also, all Go Global: Science Research participants work with university student-researchers, and with a closer age difference high school students may well relate more directly with those student-researchers in being able to see themselves as scientists.

The WIAS instrument (completed prior to program) asks students to identify five scientists who have made the biggest contributions to science. It is significant that most students are not able to even name five scientists, and most of those that are named are male and not living. In another section we ask students to name up to five Canadian scientists, and very few names are listed (with David Suzuki being by far the most popular choice). This should be of concern that even students predisposed to science have few role models in terms of well-known scientists.

Another part of the WIAS instrument asks why science is important. While the question ended up not being very discriminating (almost all options scored highly), at least among this self-selected group with an interest in science, they viewed that practical applications (e.g. engineering, medical applications, and to solve environmental problems) were somewhat more important than to understand the nature of things or because it is interesting.

Modern science is highly collaborative, with most scientific papers now published by multiple authors working together, frequently from multiple countries. From the outset we wanted to design an experience that was collaborative, with the high school students working as part of a research group that included one or more faculty members, university students, and in most cases other technical or professional staff. In a number of cases the students had some contact, or at least sense of group contact, with wider global collaborations of the research group.

The role of discussion in collaborative environments cannot be over emphasized. Williams et al. (2005) found for studio style learning environments that the single most important aspect is peer discussion in a hands-on laboratory setting, moderated by occasional guidance from instructors. The faculty and undergraduate students played a similar role in the research laboratory setting.

As well as their research group collaboration, there is a strong sense of community among the high school students in the program, developed through the numerous group experiences during the program. In both the focus group, and the individual reflections, the importance of this interaction is clear. For example, one participant wrote in a way that is representative of a general view:

> I think it's neat how everyone here loves science and it is encouraging that science can bring everyone together. I'm glad that I'm not the only one so passionate about research.

On another day a student wrote:

> I really enjoy it [science research] and admire the passion scientists show about their work.

Rahm (2007) discusses the role of students actually interacting with scientists as a stereotype changing experience, the differences between student preconceptions of scientists, and how scientists view themselves. According to Rahm (2007):

> the scientists portrayed their career trajectories as being driven by their interests and not their level of achievement or even an appreciation of all the subject areas they had to master to get there—a vision not necessarily much in line with youths' (prior) notions of a science career as boring, complex, difficult, hard, and beyond their reach.

The Go Global: Science Research program provides informal opportunities for scientists to discuss their careers, and the impact on changing views of scientists is profound.

On the last day, one student wrote, reflecting on return to home and ultimately to school:

> Right now I don't really know if I want to go home … The people at my school tend to shun anyone who tries anything out of the ordinary, such as a science camp. Nobody there likes science very much. I wish for the camp to be longer …

The quote eloquently expresses the yearning for a supportive environment that highly valued science. There seems to be clear evidence for the importance of opportunities to interact with other students who are enthusiastically interested in science, and therefore for informal science opportunities such as science clubs, science fairs, science centre visits, science camps, mentorship and internship programs, etc. Other papers in this volume address ways to provide these positive environments.

Rahm (2007) makes the point that unrealistic views of science are unfortunately "resistant to change and appear to have been taken as unquestionable realities." We were pleased to report that a limited duration of working within a science research community seems a powerful way to replace these unrealistic views of scientists, views that may well play a major role in students deciding not to follow science-based career paths.

IMPACT ON THE MENTORS

It is natural, and appropriate, to primarily consider the impact of programs such as Go Global: Science Research on the high school student participants. However, if a primary goal is to positively impact science, one should also look at the impacts on those involved in other roles in the program—the faculty mentors, the undergraduate science student mentors, and perhaps others. We consider in this section the impact on the undergraduate science student mentors.

In most cases in our program one undergraduate mentor is assigned to each high school student, although usually there are other undergraduates doing research in the same lab. Initially some undergraduate mentors felt some hesitation about their science leadership skills. As one wrote:

> The Go Global program offered me an exciting opportunity in my first year of summer research. Not only was I new [to research] but I would be teaching the essence of research to someone else. This was as scary as entering the classroom for the first time; I had little experience with this task. What would I teach them? What are they interested in? How could I help them take something from this experience? These were questions I played over and over in my head … After a week of activities, lab experiences, and one-on-one lessons from professors as well as the student-researchers, I believe that we got just as much out of the experiences as they did.

One mentor expressed the initial feeling that the high school students would not be ready for research, and how clearly he felt proven wrong.

> I didn’t believe these students were going to understand what it was that we were doing. I was to be proven wrong, time after time; my theories of learning to be ever-changing. The student that was partnered to me was a cautious individual, but the eagerness to learn could be felt; this feeling was judged to be common amongst the researchers. We spent the first day getting to know each other, where the various glassware was kept, and what to do in case of an emergency. After a relatively quick discussion into a product that we wanted to make and a little explanation for why, we set up our first reaction. The student was careful and observant; soaking up every detail we gave him. Already, my impressions were disappearing.

As one undergraduate mentor, who is now a pre-service teacher, wrote, reflecting both on the program impact on the high school students, and on the role of being a mentor as a step on the path toward being a science teacher:

> In that one week I witnessed a student change from a high school mentality to a university-level researcher. The one-on-one experiences were extraordinarily powerful … suiting to the needs of the student on an individual basis goes so far; remarkable … at that moment, I was being defined as a teacher and learning what it means to teach.

Some undergraduate mentors worked in the program more than one year, and had a chance to refine their mentoring skills.

> In my second year of participating in the program, I was again gifted with an eager student who was excited about trying something that had never been attempted before. I took a larger leadership role with them and taught more concepts everyday; the basics and how they applied. Every free moment we had, I took advantage of to explain things and see if they could predict what would happen. Teaching was just as exciting then as it had been in the previous year. Making that special connection with a student and seeing a smile of understanding made me feel good. It was a smile of interest, a smile of curiosity, and a smile of understanding. They were all as excited to learn as I was to teach them and see their skills improve.

Another mentor refers to the realization of the role of different learning styles through the program.

> Although I had been told before, it took me time to realize that people learn in a wide variety of styles. It is difficult to make a one-size-fits-all type program and so it must remain fluid. There needs to be opportunities to improvise and adapt to many different situations.

The role of experiences such as these in being a first step for mentors on a road to becoming a teacher cannot be over-estimated. As one mentor commented:

> the one-on-one approach allows the teacher to truly make a connection with their student and understand how they learn best. This connection not only requires knowledge of where their interests lay, but also their backgrounds, their future plans, and what they have been learning about in previous classes. What I didn't realize at the time, was that these were important aspects to look at as a teacher. This program was preparing me to become a teacher, a learner, and a critical thinker.

A second aspiring teacher was similarly impacted by the experience, saying:

> My involvement with the Go Global: Science Research program during years two and three was a unique role where I functioned as a counselor, mentor and supervisor, having also conducted many of the interviews beforehand. I was with the students at all times during the ~10 days, except while they were conducting research in the labs. Because of this, I was in a position to be confided in and was able to closely observe the influences of the experience on the students. With the majority of students, I witnessed a growth in their confidence as a practitioner of science. The students greatly appreciated being treated as contributing members of a research team and felt a sense of accomplishment when their input was valued. One student mentioned suggesting a new idea for an experiment, and even though it was not successful, the fact that his idea was respected and acted upon gave him a strong sense of ownership and pride. Many of the students demonstrated that

> not only were they capable of participating in discussions on (sometimes controversial) scientific issues, but also that they enjoyed the opportunity to discuss their own opinions and experiences with others of similar background and interests. The importance of this collaboration in the lab and the discussions cannot be overemphasized, as learning is an active, social process. These experiences, as well as the interaction with "real" scientists both in and out of the laboratory, helped the students to envision themselves as scientists and they indicated a greater interest in pursuing a future in a scientific field. Regardless of their age and inexperience, these students were capable of expressing insight and creativity; these aspects are too often suppressed in the traditional high school science classes, but are a crucial part of scientific research. This impacted me as an aspiring teacher by suggesting that students require authentic experiences where they simulate the role of real scientists. Providing them with these opportunities will intrinsically motivate them to take ownership and be active agents in their own learning. Furthermore, the importance of collaborative learning environments was impressed upon me, being suggested and remarked upon by the students themselves as having substantial impact on their understanding.

Clearly there is a fertile area for further research in the significant impact of mentoring opportunities on those early in a scientific career. From this limited early analysis we summarize the key points below.

a) Sensitivity to consideration of different learning styles is emphasized.
b) A solid base is established for problem-based learning (PBL) approaches, since essentially research is an example of PBL.
c) Considering the background of the students, mentors learn the importance of employing spiral modes of learning in which topics are revisited at increasing levels of complexity.
d) The need to gradually assign greater independence and responsibility to the students is understood.
e) The mentors develop confidence in the ability of student participants, and this will lead to confidence to implement in formal learning settings inquiry and problem-based modes of learning.
f) The mentors recognize the importance of a collaborative learning environment in which students and teachers are encouraged to work together, question each other, and share insights to develop their understandings.

DISCUSSION

We first want to highlight some of the important findings of this analysis of our program.

- Although this program was shorter than many similar research-intensive experiences which may last several weeks or months, it was still met with positive participant reactions. This suggests that even those research-intensive programs of limited duration (~10 days) can have a significant impact on students.

- This program served to highlight the importance of authentic science experiences as being key to students' success and enjoyment. It is necessary that students perceive what they are doing as being realistic and worthwhile. The type of authentic research experiences provided by this program is difficult or impossible to implement in formal education settings, which indicates the necessity of such opportunities to be offered by universities and other science institutions.
- When students are given the opportunity to be active and contributing members of a scientific community, they undergo profound changes in the manner in which they view themselves and science. Many students gain confidence in their own abilities and are better able to envision themselves pursuing careers in scientific disciplines.
- Experiences such as this one, where high school students directly interact with "real" scientists, are powerful agents for changing stereotypes and misconceptions about the nature of scientists. Students are able to relate with the researchers as human beings and this, in turn, influences the ability of students to see themselves as scientists.
- The drawback of having a duration of only ~10 days is that it is difficult to assess the long-term influences of such programs on the understanding of the nature of science. The changes that participants of this program experience are too gradual to be significantly different from their preconceptions when they first arrive. To produce a measurable effect, it would be necessary to extend the experience for a longer period of time.
- With research experiences of this kind, it is not only the high school students who are influenced, but also the professors, researchers, and undergraduate students who work in partnership with them. These mentors learn how to efficiently make use of spiral modes of instruction and when to give increasing responsibly to the students. They come to have confidence in discovery and problem-based learning techniques, which can be particularly useful learning experiences for those mentors interested in pursuing a teaching career.
- The inclusion of daily discussion sessions related to the interface between science and society is a key element of a comprehensive program. Allowing students the opportunity to collaborate, debate, and share their ideas and opinions with peers and mentors on current scientific issues is crucial in helping them come to a more developed understanding of the ways in which science and society interact.
- Students themselves are a valuable resource in determining which experiences best suit their learning needs, and consulting them provides valuable feedback which may sometimes go overlooked in the research process.

Student suggestions were incorporated into the development of our program. This was achieved in all three years by holding a focus group near the end of the program to specifically inquire both about design of an optimum research-intensive program, and to reflect on how the program had changed their views of science, scientists, and science career options.

- In the first year the most requests for change were for non-interrupted laboratory research experiences during the day. Indeed, in all three years the research opportunity of the program was the most appealing for students.
- In the first year, we arranged some group experiences (e.g. on instrumentation, science related tours, etc.) for students during the days, and students felt that was a distraction from their research project. As per students' suggestions, in the second year we reserved most of Monday to Friday from 8:30 am to 5:00 pm (except lunch time) for student research.
- Also from discussions with students in the first year, we noticed that they are quite eager to engage in dialogue regarding different aspects of science, hence from the second year we had nightly discussions with students on different aspects of science, research and science ethics, etc.
- In the second year, the majority of students suggested that the high school students work in pairs on one project. We made this change in the third year wherever possible (for most students).
- In all three years, we held a science seminar on one of the nights during the program. For the most part, students suggested that this was the least interesting aspect of the week, although a few in particular indicated that they enjoyed the seminars. The two major complaints with this event were that it was held too early in the week and students were tired after having travelled long distances, and that the content was too advanced for them to gain significantly from the lectures. In the third year, most students suggested that we keep the seminar but make it closer to the end of the program.

One interesting aspect of the program was that it included a wide variety of informal learning opportunities, which provided for comparative assessment. While the main focus was on the research-intensive experiences, and these were rated most highly when students were asked post-program to comment on the importance of each experience, a number of other activities were also included. As described earlier, nightly discussions were a highly rated component of the program, and one which seemed to add significantly to the overall experience. In addition, each year there were a number of tours and field trips throughout the 10 days (e.g. wetlands, fossil cliffs, university research facilities). These ranked below the research and discussion aspects, but were still highly rated by participants. In the first year of the program, a science demonstration show was included, but surprisingly resulted in limited interest from the students. The opportunity to work with high technology equipment was strongly emphasized, both in the pre-program expectations and in the post-program evaluation. For example, the students were able to use the university scanning electron microscope, and the participants viewed this as a particularly valuable experience. Furthermore, some type of science presentation was offered each year, and this received a moderate rating from the high school participants.

By the end of the program, almost all of the participants expressed positive feelings about their experience. The majority of the students held optimistic views on science and science education, which were either reinforced or improved as a result of this experience. Many students were astonished by the fact that undergraduate students can make significant contributions in scientific research, and were pleased that they too could play a modest role in this research. Observing first hand that even a high school student in a short time of ~10 days can have a meaningful scientific research experience was another important result of this program. After completing the Go Global: Science Research program, all of the students (with one exception) went into a science program at university, and a number are already involved in university level research.

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NOTE

[1] The WIAS instrument is available from the authors.

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AN EXPLORATION OF SUMMER SCIENCE CAMPS AS AN INFORMAL LEARNING ENVIRONMENT

INTRODUCTION

Informal learning has been defined as "activities that occur outside the school setting, are not developed primarily for school use, are not developed to be part of an ongoing school curriculum, and are characterized by voluntary as opposed to mandatory participation" (Crane et al., 1994). Children thus become involved with informal learning at a very young age. This often occurs through play and by watching those around them. They work alongside their parents to cook, work on cars, build things or do gardening, and are essentially acting as mimics or apprentices. Young children learn by mimicking the role models they see around them. They recreate scenarios they see in their homes or on the playground. Role-playing scenarios allow children to mimic older people in real-life situations. Role-play is an example of informal learning in which children learn through their own creative experiences. While role-playing, children can become totally engaged in mimicking their role model and the activities they are involved in.

As children get older, they may participate in more complex informal learning experiences, and take on more responsibility for their own learning. Such opportunities are provided by science outreach activities offered at St. Francis Xavier University (StFX) each summer. Children aged 5-14 years attend week-long summer camps and are provided with an opportunity to participate in scientific activities in an actual science laboratory. In a way they are becoming students of science, role-playing by dressing up like scientists and mimicking what they see the camp leaders do. Under the guidance of "real" scientists, the children act out the job of a "real" scientist and in doing so learn science. The "scientist" leaders are actually science undergraduates, who guide the children through a series of science activities related to physics, chemistry, biology, and earth science.

There is a culture that exists in summer camps—in this case a science learning experience for elementary school students. We ask: how do the children respond to this culture? In this paper, we explore these elementary students' experiences of "playing scientist" or becoming "students of scientists" within the culture of a summer day camp program. We use the perceptions of children, parents, and leaders involved in an informal science camp to discuss the ways children engage in the informal learning of science. We also discuss how the nature of the science

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camp program helps foster the engagement of the young participants in the learning of science.

Informal Science Outreach Programs

Opportunities for children to participate in informal science activities, often connected with university faculties, are becoming more common (Kleinert, 2009; LeDee et al., 2007; Pitts Bannister et al., 2007). Due to the increase of science outreach programs, there is a growing interest in examining their effectiveness (Krasny, 2005; Stamp & O'Brien, 2005). Science professors are examining the possibilities presented by informal science programs for children, where children are helped to think and act like scientists (Alper, 1994; Beck-Winchatz, 2005). Research also examines the effect these informal opportunities have on the understanding of science developed in the participants (Van't Hooft, 2005). Universities offering informal science camps are investigating both short term and long term effects (Knox, Moynihan, & Markowitz, 2003; Markowitz, 2004). Swim (1999) and Voegel, Quashnock, and Heil (2005) examine how elementary children begin to develop understanding of chemistry concepts. Other literature describes the perspectives of the children who attend summer science camps (Kleinert, 2009) or the perspectives of teachers who help develop these camps (Hymer, 2005), but in most cases the literature is very limited: most studies focus on one aspect of a camp with one or maybe two methods of data collection.

University-based science outreach programs have been shown to have a positive influence on students' understanding of the nature of science and science inquiry (Bell et al., 2003; Kimbrough, 1995), as well as a positive influence on their performance in subsequent school science courses (Knox, Moynihan, & Markowitz, 2003). Such programs have been shown to lead to renewed enthusiasm and knowledge in the sciences (Atwater et al., 1999; Bleicher, 1996; Gibson & Chase, 2002; Helm et al., 1999; Richmond & Kurth, 1999).The use of informal education activities is seen as a particular opportunity to improve access and engagement with science for marginalized or under-priviledged groups of children (Jones, 1997). Some argue that as we gain insights into what contributes to a successful informal learning experience, this knowledge could be used to "significantly influence school-based instructional practice" (e.g. Korpan et al., 1997).

In addition, it has been reported that in many countries, pupil attitudes towards school science decline progressively as they advance through grade levels, with fewer students choosing to study science at higher levels and as a career (Braund & Reiss, 2006). It is with this in mind that the camps have focused on increasing the awareness of, engagement in, and enjoyment of science for the participants.

Researchers have also raised concerns about the research on summer camps. Many science camps do not cater to the younger end of the school age group. This deficiency was noted by Hymer (2005), who then organized such camps in Stephenville, Texas with a lasting impact on the community. The summer camps described in this paper are designed to provide a science experience for young children in a rural community.

A number of review articles, including those of Vadeboncoeur (2006) and Rennie et al. (2003), have touched on the difficulty of assessing the nature and extent of informal learning. Rennie et al. (2003) noted that collecting data through recordings and videos is important to supplement information gained from surveys. Rath and Brown (1996) used videotapes to analyze students' orientation towards phenomena at a summer science camp.

How Children Learn Science

Two basic principles in child development and learning that enhance scientific literacy are that (1) "children construct knowledge" and (2) "children learn through play" (Bauer, 2009, p. i). What this means when we consider how children learn science (and other curriculum content) is we believe children create their own knowledge through dynamic interactions between themselves and their physical and social environments. Children learn and gather or discover knowledge through experimentation. This constructivist principle states that children formulate their own hypotheses and test them through mental actions and physical manipulations. The newly acquired information becomes part of their schema. These are the same steps that are followed by scientists throughout the world as they research answers to their questions and problems. By nature, children use the scientific method in order to make sense of their surroundings (Bauer, 2009). Informal learning that promotes this play-like experimentation may well encourage the development of scientific understanding in ways that most closely align with a child's natural way of learning.

Scientists also learn by apprenticeship. Graduate students and postgraduate students work in a research group under a chosen supervisor, and within each research group newer students are mentored by those more experienced. In general, it is well known that apprentices work side by side with their "expert" role-models (Barab & Hay, 2001) and learn as they physically practice tasks (Pratt, 1998).

However, while there is much focus on literacy and numeracy in schools, science continues to be a curriculum area that some elementary teachers can find difficult to teach. Research has identified challenges involved in teaching elementary science (MacDonald & Sherman, 2007). One challenge for many elementary teachers is a lack of previous experience with hands-on science. Furthermore, many tend to make limited use of both hands-on and inquiry-based activities in their classroom teaching (Goodrum, Hackling, & Rennie, 2001). Bauer (2009) says that some educators have allowed themselves to believe that science is hard, that science processes and content are not appropriate for everybody, and that it is better to concentrate on reading, writing, and mathematics. In doing this, they have prevented the development of scientifically literate citizens.

THE SUMMER SCIENCE CAMPS

The camps described in this paper take place in a small rural town in northeastern Nova Scotia, about two hours from the nearest large urban area. Participants thus have no immediate access to museums and discovery centres, and are at a disadvantage in this respect compared to their counterparts in urban areas. The goal of the camps is to give young children in this rural area a chance to experience science first hand. We want them to be interested in and excited about science, and for them to be socialized into the culture of science by working in a real laboratory and interacting with young scientists in an inclusive, non-judgemental setting. How much a child participates, whether they answer questions, take notes, or conduct an activity is entirely up to them, but they are constantly given positive feedback. We aim to create an atmosphere of excitement about science, where the participants feel inspired to model themselves after the emerging scientists we provide as their leaders to guide their activities, ask questions, and spark discussions.

The leaders are mostly undergraduate science students with an interest in children and in promoting science. They are also chosen on the basis of their organizational skills, outgoing personalities, and communication skills. Some have completed their Bachelor of Science and are in the Bachelor of Education program. They are asked to create a suitable learning environment for the children and to actively attempt to present material in a manner that is interesting and engaging to the children and promotes further inquiry. Before the camps begin they spend six weeks visiting schools and presenting science workshops. This gives them teaching experience in classes with a teacher present before they run the camps. It also gives them experience with interacting with children of a variety of ages and skills. Interactions of leaders with individual or small groups of students are strongly encouraged during camp presentations in order to stimulate discussion. We posit that these science camps should provide a better chance to learn "why" or "how" than do visits to science centres as they provide leaders who facilitate the meeting of outcomes through interactive activities. The leaders not only guide the children through experiments but also facilitate the children's reflection on, and understanding of, the activities. Additional research is currently being conducted on the role of the camp leader for future publication as little current research on science camp leaders presently exists.

Over the last five years, camp organizers have tried a variety of science activities with each age group during the camps, in an attempt to best facilitate the engagement of the children with science and try to determine which activities are better suited for engaging the children at various age levels and developing their interest in science. Initially only three camps were offered, but as demand grew the number of camps was expanded so that the number of children participating in each camp was kept around 20-25, to facilitate interactions with the leaders.

The camps (Chemistry Gr. 1-2, Chemistry Gr. 3-4, Chemistry Gr. 5-6, Girls Science Gr. 1-4, Science Gr. 1-2, Science Gr. 3-4, Science Gr. 5-6) provide opportunities for exploratory learning by encouraging children to engage in a variety of hands-on activities which are designed to arouse their curiosity and provide a platform for inquiry-based learning. Participants generally come from areas within an hour or so of the camp. Most are permanent residents; others attend while they are staying at StFX for the summer.

Student leaders and a variety of mentors (mostly professors) stage demonstrations and facilitate a variety of interactive experiments which are done in a laboratory setting. On a daily basis, the camp programs offer an overall general science or chemistry theme. Most of the activities are based on the inquiry-based model of learning. Each topic (four to five per day) is introduced to the children in a way that enables them to engage and experiment with the topic as they relate the subject to personal experiences from their daily lives. For example, when introducing the subject of flight, one of the instructors gives a short (10-minute) computer-assisted presentation about flight, including the basics of Bernoulli's principle, and then uses a shop vac and ping pong balls to further demonstrate this. During the presentation, the children are encouraged to ask questions and provide answers. The children are then shown how to make a variety of paper airplanes, and are encouraged to try different shapes and folds and test the effect on the aerodynamics. They also discuss birds and feathers with respect to flying.

Typically, the children are asked to innovate or be creative within their experiments, to encourage them to learn by inquiry. For example, after a presentation on the basic principles of weight and gravity, the children are presented with various materials (e.g., wooden blocks, Styrofoam, sponges) with which to construct a vessel that will float on water while carrying a load of marbles. The intent is to try to create a boat that holds the most marbles.

The hands-on activities are gently guided while the children are encouraged to carry out the activities as independently as possible. The children are also supported as they make and record their own observations using notes and/or pictures. The children are constantly encouraged to ask questions as the leaders circulate around the room asking the students to talk about what they are doing. The activities evoke a great deal of excitement from the children, particularly when they can alter the outcome themselves by making changes in the procedure. Equal encouragement is given to all students, whether they carry out the planned activity or create their own version.

METHODOLOGY

This research draws on methods used in phenomenology, but because of the short time we spend with each group of children (generally one week) it cannot be classified as a full phenomenological study. Both quantitative and qualitative research methods were used, including surveys, observations, and interactive interviewing. Interviews were conducted both during the camps and at the end of each camp with individuals or focus groups of children and with individual parents. Data collection included the innovative use of iPods for audio recording conversations and discussions held in the lab.

One aspect of informal learning is that there are no defined expectations or outcomes, so that the use of open-ended surveys and interactive interviews was particularly important. Leaders were asked to observe the children's behaviour and were later interviewed. As the role-models who interacted at length with the children, their comments were particularly relevant. They remembered many of the discussions they had with children as well as the overall class response, and also interacted with parents on a daily basis. Parents were also interviewed by the researchers, often very informally while they waited to meet children after camp. They were asked about the changes that they saw in their children at home that reflected their development as apprentice scientists.

Another aspect of informal learning is that there is no testing, and this is the case in the camps. However, before selected activities the children were given a set of pre-activity questions to answer, and then another post-activity set of questions after completing the activity. It was always emphasized that we were just interested in their ideas and it was not a test, and if they did not wish to respond or they couldn't decide what to write, that was okay. The children were also given notebooks for the duration of the camp and the leaders introduced record keeping as an important role of scientists. The children were encouraged to record what they were doing, and what they thought about it, including illustrations. Copies were made of the students' science notebooks towards the end of each camp. These observation records were then examined during the data assessment process. The children also completed an online survey towards the end of each camp (Appendix A, n=138, R=133) at the beginning of their computer lab, where n = number of camp attendees and R = number of responses.

Parents were asked to fill out surveys/questionnaires at the end of each camp (Appendix B, n=86, R=52), where n = number of forms given out. Some parents were surveyed by telephone several months after camp (Appendix C, n=12, R=9). Other parents (Appendix D, n=32, R=28) and their children (Appendix E, n=45, R=45) were surveyed and interviewed when the children returned to camp the following year. Returning students answered survey questions orally and a researcher wrote down the responses. In addition, comments made by the children as they carried out activities, responded to questions posed by the leaders, and engaged in small discussion groups were noted by leaders, while audio recordings of many of the activities and discussions were also made. The highlights of these were transcribed. For the audio recording part of the research, a subset of the children was chosen at random. iPods equipped with clip-on microphones were attached to the children's waistbands and at the end of the day, the voice recordings were uploaded onto an external hard drive and the iPods were recharged overnight. One challenge associated with audio recording was finding the most suitable way for the children to wear the iPods and microphones, including positioning the devices so that they were not knocked off during activities and the connection remained established for the entire day. The most successful place to attach the devices was found to be to the centre of their back on a waistband. The devices were also used for small group discussions after activities, and some were worn by instructors to capture the student-leader dialogues. The use of recording devices and subsequent transcription was time-consuming, and was thwarted by some children not wanting to wear the recorders for consecutive days. However, recording allowed for the collection of the spontaneous, uninhibited comments and reactions of the children while they were engaged in activities and indeed in some camps, it was considered an honour to be chosen to wear the device.

This study and the associated surveys were approved by the StFX University Research Ethics Board. All participants and their parents signed consent forms which explained the purpose of the study and explained that participation was voluntary and that they could withdraw from the study without penalty at any time.

WHAT WE LEARNED

Though groups of children were with us only a week, over the weeks we learned a number of things about their experiences and what promoted the learning culture of our science program. We learned that these young children really liked attending the science camps, that they came to learn, that they actually learned science ideas and thinking, and that they changed their thinking about science. We also learned that the interactive nature of the program—having children work with undergraduate science students—and the attitudes of these young scientists, were critical to creating a culture of science in the summer camp.

Children Liked Attending the Science Camps

There are a number of pieces of evidence that support this. When 133 children were surveyed, 72 said their camp was amazing, 19 said it was very good, while 29 said good. There were 128 that said "yes" or "maybe" when asked if they would attend another camp. Forty-four percent of the children had returned to camp from previous years while about 28 percent heard of the camp by word of mouth or from friends who attended during a previous summer. Eight percent had attended twice before and 10 percent had attended three or more times. Typical responses from parents when asked why the children returned to camp were "enjoyed it last year" and "just assumed she would go again." Children explained "its awesome, we get to make stuff," "I like science," "I want to learn more." Most (110) children surveyed said they would tell their friends the camp was "fun," "awesome," "amazing," or "cool." The most consistent request for change (39) was for the camps to "go longer." When questioned about what they enjoyed most about the science camp program, 27 noted that they enjoyed all of the activities, while 79 named a specific activity. Although camp leaders heard many of the student discussions, and often made notes of interesting exchanges, the use of the iPods enabled us to explore the actual extended dialogue at leisure. A typical recording during an activity often included comments such as "It's going to explode!" or "Look at mine!"; "This is awesome!" Another example of a recorded comment was: "I'm gonna try and freeze gas, but I need lots and lots of chemicals." Such comments show the children were very much engaged by the activities and so it was worth taking the time to collect and transcribe the data.

The parents reported that the children showed a high level of anticipation for each day of camp. The fact that the children would go home and discuss the day's events with their parents is an indicator of a successful learning environment. “This opportunity is fantastic. He feels important working in the lab with real chemicals and real scientists.” “She also wants to do more science related things at home and show them to her younger brother.” Creating the link between science and having fun, through the method of exploratory learning with strong mentoring from the camp leaders, creates a memorable experience for the child and is an important factor in generating a lasting interest in science in young children. Building a boat that could float and hold weight, and making a device to protect an uncooked egg from a 12-foot drop, were two examples of activities suggested by the instructors that really stood out as engaging the children and harnessing their energy and creativity.

Parents noted: “I think it has helped expand her perspective on possible career opportunities,” “The camp helped him develop a sense of what real scientists might do,” while leaders found that when given the opportunity to utilize laboratory equipment like magnetic stirrers and glassware, the children were always very excited because it gave them a sense of trust to work independently, and made them feel as though they were acting like scientists.

Children Came to Learn

When the children were asked verbally why they thought kids came to the camps, many used the word “learn” in their responses along with “fun,” i.e. “to learn and to have fun,” “to learn about science and chemistry,” “to learn about science and get to do experiments,” “to learn, get new experiences, and just have a good time,” “because it’s a good camp and you learn a lot.” A number of children also told us that the material and topics they were exposed to in the camps were not entirely new to them. Some had been exposed to similar ideas at school or on television or in books. However, they all noted that they particularly enjoyed being immersed in an activity as a full participant rather than simply as an observer: “I like doing science”; “I feel like a scientist in the lab.” A large number of parents described their children as being interested in an exciting summer activity where they could learn about science and make new friends. Eighty-seven percent said they enrolled their child because he/she was interested in science, or because they wanted to expose the children to science. Most (90 percent) of the parents considered the camp content (science focus, activities, and projects) to be the most important feature of the camp.

Children Learned Science

There were a number of strong indications that the children did indeed learn science, and/or a scientific way of thinking, while at the camp. Certain activities were chosen where students were asked the same written questions before and after the activity. The responses to two such questions for an activity which involved adding salt to soda pop and watching bubbles form are shown in Table 1.

Table 1. Grade 5-6 Chemistry: Foamy Soda Activity

Question Asked: What are the bubbles in soda?

Pre-activity answers	*# of responses*	*Post-activity answers*	*# of responses*
Air bubbles	7	Air bubbles	4
Sugar	1	Carbon	1
Carbon dioxide	2	Carbon dioxide	6
Fizz	2	Carbon hydrate	1
Oxygen	1	Sodium and chloride	1
Caffeine	1	Sodium chloride	1
Bubbles caused by a chemical reaction	1	Reaction caused when sugar reaches air	1

Follow-Up Question: What will happen if salt is added to soda pop?

Pre-activity answers	*# of responses*	*Post-activity answers (responses all different)*
Keeps it from fizzing	1	Salt dissolves.
No more fizz, bubbles	3	Soda fizzes because of air.
Salt will disintegrate	1	Soda fizzes because of sodium chloride.
Soda will overflow	1	Fizzes because the sodium and chloride separate.
Fizz more	4	Foam expands.
Nothing	1	Overflows.
Ruin the secret formula	1	Water gets in between and separates it.
It will get fizzy and pop will overflow	2	Foam shoots up.
Cause a chemical reaction	1	Salt caused more bubbles and it dissolved.
		The soda bubbles rise.
		Salt spreads apart and there is no more room so the carbon dioxide is pushed up and creates bubbles.
		Fizzes b/c bonds break from water atoms and carbon dioxide pushes sodium chloride up and makes it fizz.
		Bonds in salt break and water atoms go between the sodium and chloride. Then there isn't enough room for the carbon dioxide so it escapes.

In the above examples, the children may not have all given the correct explanation but they are thinking about what has taken place and have remembered much of the vocabulary. We can also see a growth in the details of their use of language, using words like "bonds," "dissolves," "atoms," and "carbon dioxide." The examples also demonstrate a greater complexity of their explanations as a clear indicator of the growth of their understanding. The responses show that many of the students were able to make observations and formulate interpretations based on those observations. When leaders verbally questioned children about previous activities, children were able to describe them using newly learned vocabulary.

Writing in their notebooks was also strongly encouraged as an activity very important for scientists. Leaders often posed questions and suggested the children could write or draw the answers in their notebooks, as well as discussing the answers with the circulating leaders. The observations recorded in their notebooks demonstrate that the children were absorbed in what was taking place and thinking about what was occurring. For example, the following notes were written during the Grade 3-4 camp when yeast granules were added to a warm sugar water solution:

> they are going up and down. They are going to eat it, I guess. I don't know for sure. The water is yellow and there are bubbles. The water is yellow and peach. It is in a 250ml cup. The bubbles are yellow. Kelly's bubbles are heavier than my bubbles at 10:30
>
> 10:40 am. They are going up and down. They are funny. I think they are funny. They sound like bubbles popping. They now look weird. Everything is fizzy. It is cool. It is peach and yellow. Now they are all inside, I can't see them anymore.

These notes clearly demonstrate that the students are actively seeking to make specific and detailed observations. Many students were able to describe the experiments they had completed in some detail. The majority of the students described accurately the materials used in experiments and could describe the steps taken throughout the experiment. The students used appropriate vocabulary and were able to describe things they had learned, for example, the relationship between molecules and atoms. This demonstrates a level of engagement with the content of the science activity. These are science concepts not normally taught to children at this age, but the children enjoyed learning and thinking about these concepts. The level of detail the children were able to provide was impressive. For example, "Paul" described an experiment completed in the Grade 1-2 camp:

> Paul: We did this experiment. I remember it [the paper circle] needs the cut in the middle and then we put it in the water. We took our piece of paper, put a black dot on it, filled up our beakers with water, we took our scissors and cut to the centre. The dot would be in the middle, then we put it in the water and it started to spread out with colour.
>
> Researcher: Which part went in the water?
>
> Paul: The little flap. Then the water came up and started to spread out. Mine had a black outline then blue, orange, red, and yellow.

This is a detailed explanation for a six year old. He was able to list all materials used in the experiment and describe what he saw happen in the correct order, providing an explanation that is of a calibre that was initially surprising to the researchers.

The leaders encouraged the children to think critically and question everything that they were observing. The following two examples demonstrate the kinds of questions the students asked during their observation of an activity. During the Grade 5-6 camp, the following snippet of conversation occurred while using a magnetic stirrer, where a beaker is placed on top of a special plate and a small magnet is placed in the solvent to help stir and dissolve the solute:

> Child: How does it turn though? I don't get how it turns. Wouldn't a magnet stop if it was in the water?
>
> Leader: What makes it [the magnet] spin?
>
> Child: The plate underneath.

During the Grade 1-2 camp, "Dancing Raisins" are demonstrated where raisins are added to water with baking soda and vinegar in it:

> Leader: Okay, put them [the raisins] in. Watch very carefully. What happened to the raisins?
>
> Child 1: They're alive, my raisins are alive!
>
> Child 2: The air bubbles are attaching to the raisins at the bottom, bringing them up, and when it gets to the top, the bubbles are popping and dropping the raisins.
>
> Child 1: The bubbles are lifting it up, then the raisins are diving back down!
>
> Leader: Why is that [the raisin] going up like that? I don't understand. Why are they able … why are they lifting up?
>
> Child 2: Maybe it's because the air bubbles are attached to them and they're floating up and when they're at the top, the air bubbles pop and they keep on going down.
>
> Leader: That would make sense. The air bubbles attaching to them, raising it up.
>
> Child 1: And as soon as all the air bubbles break, they go down.

It seems apparent that Child 2 has already encountered this phenomenon and is aware of the explanation for the dancing raisin. It also seems likely that the understanding of Child 1 is more naive initially, but as the exchange continues, Child 1 begins to focus on more specific details of the phenomena and thus seems ready to develop a more complete understanding of what is occurring. Child 1's thinking moves from being anthropomorphic to one more focused on observations of what is actually happening in the dish. Both snippets demonstrate that the children were engaged in observing details and asking questions while watching their experiments.

In summary, the children learned new vocabulary, made observations, asked questions, attempted to formulate interpretations, and some were even able to consider and answer questions that required critical thinking. Their responses demonstrated an interest and engagement with the material and an enjoyment attained through participation in the camp. The children developed an understanding of concepts and learned to pay more attention to details. They enjoyed the participation in the hands-on activities and were excited by using new equipment and the opportunity to act like scientists.

Children's Thinking about Science Changed

For the children, science camp instilled more interest in science, more willingness to continue studying science, and more confidence in talking about science as well as increasing their understanding of science. Parents felt that the camps provided a fun and educational experience that expanded their child's thinking about science. One said *"*The camp has encouraged her to investigate the world of science as fun. This has been successful due to the female representation of camp leaders." Many parents reported an increased interest in science shown by their children: "All he wants to be when he grows up is a scientist"; "He had many more experiments to try at home"; "enjoyed explaining why certain things happen…explaining the science behind things"; "Last year after camp she started watching more science programs on TV." Parents thought that their children had been instilled with a greater scientific curiosity, that they had become more inquisitive, and had sought to find explanations for things in ways they had not done before: "He is always talking about scientific things and has been reading the two magazines given to him at camp"; "The camp seems to have awakened her sense of curiosity. She enjoys mastery of new knowledge such as understanding why a balloon floats. She expressed interest in duplicating some of the experiments at home"; "Her interest in science, even everyday science, has increased significantly. She asks regularly how things are made or work." Parents also told us that some of the children also talked at home about ideas they had not learned at camp, asking specific questions about the human body and insects, two topics that were not covered during their camps. The children's willingness to share ideas and excitement with camp leaders and researchers, and to talk to their parents about what they experienced each day overall reflects their developing scientific curiosity.

Forty-two percent of the children said they were at least a little more likely to take an optional science course in school now, while another 30 percent said they were a great deal more likely to take more science. Eighteen percent said their interest remained the same, but as some parents and students explained during interviews, some participants were already very keen on science before attending camp and attending the camp did not change that.

Comments from parents showed that the summer chemistry/science camps had a clear and direct impact on the children's communication skills. Many of the children arrived home at the end of each day excited and animated about what they had completed that day, speaking about projects or activities carried out during the day with a new “scientific” vocabulary: “He always showed me what he made or worked on that day … always very excited and confident in what he was telling us”; “I think when science fair time comes at school, she will be more confident that she can do it.” The leaders generally asked many questions as they presented an activity, and children following their role would do likewise. Many children seemed more excited about learning, attempting their own experiments at home, asking questions, and speaking about science in general. One parent, in particular, was also very pleased with the confidence of his child to stand in front of a large group of people giving a presentation the child had completed during camp. According to the surveys of the parents, every child who attended the camp spoke about at least one experiment or activity that they had completed during their week at camp. One of the most talked about activities involved holding a sheep’s brain. A guest speaker from the Department of Psychology introduced the topic of the human brain to the children. As a group, they discussed functions of the brain and were then paired up and left on their own to explore sheep brains. Armed with magnifying glasses the children held the brains in their hands and identified the different parts.

Other experiments the children talked about with their parents included creating the “Solar System,” “Colouring Flowers,” “The Volcano,” “The Quarter Jump,” and the “Liquid Nitrogen Demonstration.” As examples of exploratory learning, each of these experiments had a lasting impact on the children as evidenced by their excitement when sharing the experience with their parents.

In summary, for these summer students, attending the Chemistry Camp was a positive experience—an experience they chose because they wanted to learn. Not only did these participants learn science and gain an understanding of the way scientists work, we gained an insight into their learning itself. We were pleased to learn that many of these students said they would be more likely to take optional science classes in their schools. The best information on how successful the camps were in exciting the participants about science came from discussions with parents after the end of camp, particularly those that returned the following year. Overall the parents indicated that the camp experience inspired an interest in science and also built confidence, self-esteem, and communication skills.

The Leaders Are Important Role Models

Parents reported that the leaders’ personal levels of excitement, about both science and the children, made a strong impact on the success of the projects completed during the week. When a leader was excited and curious about an activity, this was reflected in the excitement of the children as recorded during the sessions. Children noticed when the leaders were excited themselves about the science they were sharing with the students. Parents felt that the leaders were good role models: “It was valuable for her to be in a university environment and to experience positive role modelling from undergraduates studying science.” Some parents chose the camp because the child did not enjoy sports-related camps and then were very happy with their choice: “I think our daughter has been encouraged to seriously imagine being a scientist as a career option along with her desire to sing and dance." That the children reflected the feelings of the leaders and were excited about what they did is confirmation of the idea that the children are following the actions of the leaders.

DISCUSSION

Each day at camp, participants were able to learn how to socialize with scientists to learn the culture of science communities by having an opportunity to role-play and interact, to work in small groups where they were able to reflect, share ideas, learn skills like keeping records, and get feedback from scientists-in-training. In effect, the children were acting as apprentice scientists. They worked in a laboratory, dressed like scientists, made observations, and used scientific equipment. The leaders, young scientists, were their role models and asked many questions to stimulate discussions and reflection. The children responded by themselves asking questions. They were keen to describe their activities to their parents and some wanted to try other activities at home or to teach what they had learned to their siblings. Thus the camp is acting like an apprenticeship program where appropriate scaffolding is supplied for learners (Collins, Brown, & Newmann, 1989). It could be described as learning in the workplace. The participants learn by observing behaviours and then mimicking them (Hansman, 2001). Scientists also learn by being apprenticed (graduate students and postgraduates) to more senior scientists. High school students have been shown to learn more sophisticated ways of thinking when allowed to participate in authentic science inquiry (Charney et al., 2007). Much younger students at our camps were immersed in a culture of science. The fact that several of the camps focused on children of ages six and seven put limits on what could be done in the program and, more particularly, how our research was carried out. However, we believe that the mentoring experience that occurred provided important foundations for science learning. The atmosphere of the camps was personal, and the leaders were able to interact with children on a one-to-one basis during activities and small group discussions. The response of the students was apparent in their subsequent communications to their friends, their leaders, and their parents.

The connection between learning science and having fun is important in creating a positive view of science with young children. The camp experience is very much like the interaction of a child with a parent in the kitchen, and, as such, is an informal learning experience. For example, children watch, help, and participate but cannot immediately understand all the complexities of making a roast dinner. However, they absorb the words and ideas and the feeling of accomplishment, and in general enjoy the process. In this example, the role model is the parent, while at the camps the role models are the young scientists. The response of the children to the leaders strongly supports our role-playing model of the way the children are learning at the camps. The idea of students enjoying themselves while being extremely focused on solving a problem, has been referred to by the term "hard fun" (Papert, 2002).

An important feature of the camp was the strong emphasis on hands-on activities. Doris (1991) notes how various reports and educators in the past 25 years have recognised the value of hands-on science instruction, while noting that many elementary science classes did not use such instruction, often because of a lack of experience.

The finding that the students showed an increased interest in taking science courses after attending science camp, as well as a greater awareness of science in general, supports suggestions in the literature that informal learning can play a valuable role in supporting the science curriculum in schools (e.g., Honig & McDonald, 2005; Wellington, 1990). Voegel, Quashnock, and Heil (2005) found that elementary students showed a small but significant ($p<0.01$) increase in their scientific awareness, attitude to science, and interest in a career in science. This is one of the few studies that has included students as young as grades 1-2. Their assessment instrument was a 12-item survey. Although we included surveys and before and after sheets in our research, these presented some difficulties with the younger children because of their reading and writing skills. Thus the inclusion of recordings of their dialogue and input from the leaders and parents was important in obtaining an overall picture of their response to the camps. This comprehensive research indicated that participants did more than show an increased interest in and better attitudes towards science—they actually learned science. Thus it is possible for young children to learn science ideas and concepts in even a short period of time. This success was attributed to their being in the lab, to having scientist-leaders to model themselves after and interact with, and to working in small groups.

Science camps for older children have been classified as constructionist (Papert, 1980) or cognitive apprenticeships (Collins et al., 1989). However, Fields (2009) notes that these models do not need to be mutually exclusive. Elementary children, especially the younger ones, are not ready to conduct research with working scientists, but interactions with their young scientist leaders are still important for cognitive apprenticeship. By using video analysis and case studies, Rath and Brown (1996) identified six frequently observed orientations towards phenomena: exploration mode (to find out about the object and study its basic properties), engineering mode (a focus on making something happen), pet care mode (a personal connection focused on nurturing), procedural mode (an imitation and step-following orientation), performance mode (soliciting attention using the phenomenon as a prop), and fantasy mode (an imaginative play activity which builds on some aspect of the phenomena).

Mimicking the actions of the leaders and following instructions would be classed as procedural mode while students acting like scientists, as demonstrated in some of our recordings, would be classed as performance mode. These two modes were the ones most commonly observed in our camps with the younger children, although there were a number of examples of pet care mode.

We found that having camp leaders who are themselves members, or are learning to be members, of the science community, and who are enthusiastic about science, is critical to creating a sense of the culture of science in a summer camp.

In particular, their enthusiasm was a key element in getting the children excited about science. The leaders' abilities to connect with the children, to relay information in a way that appeals to them, while helping them reflect on what they have learned, definitely influenced how and what the children learned. This kind of interaction worked best in small groups and the camps were structured to ensure that the children completed experiments and held discussions in groups of no more than five or six. This allowed the children to be more confident and willing to share their ideas as indicated in the iPod recordings. However, keeping the camp sizes small always has to be balanced with program costs, facility availability, and the desire to make the program inclusive rather than exclusive.

The informal atmosphere at the camp and the interaction with the leaders provided a good atmosphere for socialization with respect to scientific practices and vocabulary, in accordance with similar observations made previously by Heath (2007). Fields (2009) also noted that one of the positive features of an astronomy camp, as identified by the participants, was the interaction with the leaders and notes that they were "resources rather than bosses."

Having classroom teachers who are as excited about science as are our camp leaders may help keep students themselves interested in science as they progress toward graduation. This may be very important as, in many countries, pupil attitudes towards school science decline progressively as they advance through grade levels, with fewer students choosing to study science at higher levels and as a career (Braund & Reiss, 2006). Korpan et al. (1997) suggested that knowing about "children's science-related experiences outside of school could significantly influence school-based instructional practice." It also suggests that one of the indicators that should be used when hiring student leaders is their enthusiasm and interest in science activities and children and how well they convey this, rather than their academic achievement alone. In fact, this has always been one of the deciding factors in hiring leaders for these camps. Communication skills are very important in science, not only for teachers and leaders, but also for communication of scientific ideas between scientists. In a paper on teacher retention in science and mathematics, Thomas et al. (2010) found that some teachers, who were most committed to their teaching, had experiences as leaders in summer science camps.

Whereas a great deal of cultural socialization takes place in the family unit, a science outreach camp provides an ideal place for socialization with respect to the sciences. For instance, the leaders become very involved with the children, play games with them at lunch time and spend a great deal of time in one-to-one discussion during activities. Seeing the leaders/young scientists in less formal settings where they are interacting in an informal way with the children seems to have a positive impact on the children's perspectives on participation in science activities. The direct interaction with the instructors seemed to be particularly rewarding for the children, as well as for the instructors, because a personal level of excitement about the experience can be shared. This gives the children a chance to feel that their ideas are important, to verbalise what they have learned, and to be guided by the input of their leader. Perhaps their willingness to share what they were learning and thinking about was the most successful measure of increased interest. It has been said that “learners in an informal setting are intrinsically motivated to gain personal meaning from their learning, which has greater value than memorizing facts or doing well on a test” (Ramey-Gassert, 2007). However, as the children work on activities and interact with leaders, they are absorbing many ideas along with lots of information. So while they are not memorizing facts per se, they are learning them, but in a more fertile way for future growth. The integration of a science camp approach to the school classroom during a major portion of science classes would be beneficial to sustaining or increasing an interest in science among the learners. This does not simply mean changing the lesson plan or using more hands-on activities, but requires that teachers act like scientists, radiate enthusiasm for what they are teaching, and be ready to discuss all aspects of the activity in an inclusive and positive fashion.

FUTURE CONSIDERATIONS

Researching the impact of informal learning is challenging because the outcomes are rather broad. The response to informal learning is unique to the individual’s own personal experience and varies by context. In this study, a variety of research tools were used in order to cover the varied responses of the participants. However, further research is needed into ways to successfully collect data from young children, as their writing skills are rudimentary and in group discussions they are often influenced by their peers, as well as the way a question is posed. Future work on science camps could also incorporate a greater focus on understanding what conditions foster the long term learning of science in informal settings. Specific focus could be placed on ways to bridge the gap between the theoretical understanding of learning and the practical application in these informal settings where we continue to ask ourselves how the camps can be even better designed and implemented to facilitate inquiry-based learning.

Research is needed (and is currently underway in conjunction with this program) to follow the leaders’ experiences and examine ways that working in these camps acts as professional development for them. What kind of leadership and learning experience was the camp for the leaders? Did they understand all of the science concepts themselves before they started? What kind of interpersonal skills did they feel they developed through the interaction with the children? All of these will be interesting aspects of the camps to examine in the future. Further research involving the leaders could include having them wear the iPods to keep closer track of the kinds of questions and discussion prompts they are actually using with the children. Are the leaders’ questions narrowly focused with one correct answer in mind, or have they moved to offering more complex prompts that are open-ended and allow the children to explore the concepts in more open ways?

CONCLUSIONS

The science learning experience at our summer science camp program allows elementary school students to shift from role-playing to becoming students of science, and to interact with the young scientists who are the camp leaders, who are themselves transitioning, although at a more complex, sophisticated level. The nature of the camp helps foster engagement between the participants and the leaders. The laboratory setting allows the young apprentice scientists to engage in activities that are not offered in other learning settings and to become immersed in the role of scientist. The camps provide hands-on experience with scientific equipment that the children would not be exposed to otherwise. Learning to use safety glasses and plastic lab aprons, following lab safety procedures, and using lab equipment such as beakers, thermometers, and magnetic stirrers helps to acculturate the children into the culture of science. The children involved in this study were particularly keen on these aspects of the camp and this can be summarized by saying they enjoyed role-playing as scientists and developed a positive attitude to the culture of science. Communication skills were notably enhanced. A combination of a strong science focus, the activities and projects completed at camp, and instructor enthusiasm, resulted in a lasting impact on the camp participants. Their excitement spilled over at home, and activities were remembered well after the camp was finished.

Overall, the camps provided a positive informal learning experience for the children. They enjoyed the camps, came expecting to learn, and were introduced to the culture of science. However the camps did more than increase the children's interest in science and their scientific awareness—it also allowed them to learn some science vocabulary and concepts. Having camp leaders who were themselves members or learning to be members of the science community and who were enthusiastic about science was central to the success of this informal learning experience.

APPENDIX A: STUDENT SURVEY (ON COMPUTER)

Which camp are you attending?

Are you ☐ male ☐ female

How old are you?

Have you attended a chemistry or science camp previously?
☐ Yes ☐ No

If yes, how many times?
☐ One ☐ Two ☐ Three or more

How did you like the camp this week?

Would you come again?
☐ Yes ☐ No

Why?

Are you more or less likely to take an optional science course when you return to school in September?
☐ Less likely ☐ Same as before
☐ Little more likely ☐ Lot more likely

How did you find the level of material presented at camp?
☐ Too easy ☐ Just right ☐ Too hard

I would tell a friend that camp was:

This week at camp I learned that:

The best part about camp was:

The worst part about camp was:

I wish that camp would:

I got to do new things
(agree 5, disagree 1) 1 2 3 4 5

I learned about new career options
(agree 5, disagree 1) 1 2 3 4 5

The leaders this week were:

I liked the leaders because:
The instructors made camp fun
(agree 5, disagree 1) 1 2 3 4 5

The leaders helped me to learn something new
(agree 5, disagree 1) 1 2 3 4 5

The leaders helped me to learn something new
(agree 5, disagree 1) 1 2 3 4 5

The leaders were easy to talk to
(agree 5, disagree 1) 1 2 3 4 5

Anything else you would like to say:

APPENDIX B: PARENT SURVEY

Date:

Which program did your child participate in?

Is your child:
☐ Male ☐ Female

How old is your child?

1. How did you find out about X-Chem Outreach? Check all that apply.
☐ Newspaper
☐ Camp Brochure
☐ Website/Internet
☐ Information Sent home from school
☐ Word of Mouth
☐ Previous Participation
☐ Other (Specify)

2. How was our registration process?
☐ Very Challenging
☐ Challenging
☐ Acceptable
☐ Easy
☐ Very Easy

3. Why did your child attend camp?
1st Reason:
2nd Reason:

4. Which of the following do you see as being the MOST important feature of our program? Please select only one.
☐ Camp hours
☐ Instructors
☐ Low registration fee
☐ Science Focus
☐ Computer Focus
☐ Activities and Projects completed at camp
☐ T-Shirt
☐ Other (please explain)

5. Overall, how satisfied were you with your child's experience at camp?

Not at All				Very
1	2	3	4	5

6. What was YOUR favourite project that your child completed at camp?

7. What did YOU like most about our program?
1st:
2nd:

8. What did YOUR CHILD like most about our program?
1st:

2nd:

9. Tell us some science ideas that your child talked to you about at home.
1st:
2nd:

10. What impact do you think the chemistry camp experience is having on your child's thinking? For instance, have you noticed your child using new words, playing in new ways or making science connections at home? Please explain.

11. How does this camp compare to other day camps your child has attended:
Please select one.
☐ Much Worse ☐ Not as Good ☐ The Same ☐ Better ☐ Much Better

12. What could we do to improve our program?

13. Will your child come to camp next year?
☐ Yes ☐ No
Reason:

APPENDIX C: TELEPHONE INTERVIEW QUESTIONS

1. Which Camp did your son/daughter attend?

2. Was this the first X-Chem Outreach camp they had attended?

3. Did they attend the camp because of their own interest in science, or to be with friends, because of timing or other?

4. Can you tell us any "after-effects" of the camp that you noted?

5. Did it stimulate their interest in science?

6. Did it change the way they look at everyday events/objects?

7. Did it change the way they talk about everyday events/objects?

8. Do they ask more questions or suggest hypotheses/explanations?

9. Has their interest carried over into what they do at school?

10. Has it affected how much they tell you about their classroom science?

11. Compare this camp to other camps they have attended.

APPENDIX D: PARENT SURVEY—RETURNING PARTICIPANT

1. How many times has your child attended an X-Chem Summer Camp?

2. How was the decision made for your child to attend an X-Chem camp again this year? Did you or your child first mention coming to camp?

3. Which week(s) has your child previously attended? Which week(s) are they coming to this year?

4. On a scale of 1-10, with 10 being the highest, how much did your child enjoy science BEFORE attending camp. Please explain:

5. On a scale of 1-10, with 10 being the highest, how much did your child enjoy science AFTER attending camp:

6. Can you tell us why the change or no change?

7. Did your child talk more about science after attending camp? If so, what kinds of things did they say? Did they use any new vocabulary?

8. Did attending camp have any other impact on your child?

9. Do you think participating in X-Chem Summer Camps has been a valuable experience for your child? Please Explain.

APPENDIX E: INTERVIEW FOR RETURNING CHILD

1. Can you tell me why you decided to come back to X Camp?

2. Are you doing the same camp as before or a different one? Why?

3. Can you tell me the three most important things you remember learning at last year's camp?

4. Did anything at X Camp surprise you last year?

5. What kind of activities did you like the best?

6. Which activities did you learn the most from?

7. Have you been doing any science since camp last year?

8. Why do you think kids come to X Camp?

9. Do you think all kids would like to come to X Camp if they had the chance? Do you think everyone should?

10. What if people said no more X Camp? What would you say to them and why? Would you agree?

11. Did you learn anything new this year?

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TECHNOLOGY ENHANCED PROBLEM-BASED LEARNING

INTRODUCTION

In the literature, many researchers agree that the key to success in teaching is having the active participation of the learners in the learning process, regardless of the pedagogical approach being used (constructivist or cognitive). It is evident, whatever the reason may be, that if the learner is not engaged in the course (because she/he is not motivated to learn the content, the lesson presentation is not captivating, the class is boring, etc.) then she/he will not comprehend the course material. The literature on engagement often stresses the "cultural" dimension of the problem: how the culture of the classroom motivates students' attention or lack of attention; or how peer- and media-culture encourage or discourage learners' connection to particular problems or tasks. Murray, Olivier, and Human (1998) describe classroom culture as "the didactical contract between teacher and students (their mutual expectations and obligations); it also includes the ways in which the learning situations are physically set up and the rules under which they operate" (p. 2). A study by Keith, Puzerewski, and Raczyncki (1999) establishes the positive effect of using methods other than direct instruction to engage students. Moreover, students tend to be motivated by activities that grant them autonomy and allow them to be original. As for classroom culture, Protheroe (2004), in a study on effective teaching, establishes a 28-category framework of variables that have an influence on learning in which she rates classroom instruction and climate as having almost as much impact on learning as students' aptitude. "In fact, one of the teacher-related factors—classroom management—had the most impact of all of the twenty-eight variables" (p. 2). She also reports on research by Jere Brophy which concludes that effective teaching should focus more on the atmosphere and overall structure of the classroom. In fact, by establishing a supportive classroom climate, "students learn best within cohesive and caring learning communities" (p. 3). Teachers can create an environment to maximize learning by making the classroom atmosphere one where all students are encouraged, reinforced, and not afraid to ask questions or give their opinion. Even beyond classroom culture, Black (2004) argues that schools must create a school culture that supports and sustains student achievement and she hopes that "teachers will avoid teaching what she calls narrow, skill-based, understanding-poor lessons" (p. 4). Learning is most likely when placed in meaningful contexts and in an environment that supports exploration, risk taking, and critical thinking.

K. S. Sullenger & S. Turner (Eds.), New Ground, 93–104.

The problem of ensuring student engagement is likely to be particularly acute in online and computer-assisted learning, where, for reasons we discuss below, much of the available software has been modelled upon techniques for adult self-learning, and so provide school-aged learners with an impoverished learning culture that fails to hold their interest. Such a learning strategy does not adhere to the shift from knowledge transmission to knowledge construction. Also, as stated in the document *Excellence in Education* (New Brunswick Department of Education, 1995), this method does not respect one of the six educational principles coherent to teaching which is that "Intellectual and social development happens through contact with others; social interactions in the classroom play a key role in learning." Computer-assisted self-learning lacks this important element. According to Massa (2008), "by expressing ideas and listening to what others say, students are able to gauge their own level of knowledge, absorb new information, increase their level of understanding and awareness, and converge on a solution that represents the collective knowledge of the group" (p. 20), and as a result of this informal learning context, the student is more engaged in the construction of knowledge.

Enhancing engagement also depends upon the particular teaching/learning strategy that is chosen, and this is as true for computer-assisted learning as for traditional classrooms. In this paper, an educator and a didactical software designer present and analyze the pedagogical and technical aspects of a specific Web-based software. They developed this software to address the problem of engagement as well as that of ensuring effective learning. The software is based on a proven learning/teaching approach (or strategy) which ensures the full participation of the learners while redefining the educator's role. More specifically, the software adopts a problem-based learning (PBL) approach and employs it with our Online Co-operative Working System (OCOWS).[1] First, we discuss the problematic in the development of didactical software as well as include a brief description of the PBL approach. Then, we present a summary of our research in assessing student and teacher reactions to our pedagogical software and its application, and we present the more technical aspect of OCOWS. The conclusion further discusses the relationship between online learning, the engagement problem, and the choice of an effective learning/teaching strategy.

PROBLEMATIC

A lot of didactical software has been developed without relying on any well-established learning/teaching theory. This type of software is most likely an information system organized into lesson content, quizzes, exams, questions, query searching, etc. Even with some interactive features and numerous animation files, it may be qualified (at the most) as software for *adult self-learning*. The risk associated with such a learning method is achieving very superficial knowledge. Such software does not support the acquisition of new and deep knowledge. With such software, the response to the question, "How does one learn with it?" is typically addressed with, "The learner must follow the course plan, read each lesson to understand it, and then try to answer the questions or do the homework. She/he can also navigate on the website to find an answer she/he is looking for, etc." We believe that such didactical software is not attractive for younger learners, and does not encourage the real participation of the learner in the learning process. It does not facilitate the learners' engagement and cannot create a shared learning environment conducive to deep learning. We believe that the most important aspect of didactical software (in the school context) is that it follows a proven learning approach, specifically collaborative or co-operative learning, and does not rely exclusively upon self-learning. For example, with our proposed software (applying the PBL approach), the above question will be answered as, "The students can learn this course matter by searching or consulting the sources given by their educator, by discussing with peers about the defined problem, and by sharing discoveries in order to reach better solutions for the problem." On the technical side, designing didactical software to apply an appropriate learning approach is a challenge. This is particularly true in the actual Web-based technology context, where an online system must have enough attractiveness and usefulness to be successful.

PROBLEM-BASED LEARNING BY USING OCOWS

The problem-based learning (PBL) approach is a pedagogical student-centred approach (Allen, 1997; Tardif, 1998; Woods, 1995) which applies both co-operative and collaborative learning. Co-operation between the learners allows for task-sharing in order to resolve a particular problem; each learner has a unique role and special work to fulfill. Collaboration of this kind has been difficult to achieve using older didactic software, but it is realized in our newly-developed OCOWS software by allowing comments and discussion of the work by each learner. These comments, sent by other learners and by the educator, are visible onscreen for each part of the problem (or subject), similar to familiar online forums. Students can learn from and support each other. In the new pedagogy paradigm, the shift from teacher-centred instruction to learner-centred instruction has resulted in more non-formal learning strategies, "learning which is embedded in planned activities not explicitly designated as learning (in terms of learning objectives, learning time or learning support), but which contain an important learning element. Non-formal learning is intentional from the learner's point of view" (uteacher project, 2005, p. 1).

This proposed software also allows the role of the educator in the PBL format to be more effective. Tardif (2006) defines the educator's role in a workshop setting. He states that initially, educators must define and clarify the problem. Then, they must participate in the discussion with the learners about the hypotheses leading to one or more solutions. The educator provides the learners with resources to learn or consult, and then validates the learning plan to ensure that it can reach the desired solution. While doing so, the educator helps the learners in task sharing and setting up a work calendar. When the work plan is ready, the educator writes it down as a table of contents, making it permanently available onscreen for all learners. Then, learners accomplish their work by writing their findings in the reserved area, protected by their names and passwords, corresponding to the attributed task in the general plan (table of contents). During the process, the educator is able to monitor the learning evolution and give advice (i.e. comments on the work) to each learner. Finally, the educator guides the learners in a self-assessment, to generalize the new knowledge and link it with previous ones.

This computer-assisted PBL approach includes practical or active learning while emphasizing many of the advantages of co-operative learning such as enhancing the students' self-esteem and social interaction. Unfortunately, most teachers fear that computer-assisted PBL will require a lot of curriculum time (Chevalier, 2000).

The Online Collaborative Working System was inspired by a multi-user online content management system that we developed previously. Although OCOWS was originally designed for online co-operative work and actually used in some projects, this system is perfectly convenient for the PBL approach, especially when used with secondary school students. In the latter context, a problem (or a project) related to course curriculum is presented by the teacher, and the students work together in small groups, asynchronously and at any site they may choose. They work on the solution for a period of one or two weeks.

PBL is even more enhanced with the use of our online system. It adds many advantages for the students. Regular group work is often limited by time and space of the classroom, whereas with OCOWS students are free to work and send their comments or questions at any time on the integrated forum. When working in groups, the more dedicated students often tend to do most of the required work. With OCOWS, each member has to do their part because each one must fill his or her space on the screen. Also, each student has a reserved area where they can freely express ideas with enough time to prepare them, unlike traditional group work in which some students have trouble properly expressing themselves when they are put on the spot with not much time to reflect. Often with regular PBL, the resources available are limited to books and documents available in class, if any, whereas with our software, all kinds of resources can be found on the Internet.

A reproduction of the screen design can be found below. It shows the details of the proposed software user interface. Please note that there are three areas for editing input. The area on the left side is the general plan, and exhibits a table of contents (initialized by the tutor). The central area is the content contributed by each learner (corresponding with the selected item on the table of contents). The right-hand area is for comments from other students and/or the teacher.

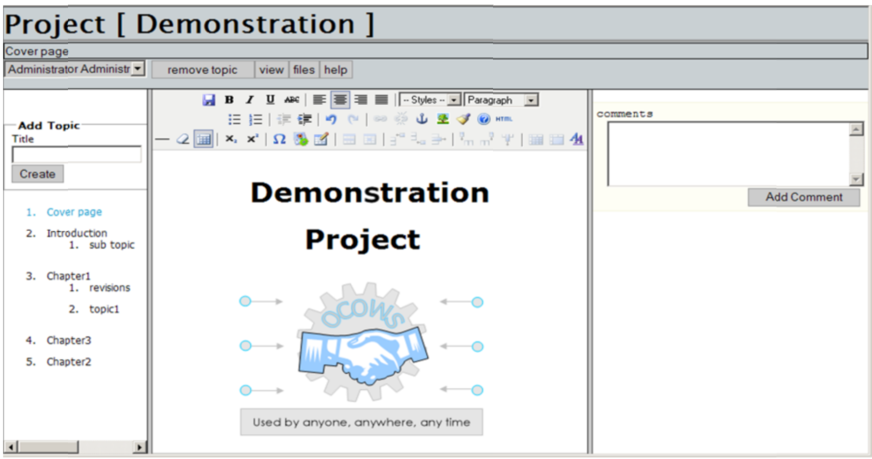

Figure 1. OCOWS screen design

ASSESSMENT

We wanted to assess three aspects of the OCOWS software in use. Firstly, we want to know if this PBL approach and software enhances teaching and learning. The second is to confirm that the PBL approach and this software encourage both co-operative and collaborative learning, thereby enhancing student engagement in the learning process. The third is whether other advantages result from using this pedagogical approach, for example the quality of the acquired knowledge and its relation with previous knowledge.

We recruited six school teachers from an urban francophone high school, with a population of 1,000 students. Grade 11 students involved in the assessment were between the ages of 16 and 18. Six teachers used the OCOWS software in four different semesters: one math teacher during the first and second semester (from September 2007 to June 2008), three math teachers during the first semester (from September 2008 to January 2009), and two applied technology teachers during the second semester (from February to June 2009). The participants were trained to use the software and to apply the PBL approach in a systematic manner. As well, the first teacher served as a resource person for the following five teachers. Each teacher defined one problem during her/his course for use with the software.

The first groups each consisted of four grade 11 math students. Their project allowed them to learn how credit cards function as well as compare different credit cards. Each student was given an initial situation in which they pretended to purchase new items for their new apartment up to a limit of $500. Then, they were assigned a specific credit card. Each group of students were given four different credit cards. The students needed to research to find the specifics of their card (interest rates, minimum payment, etc.) and add a summary of this information in their reserved area. They concentrated on the effects of only reimbursing the minimum payment required each month and showed the calculations. Many imported a table from Excel. They also had to incorporate a fixed payment when the minimum percentage was below a certain amount. The problem allowed them to discover how much time was needed to pay the bill in full as well as the real cost of buying with credit cards. In conclusion, they had to compare the four different credit cards within their group in order to decide which was best and why.

In the first exercises, students were grouped within their class. However, in the next four exercises, groups were created by grouping students from different classes; for example, team one consisted of one student from teacher X's class, two from teacher Y's classes and one from teacher Z's class. Therefore, students did not necessarily communicate with other members of their team other than through OCOWS. Each team was responsible for creating five different sections in the project, one page per team member plus one page for the conclusion. The experiments were spread over a three-week period in order to allow each group to have time in the computer labs.

The average time spent with the software was five hours for each student and approximately 10 hours per teacher. The program itself allows the teacher to see how much time was spent by each student. Teachers were asked to complete a questionnaire in which they indicated the time spent preparing the unit, guiding the students, and grading the projects. During the exercises, the teachers recorded the potential learning effects on their students, as well as the results obtained on formal evaluations. Then, they compared these results with the ones in the previous classes to show the differences, if any. Finally, they answered an anonymous questionnaire after each trial of the software and returned it in a supplied envelope. In these questionnaires, teachers were asked to rate their satisfaction with the program. Students were asked this same question. Teachers were also asked to rate the usefulness of the program as well as the quality of solutions handed in by the students. The questionnaire also verified if students reached a deeper understanding of the subject matter and if they were able to remember their newfound knowledge any better than with traditional teaching. They were also asked if, when compared to traditional teaching, the teacher's role and the students' roles were improved. These results were compiled by our team to effectively evaluate the system.

The results show an increase in teacher and student active participation. Teachers reported an increase of over 20 percent in their active participation. They also report a remarkable increase of 80 percent in the students' active participation. Also, teachers noticed an increase of five to 10 percent over previous classroom evaluation of the same curriculum matter. Overall, four of six teachers reported an increase in retention of curriculum outcome. The degree of appreciation of OCOWS is 70 to 75 percent for teachers and 60 percent for students**.**

Although the students did enjoy the project and they did learn a lot about credit cards, problems with the computers not being able to cope with the overload of participants made it very difficult. The low level of satisfaction (60 percent by students) is related to problems caused by the server being unable to allow access and updates to approximately 30 students simultaneously.

WEB-BASED TOOLS USED FOR THE TECHNOLOGY ENHANCED LEARNING

For readers engaged in the development of didactic software themselves, we include below a short technical discussion of our system and its underpinnings. OCOWS is at its root a highly interactive Web application that provides a multi-user content creation environment where user roles are enforced by the system. Its rich user experience and focus on user co-operation makes OCOWS part of the latest trends in Web development, dubbed Web 2.0. Various popular Web technologies were used to implement this system.

Web 2.0 is a term coined by Tim O'Reilly (2005, 2007) that refers to the new era of the World Wide Web. This new era marks the transition from a collection of traditional websites to a full-fledged computing platform serving Web applications to end users. The Web applications tend to focus on user generated content and on the aggregation of information. Examples of Web 2.0 in practice include weblogs, wikis, video sharing websites, and RSS feeds. Asynchronous JavaScript and XML (AJAX) is often used to implement these Web applications.

AJAX (see Garrett, 2005; Adams, 2005) is a Web development technique for creating interactive Web applications. Its main purpose is to increase responsiveness for Web pages; it accomplishes this goal by exchanging small amounts of data with the server, instead of a one-time large exchange. In essence, what this does is create a page that does not require a reload every time the user modifies or triggers an event. This improves usability, interaction, and response time. The main concern with the use of this technique is that the backward and forward buttons of the browser cease to function; this is a non-issue for systems like OCOWS because there is no need to go back or forward within the editor.

The current generation of Web-based applications tend to suffer from clunky user interfaces and limited interaction because they are implemented in scripts that serve as cleverly crafted HTML pages to the user's Web browser so as to simulate interaction. This approach is well suited for simple situations where the user's actions can be sent to the server so it can respond with the proper page. However, more complex user interfaces cannot be easily implemented this way.

In order to present a truly interactive instructional method to the users, the Web application must take advantage of certain next-generation Web technologies such as AJAX. It is used to silently execute requests between a Web browser and a Web server. It is a paradigm that is quite revolutionary in the world of Web development. A traditional approach would be sufficient to implement the functionality of this application but the frequent page requests would distract the user from accomplishing their tasks. The seamless request model provided by AJAX allows us to deliver a highly interactive application that behaves much like a stand-alone desktop application would while still providing the interconnectivity of the web.

OCOWS COMPONENTS

Each OCOWS website can be localized to the target user base and supports multiple projects. Anyone, once authenticated, can ask to join active projects or can decide to create their own. The person who creates a project is known as the project manager (an educator), and only this person can permit other users to join his or her projects. The system restricts access based on association tables for each project as well as for each topic within a project. Therefore, only the user associated with a topic can modify it; this person is known as a content editor (a student).

On the Server Side

MySQL is used to store information such as user profiles, project details, and user access rights. The table of contents for each project is represented with XML and is stored within the database. However, the actual content for each of the topics is stored in files on disk. The core components are object oriented and implemented in PHP. They are categorized into three types: Data Access Objects, Business Logic, and Remote Procedures.

The Data Access Objects

The Data Access objects are the only objects that interact directly with the database, allowing the business logic to fetch and store data. The centralization of SQL requests abstracts data access and simplifies debugging and testing. Prepared statements are used to reduce SQL injection, a common security problem for applications written in PHP (see http://www.webappsec.org/projects/threat/classes/sql_injection.shtml).

The Business Logic Objects

The Business Logic objects represent actual parts of the system such as user accounts and projects. They also implement the procedures associated with those parts such as account creation and project creation. These objects sit in the layer above the data access layer.

The Remote Procedures

The Remote Procedures handle all the client requests and reply XML back to the client. This is the highest layer in the architecture; it manages the session information and validates access before performing the requests.

On the Client Side

On the client side, the user interface is constructed with XHTML and CSS (Cascading Style Sheets) while JavaScript handles all user events and communication. Hyperlinks and buttons trigger JavaScript functions that call remote procedures. The responses are handled asynchronously to update the state of the client. This is the basis of the AJAX paradigm which is used prevalently in the Web 2.0 world. Contrary to the traditional approach involving complete page reloads and having a very negative impact on usability, this methodology allows the user interface to be seamlessly updated with new information without interfering with the user. However, this flexibility comes at a price, as the implementation is complicated by the added reliance on JavaScript, which is not implemented exactly the same way on all browsers, complicating debugging even more.

OCOWS INTERFACE

The main interface, as was shown in Figure 1, is divided into four sections: the menu, the table of contents, the content section, and the comments section. Because of the nature of the design, the interface was originally implemented using a frame for each section; however, this approach was quickly revised due to various inconsistencies encountered during testing. The main problem, in relation to the frame-based implementation, involved synchronizing dependent events across frames. Another issue was caused by the way different browsers reported mouse positions within frames. To solve all those problems it was decided to re-write parts of the editor to avoid the use of frames; the implementation is now completely frame-free.

The Menu

The menu, located at the top, shows the name of the project and the name of the selected topic. The project manager can change the topic's title by typing in the changes in the title field. The first menu item is a drop down list that can be used by the project manager to change the selected topic's user association. For normal users, the drop down list simply serves to indicate who can edit this section. The second item is the remove topic button; only the project manager can use this button. Next are the view and files button. The view button simply allows the topic editor to visualize the content without the editor while the files button allows the topic editor to manage the files associated with this content.

The Table of Contents Section

The table of contents section allows the project manager to create new topics and to organize them by dragging and dropping topics around. Dropping a topic on another topic marks the dragged topic as a child of the other. An entire sub tree can be moved around easily. All of this functionality is implemented in JavaScript. To view a topic the user simply has to click on it; depending on their access rights, the content will either be in read only mode or loaded into the editor. The table of contents is represented in XML and is updated in real time to all clients.

The Comments Section

The comments section shows the comments associated with the selected topic. Any user can add a new comment that will be shown to the other users in real time. The comments are therefore in context with the topic (see Lê & Roy, 2005). Such rich user interactions are at the core of Web 2.0 and can only be effectively achieved through the use of AJAX.

The Content Section

The content section is either a read-only view of the selected topic or a WYSIWYG editor, depending on the user's access rights for this topic. TinyMCE was used because of its widespread use and simple integration. Slight modifications were made to make it AJAX compatible. This editor allows non-technical users to create and modify rich content in a familiar way.

Figure 2. OCOWS's Login

CONCLUSION

This study has demonstrated that didactical software can be developed which incorporates advanced learning theory, overcomes the problem of student engagement, and creates a virtual "learning culture" which enhances student achievement. It has done this by describing our newly developed OCOWS system, which incorporates the PBL approach, and the results of trials designed to confirm its potential. The trials confirm that the learners must fully participate in the co-operative and collaborative learning process if they are to receive full benefit from the PBL approach. In fact, they appreciate being able to share information rather than merely duplicate it. They can see their contributions as concrete and useful (thanks to the collaboration with their peers). Massa (2008) summarizes the student's perspective as follows: "The students believe that they learned a great deal more by solving a real-world problem than just by listening to a lecture or just reading about it" (p. 20). As well, teachers' comments confirm our belief that the educator's active role in the learning process is enhanced. Teachers confirmed that the use of OCOWS created better conditions in which to teach their students. Instead of being in the traditional role as giver of knowledge, they were able to guide their students in constructing their own knowledge.

We found the classroom trials very useful to assess our software because we had the collaboration of the teachers. They were pleased to participate because we provided them with a new kind of attractive, online didactical software to help them reach their teaching objectives. Their work was not made more time consuming because they no longer needed to "create problems" for the whole course, but rather select only one or two small and interesting problems from OCOWS to be solved by their students. During the trials, the teachers observed the effects on student learning in order to compare their results in prior years. They were pleased to see an increase in student participation and engagement and an improvement in the results of formal evaluation.

In conclusion, the results show an improvement in students' learning, indicating that the instructional method as delivered through our software created sustained student engagement, which resulted in a better understanding of the subject matter.

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Section II: Questions and Dilemmas Associated with Informal Learning Research

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INTRODUCTION

CRYSTAL Atlantique comprised a unique collaboration among education researchers and researchers from other scientific disciplines. In this set of chapters we feature some of the work done by the education researchers. While the informal learning contexts in these four chapters were diverse, our conversations at the end of the project revealed characteristics of researching informal contexts that would warrant attention of researchers investigating any informal learning context.

What is informal learning? This is the question that was at the forefront of discussion among the CRYSTAL Atlantique education researchers throughout the project, even at the close of the project. While each research context in this project was outside of school programming, it was impossible to claim that any of the contexts were completely independent of formal schooling. Each informal context was organized to develop knowledge and skills related to sciences and mathematics. School science and mathematics classes and curricula have the same goal. How then can these contexts be seen as independent from each other?

It was noted that many of the research contexts were organized to develop knowledge and skills. Such *organized* program development, due to the fact that it is organized, seems to transgress the boundaries of informality, but if there were no program developed it would be difficult to research it. In this way it seemed that informal learning should be characterized by its independence from mandatory schooling, not necessarily by its lack of organization. Alternatively, we know that people learn even in activities that are not centrally organized around the idea of developing knowledge and skills. For example, people learn when living in community, addressing their human needs, playing games, and the like. When considering the learning of science, mathematics, and technology in such unorganized endeavours, researchers are left to compare this learning to formal conceptions of science and mathematics, which by nature are situated in academic contexts. Thus connection to school science, mathematics, and technology appears even with contexts organized around other priorities besides the development of knowledge and skills.

This conversation about the nature and independence of informal contexts highlighted for our team some key insights into the research of informal learning. Perhaps the principal characteristic of all informal learning is that it is somehow free from the formalized expectations of mandatory schooling, whether it is within an educative program outside of such schooling or it is learning that happens as part of other endeavours. This distinguishing characteristic turns attention to the values and goals that inform learning. Working in contexts outside of mandatory

K. S. Sullenger & S. Turner (Eds.), New Ground, 107–111.

schooling, the CRYSTAL researchers were attentive to the goals and values of the participants in the contexts, and also to the way each participant experienced the context. It should be noted that such attention to the goals, values, and experience of children in schools warrants attention, too, but the positioning of the learning outside school seems to highlight the necessity of this shift in attention.

Attention to the differing goals, values, and experiences of participants has significant implications for the way a researcher evaluates learning. The criteria through which one evaluates learning impacts research questions, methodological approaches, and theoretical frames. In order to evaluate learning in terms of participants' agendas, one has to identify these agendas. And it is important to note that there are multiple agendas at play in any one context. This identification may be explicit or implicit in the research question(s). The orientation around the agendas of participants adds complexity to the methodology because the researcher has to both identify how to evaluate the learning and evaluate the learning based on these criteria. Furthermore, because of the attention to multiple points of view, researchers need to find a way to reconcile this diversity in evaluating learning. This reconciliation has implications for the theoretical framing of learning. Theoretical framing may express itself in terms of cultural differences among participants, especially in juxtaposition with the dominant school culture that is associated with Western values.

The CRYSTAL Atlantique funding proposal emphasized the significance of contrasting cultures in informal settings. The theme of the project was stated as follows: "understanding and promoting the culture of science, mathematics, and technology (SMT) across the Atlantic provinces." This theme was elaborated with a description of culture that goes beyond ethnic differences, allowing for cultures within an organization, within schooling, and within any collective of people:

> By the "culture of science, technology, and mathematics" we mean both the nature of research communities and conventions that govern their work, as well as public awareness of the impact of science-, technology-, and mathematics-related activity on the economic and social well-being of citizens of the region.

There are also relatively mundane though still significant implications for research associated with contexts free (or at least loosened) from the grip of formal schooling. The first encounter the CRYSTAL Atlantique researchers had with this freedom was the challenge of securing the informed consent that is required for ethical research and for meeting standards of university research ethics boards. Schools have procedures in place for disseminating information to parents of children and for requesting permission for the children's participation in various activities. Along with these procedures there is an implied expected complicity in which the children are expected to follow the agenda of the adults chosen to guide the learning of the community's children. It was evident to our team's researchers that neither the procedures nor the implied complicity were present in the informal contexts. This was true both for children participants and adult participants. The fact that participants (and/or their parents/guardians) seemed to be more thoughtful and careful about their consent to participate was a little surprising and even sobering. Nevertheless, from the standpoint of a researcher it was a hurdle that made the research more challenging than expected. On the other hand, the care with which participants considered their involvement probably meant for richer and more authentic data, as compared to research in contexts where participation is relatively thoughtless.

In the conversation at the end of the CRYSTAL Atlantique program, one researcher captured both the mundane and deeper aspects of the relative freedom felt by participants in learning environments outside of school with the following reflection:

> You're trying very hard not to change the community that you're working in as much as possible, and that's impossible to do of course. But, you try as well as you can to keep the nature of the learning community relatively intact. That is very difficult within the informal community, partly because the participants see themselves to be in a freer space …. So, pulling a young person or a child out of an informal learning setting [to ask them questions relating to one's research agenda] is sometimes seen by the child as an incursion on their environment.

Finally, a characteristic that is present in all education research is exacerbated in informal contexts. In any education research it is a challenge to formulate warranted claims that have any sense of generalization in them because of the diversity across education contexts. What happens in one classroom would not appear the same in another classroom because the participants are different, with diverse backgrounds, diverse goals, and diverse community needs. Thus claims in education research tend to look inwards, with a careful articulation of the context and analysis of events in that context. It is then up to readers to make connections between that research and their own contexts. This challenge for education research is even greater when considering informal learning because informal contexts differ even more than do school contexts, which typically share common agenda, curricula, and procedures. Thus, the research on informal learning shares this feature of research on formal education—the reporting features strong description of context and what happened in that context.

For each of the above noted challenges, there are associated opportunities. The challenge of attending to multiple agenda made for development of good theory and methodology that takes seriously these agenda. This highlights a lack in some education research that takes for granted certain agenda. The challenge of garnering participation made for thoughtful and authentic participation. Finally, the challenge of diverse contexts is also another way of thinking about an opportunity. Our group noted an ever-increasing potential for contexts in which to conduct research of informal learning. Indeed, technological developments and their associated social developments—social media in particular—make new informal learning communities available for investigation. One of the research groups within CRYSTAL Atlantique worked in such a space, but there are new and other possible spaces that could be explored.

What kinds of research did the education researchers in CRYSTAL Atlantique conduct? The three chapters included in this section exemplify the broad range of research that might be done in informal contexts. With this set of chapters, one may note the diversity of methodologies and research questions among the three research programs. This is only a sample of the wide range of research that might be done in informal contexts.

In the first chapter, two mathematics education researchers, David Wagner and Lisa Lunney Borden, give an account of their ethnomathematical conversations with Aboriginal elders in Eastern Canada. They identified distinctions between the values in cultural mathematical practices in Aboriginal communities (both traditional and modern) and in Western-oriented school mathematics. The elders highlighted the importance of common sense in problem solving, which by nature needs to be grounded in a particular community context. Following the insights of the elders drawn from their experiences of learning mathematical practices informally in their community, Wagner and Lunney Borden raise questions about the effectiveness of school mathematics that is becoming increasingly removed from common sense grounded in community needs.

In the second chapter, Ildikó Pelczer and Viktor Freiman, who research creativity and the uses of information technologies in mathematics education, develop a framework for identifying the difficulty level of mathematics problems. The data in the analysis comes from the problem-solving community CASMI (Communauté d'Apprentissages Scientifiques et Mathématiques Interactifs), which is an informal online environment that attracts schoolchildren from different regions, schools, and grades. Participants were separated in time and place, working at their own pace. They produced different solutions, communicating them differently based on their skills, schooling, motivation, and own way of thinking. Pelczer and Freiman compare inherent problem characteristics, success rate, and participants' perceptions of difficulty of problems. With this focus on the users, they challenge the idea that problems have inherent levels of difficulty.

In the third chapter, education researchers Ann Sherman and Leo MacDonald collaborate to report on their interactions with children in a summer science camp on a university campus. Children participated in laboratory experiments and other outdoor science-related activities, and were encouraged to work like "little scientists." The research interviews aimed to understand the participants' experience and perceptions of scientist work. The researchers question traditional methods of understanding students' learning in school, and describe their approaches to informal interviews seeking to allow the children's voices to be heard.

In the fourth chapter, Essie Lom and Karen Sullenger collaborate to report on the professional development of teachers involved in Science in Action, an afterschool program for elementary and middle school children. This brings together Lom's interest in professional development (which might otherwise be referred to as the learning of educators) and Sullenger's interest in children's conceptions of science. Their work included a wide range of research involvement among participants as they were all invited to engage in program planning and in the research to their level of comfort. For this chapter, the co-operative inquiry model used in this research gave Lom and Sullenger grounds for reporting on the rewards and challenges reported by the participant teachers. Their work features insight into questions relating to the role and experience of novice researchers, teachers in this case, who are also research participants.

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COMMON SENSE AND NECESSITY IN (ETHNO)MATHEMATICS

"You just take a [piece of birch] bark and hold it over the circle. Fold it in half and fold it in half again to get the centre." Mi'kmaw elder, Diane Toney, was well known for the quality of the boxes she made out of porcupine quills. For her, folding a round piece of bark to find the centre of a circle was common sense; it was not mathematics.

As part of a wider investigation of mathematics and science learning in informal contexts in Atlantic Canada, we interviewed Mi'kmaw[1] elders and other leaders to identify some of their everyday practices (both traditional and current) that could be deemed mathematical. These discussions led to the engagement of thousands of students in ethnomathematical investigations of their own.

In this article, we look back on one of the initial conversations, in which we described ethnomathematics to a small group of Mi'kmaw teachers and elders. The group's responsive identification of numerous mathematical practices demonstrated understanding of our ethnomathematical definition of mathematics. However, the group saw distinctions between these practices and mathematics. Their interactions among themselves and with us in this conversation returned on multiple occasions to the themes of common sense and of personal and community needs. Common sense and necessity, they noted, were absent in school mathematics.

First, we will place the conversation in its wider cultural context, and then consider the definition of mathematics given to the teachers and elders in relation to literature on ethnomathematics. Next, we give an account of what the teachers and elders said about cultural mathematical practices and, then more specifically, on these examples' connection to common sense and necessities for livelihood. Following this account, we reflect on the nature of this common sense identified by the elders and teachers in relation to mathematical practices, and then apply this understanding to an example of student engagement in mathematics. We close with questions about common sense and necessity in mathematics education.

CONTEXT

The marginalization of Mi'kmaw youth from mathematics has been a long-standing concern in Mi'kmaw communities. While it is difficult to gather accurate statistics on the number of Mi'kmaw students pursuing educational paths involving mathematics and sciences, community leaders recognize and articulate concern

K. S. Sullenger & S. Turner (Eds.), New Ground, 113–127.

about the disengagement of their students from these subjects. Similarly, interested parties across Canada have expressed concern about the low participation rate. The Minister's national working group on education (Indian and Northern Affairs Canada, 2002) has said that a key area to be addressed in Aboriginal education in Canada is the development of culturally relevant curricula and resources in areas of mathematics and science where there is currently an identified weakness. Although not specific to Canada, this argument is supported by a National Council of Teachers of Mathematics publication, which stated that Aboriginal people in North America have the lowest participation rates of all cultural groups in advanced levels of mathematics (Secada, Hankes, & Fast, 2002).

Ezeife (2003), Secada, Hankes, and Fast (2002), and others have identified a key reason for the disengagement of Aboriginal youth from mathematics and science—the discrepancy between their own cultures and the cultural values embedded in school-based mathematics programs. Cajete (1994) stated that when science is taught from a Western cultural perspective it acts in opposition to the values of traditional culture for Aboriginal students, which affects their performance in mathematics and science because it simply is not connected to their daily lives. Lunney Borden (2010) has shown the lack of attention to value differences and the use of inappropriate pedagogical strategies to be among the factors that result in a disconnect between school-based mathematics and Mi'kmaw ways of reasoning mathematically. As a result, many children choose to opt out of mathematics because the cost of participation is too high, demanding that they deny their own worldview in order to participate in the dominant view of mathematics. Doolittle (2006) has elaborated on this cost of participation for Aboriginal students and Gutiérrez (2007) has raised the same issue for minority groups in general. The incidence of conflicting worldviews has led many Aboriginal students to either ignore the possibility of studying science or mathematics, or to struggle within these disciplines. This marginalization is a serious issue for Aboriginal communities that look to younger generations to acquire the skills and knowledge needed to move their communities closer to the realities of self-government in this modern age.

We note that marginalization goes both ways. As Canada's majority culture continues to marginalize Mi'kmaw and other Aboriginal peoples, these marginalized people reject many of the dominant discourses of the majority. Individuals in Mi'kmaw communities could be said to be ignoring, moving away from, or marginalizing mathematics because of the cost of participation, just as the forms of mathematical instruction leave their needs unaddressed. We suggest that this kind of reciprocity of relationships between cultures is related to the reciprocity amongst individuals in interpersonal positioning. This reciprocity is described by van Langenhove and Harré (1999) and taken up by Wagner and Herbel-Eisenmann (2009) in the mathematics education context. In any interaction, when one person positions the other people in certain ways, they comply or resist this positioning, and thus take up their responsibility for the positioning in the interaction. Similarly, when a dominant culture positions a community in a way that marginalizes the people, the people in that community, in their response, may comply with that marginalization by resisting engagement with the domineering organizations and people.

There are, however, various ways of resisting that marginalization, including the acceptance of the dominant culture values (such as those associated with mathematics education), or, more productively, rejecting some of the positioning that goes with this marginalization and engaging with the dominant culture's practices while maintaining key identities and cultural knowledge. Our research efforts have been aiming to address the disconnect between Canada's dominant culture and Mi'kmaw communities, particularly as this disconnect relates to mathematics education. An aspect of this work has been to engage in ethnomathematical conversations within the Mi'kmaw communities.

The conversation that we reflect on in this article was the first conversation in our ethnomathematical research to include elders, though Lisa had had years of experience in Mi'kmaw communities and numerous conversations with elders before. We met by videoconference with four elders, Charlotte,[2] Gladys, Richard, and Diane (who is quoted above), and John, a teacher who held community honours. John and Gladys were Mi'kmaw language teachers in the secondary school, and Richard was a carpenter and a building technology teacher. Unfortunately, Diane Toney whose work with the birch bark described above, died the day before our next planned conversation.

Lisa knew all the conversants, having worked in the community as a mathematics teacher for 10 years. She and the teacher in the conversation arranged the meeting. Dave had met some of the group face to face before the videoconference. Lisa and Dave sat beside each other in one location and the five Mi'kmaw leaders sat around a hexagonal table in the other location. For the community leaders, videoconferencing was commonplace and a relatively transparent medium because of their considerable experience with it to connect with other communities across Canada. They assured Dave, who was novice to videoconferencing, that he too would soon see through the medium.

The direction of our research after the conversation central to this article is not so relevant to our interpretation of the conversation itself, but it colours our interpretation of the conversation and thus warrants some mention here. Our initial reflections on the conversation focused on the direction of our engagement with community members (the direction of our research). The quality of our interaction with these community leaders inspired us to think of ways in which children could be encouraged to have similar conversations with their elders and other community members. We wanted to remove ourselves from the position of mediators of those conversations, which was the initial model we envisioned—us interviewing community members to develop resources to be used for community children (see Wagner & Lunney Borden, 2012, for more on this shift).

Further conversations among teachers and elders, some of whom were part of the conversation central to this article, led to the development of the Show Me Your Math contest, which prompted students to investigate local practices to identify mathematics and to present their findings to the community with concrete displays as well as electronic displays posted on the Internet (see Lunney Borden &

Wagner, 2011, for more on this student engagement). In our reflection on the conversation central to this article, we will draw briefly on student investigations from this contest.

WHAT IS MATHEMATICS?

Before reporting details from the conversation with elders and teachers we ask a central question: what is mathematics? This question was formative in the direction of the conversation. After opening the conversation with necessary relational pleasantries, we said that we wanted to hear examples of mathematics done in Mi'kmaw culture, both traditionally and currently. Dave characterized mathematics in this way: "Most people think math is what happens in school, in math class, but we can say there are other things that are math." After we listened to numerous examples of mathematical practices in traditional life, Dave added: "We've been talking about different places that math happens in the real world, like when we're measuring. Like, Richard was telling stories about measuring, and Diane about measuring. Even things like when we're navigating through the world—how do we know where to go, or what directions, and all that kind of stuff?" We continued with an introduction to Alan Bishop and his list of practices in which we can find mathematics: counting, measuring, and locating, as well as designing such practices, playing with them, and explaining the practices or the designs.

Before recounting more of the conversation and our interpretation of it, we will draw attention to some relevant literature on ethnomathematics. The approach we were taking to ethnomathematical research was quite typical (cf. Powell & Frankenstein, 1997), drawing on Bishop's (1988) definition of mathematical activity (practices that involve counting, measuring, locating, designing, playing, or explaining) and on the assumption that any mathematics is an artefact of a particular culture.

Since Ubiritan D'Ambrosio coined the word "ethnomathematics" in the early 1980s (for his early writing on it, see D'Ambrosio, 1985) to describe the culturally contingent nature of mathematics, it has become established in mathematics education research and also subject to significant criticism. D'Ambrosio (e.g., 1997) himself has raised criticisms, which relate mostly to the way ethnomathematics is received, and thus by implication to the way ethnomathematics research is done and presented—for example, "Much of the research in Ethnomathematics today has been directed at uncovering small achievements and practices in non-Western cultures that resemble Western mathematics" (p. 15).

Dowling's (1998) criticisms of ethnomathematics have been related to this one raised by D'Ambrosio. Gerdes (1997), in his survey of the first decade of ethnomathematics, gave a rationale for its way of uncovering mathematics in communities that are unaccustomed to recognizing the mathematics in their practices. Ethnomathematics is seen to have emancipatory power because the uncovered mathematical practices can inspire confidence in students who may assume they cannot do mathematics. Dowling responded to Gerdes' (1988) example of ethnomathematics at work “defrosting” the frozen mathematics in a woven button and celebrating the mathematics that was already present in Mozambique, and Gerdes’ claim that this ethnomathematical work “stimulates a reflection on the impact of colonialism, on the historical and political dimensions of mathematics (education)” (p. 152). Dowling (1998) considered this an example of what he called the “myth of emancipation,” noting that the “difficulty is that it appears that a European is needed to reveal to the African students the value inherent in their own culture” (p. 12) and that this revelation is done in European terms. This critique weighed on our consciences in the development of our conversation amongst the Mi’kmaq, long before we read Dowling’s articulation of the critique.

Gerdes’ use of the word “frozen” suggests to us an image of frozen food, which only becomes valuable once it is thawed. This suggests to us that Mi’kmaw practices would only reach their potential when the mathematics is revealed, but, as our conversation with the elders and teachers showed, the practices were valued nevertheless, with or without being identified as mathematics. While there are Mi’kmaw words for mathematical activities such as counting, sorting, measuring, comparing, and so on, there is no Mi’kmaw word for mathematics, so it is unreasonable to expect Mi’kmaw tradition to identify practices as mathematical. Thus identification of practices as mathematical must come, initially, from representatives of the mathematics discipline, thus necessitating the appearance of Eurocentrism as described in Dowling’s critique.

VALUES IN MI’KMAW PRACTICES

In the conversation with elders and teachers, they were quick to identify cultural mathematical practices before we gave an ethnomathematical definition of mathematics. For example, the quotation opening this article came from a longer discussion about centres, which Diane started immediately after our request for examples of mathematical practices:

> You know, Richard, I actually use my eyes. I can measure with my eyes. I can tell you right off how big a part of my quill boxes [are]. When I do a lot of my measurings—circumference—I’m not worried about the whole area of my box, so if I say I’m going to make something nice and big, I measure it with my eyes. I’ve never looked at anything in inches, and say “I’m going to make this four inches wide or three inches wide.” I may be off a little bit, but it doesn’t matter, it’s pretty close. But I do measure with my eyes. But you know, having use of a cup would be an ideal thing, just to draw a circle around it. But then I have to find my centre.

John responded saying the use of a cup isn’t traditional, and Diane argued that he was just saying that because he doesn’t make quill boxes. It is appropriate to use the best resources available. John half-jokingly guessed how she found the centre: “You know how to find the centre? You put a hole in the middle.” She did, after all, say earlier that she measured with her eye. Diane didn’t reveal her method for finding the centre of the quill box circle until after Richard, the carpenter, placed the theme of finding centres into his professional context:

> I'll give you an example how the Natives measure. There were a couple brothers that lived down on the reserve here, but they have passed on, but they had a contract to build a house on this reserve. They didn't use a tape measure per se, but they had a long piece of stick, and they marked off where a certain stud should be and they moved it up to the top part and marked that off, and all they used was a stick to measure the openings of the windows and doors. They used a stick, they compared it to the door and transferred their measurement to the wall of the house, and they did very well. The house is still standing. These gentlemen, when they built the house, all they used was a stick. They couldn't really read the tape measure. [They used modern building materials,] but they did very well without using a tape measure. There's a way of doing stuff like measuring. I mentioned my grandfather. If he wants to find the centre of anything, all he uses is just a piece of string folded in half and that's the centre measure. And then if he wants to do it in three, he just folds the string into three.

Eventually, Diane revealed her method for finding the centre of a round quill box, as quoted at the beginning of this article and she also added detail about finding the circumference of the circle: "To make a ring, you need to go across the centre of your birch bark three times and allow about the width of your thumb to make a perfect round." Going across the centre is using the diameter. Three times and a thumb width approximates pi.

For Diane and for Richard, what mattered was that the methods used worked. The practices that they used and that they valued in others' work produced useful products—solid, sturdy, well-proportioned, beautiful.

The conversation also considered the measurement of time. The elders and teachers agreed that longer periods were measured in terms of generations and family. Relatively recent events could be recalled by thinking, as John said, "That was before I had children, when I had cars," or "that must have been just before our third child was born." He could deduce the year because he knew his children's years of birth. Longer periods were related to generations. John said, "I know some of the stories my father or mother would say. I don't even know these people, but they would say their grandfather was like this, or their great-grandfather did this. So they kept time like that, but they never went beyond great-grandparents." This got Charlotte talking about the value of writing as a medium for preserving cultural knowledge that might be otherwise lost with the bearers of knowledge in an oral tradition.

Time and distance measurement could be intertwined too. Richard told about his grandfather: "You're walking two miles or three kilometres or whatever, and there is no specific measurement … '*Eliey kloqowejuwaq*,' I'd ask him. 'Where is that?' And he'd say, 'Well, I'm going to take a walk until the stars come out.'"

Discussion about time highlighted the importance of context. The ways of mathematical reasoning demonstrated by the elders in their examples were not fixed to abstract rules but rather demonstrated a value of responsiveness to a changing context. The numbers didn't matter so much (the dates, the years, the exact distance). What mattered was the relation to one's experience. The significance of context came up repeatedly in the conversation. Diane Toney's quill box work is another example of this. The exact measurement was relatively unimportant. John interjected, "Location, location, location" (borrowing the phrase from real estate values) whenever discussion turned to the significance of context. His readiness to do this and quickness to make the connections demonstrated that he was well aware of the special significance of context in his community, and that he wanted to make sure we would be aware.

COMMON SENSE IN MI'KMAW PRACTICES

The above examples were provided in response to us asking for examples of mathematical practices, demonstrating a recognition of some connections to mathematics without the help of non-Mi'kmaw (or, as Dowling would say, European) mathematics experts. The conversation took a turn to include discussion of a wider range of practices once we introduced Alan Bishop's list of practices in which mathematics can be found. In this section we recount aspects of this elaboration, and draw attention to the emergent themes around which the elders made a distinction between their practices and mathematics. (Perhaps it is significant that the elders made this distinction more than the teachers.)

Apparently referring to the list of activities that could include mathematics, including counting, Diane pointed out that counting was not important (though over the course of the conversation she kept count of the jokes John made at her expense). She and Charlotte talked about cooking. Diane said that counting and measuring using standard units only recently became commonplace in cooking:

> It wasn't saying if you had a family of six, you were going to go cook six potatoes. You made sure you cooked a little bit more, maybe three more, and cut those in half, and that would be enough for the family of six. Whatever. You know, but you measure basically with your hands, and you use your common sense. You know basically, everybody has enough. You have enough and then you're not going to waste it.

Richard added, "Enough for a certain size family. You may have five people in your family. You just compare that—enough for that many people. And there was no actual number." Later in the conversation, Diane talked about potatoes again when describing her mother cooking a meal:

> My mother would usually send you out with a little pot. "Fill that up." And that was it. You didn't ask any questions. It always had to be enough. So that way, it didn't waste. There was no such thing as a fridge in those days.

Charlotte agreed with the importance of getting the amount right: "My mother never wasted anything. When she made pot of stew, we had stew for the whole week. You eat it until it's gone." Gladys, who was most knowledgeable about the language (Mi'kmaq) said *tepiaq*, the word for "enough," and included with the word a gesture showing the amount. The word always had a spatial gesture with it.

Richard used the same word for describing the amount of wood he would fetch in winter, but with a different gesture. "Enough" in wood is different from "enough" potatoes; the word is the same but the gesture differs. The measurement of "enough" came up repeatedly (especially after we opened up the definition of mathematics using Bishop's list), and with it the claim that the practice being described was common sense. The longest stretch of Mi'kmaq speaking among the elders and teachers during the interview was relating to the word "enough" and its accompanying gestures. This engagement among the assembled group demonstrated the importance of the concept to them.

Discussion of common sense practices was accompanied by gestures that indexed memories of the amounts necessary to serve family needs. The descriptions of the processes were also interspersed with reminders that these calculations were not merely academic; they were necessity. The above examples show some of the references to not wasting. Diane added other reminders of the context of necessity when talking about cooking, including "just make sure your hands are clean" when talking about measuring with the hand.

Common sense was for them different from number sense, distinct from mathematics. This distinction became most evident when we asked about conflicts between cultural mathematical practices, which they called common sense, and school mathematics. They responded saying that children take things for granted too much:

> John: All they have to do is just turn on the tap and get how much water you want.
>
> Charlotte: And just flick the switch—there's the power.
>
> Diane: We measure for survival.
>
> Richard: We just take it for granted that you flick the switch on, and you have light.
>
> Charlotte: They don't even have to walk to the TV to turn it on now. Remote.
>
> Richard: I think it's too easy. Once we run out of the fossil fuel we'll be going back, instead of walking to a TV, we'll be walking to a kerosene lamp, and walking to a box of matches.

Reference to the convenience of the modern world came up a number of times, always in response to our asking about differences between school mathematics and cultural practices. This pattern extended among other conversations with elders too. For example, Lunney Borden (2010) described how, in another conversation with Richard and Ma'li, a student teacher from the community, she became aware that the necessity of taking only enough related to forward thinking. One must think seven generations ahead; taking too much now might mean leaving future generations without enough. Ma'li said, "Enough is for survival, and that's *Lnu* (our people)" (p. 175). With the elders' explicit commitment to common sense it became clear that the taken-for-granted aspects of our modern world are at the heart of the perceived conflict between traditional practices (some of which remain current practices) and the mathematics the elders see children take in school.

The following excerpt from the conversation represents well the central idea that emerged from our conversation.

> Diane: With the curriculum as it is now, there's no bearing on the traditional because that way is gone for the children. But then again, it wouldn't hurt them to have a history with it.
>
> John: There's no exposure any more.
>
> Diane: Yeah, there's none. It has nothing to do with them in this day and age. Because everything is so easy; it's right there now. We didn't have that. We had to use—there's one word for it, two words—"common sense." You had to use your common sense.
>
> Dave: Are you saying that you can't learn something unless you need it?
>
> Diane: Exactly.
>
> John: You gotta *know* you need it.
>
> Diane: Exactly. If you know you need it, then you are going to go about ways of getting it.

"Whatever works" is the language of common sense. If one has no real need to relate something to, it doesn't make sense to say "enough," because there is no standard to dictate what would comprise enough. When our needs are more than fulfilled, perhaps we have to be exact in measurement for otherwise we could not know when to stop.

COMMON SENSE AND NECESSITY IN/AGAINST MATHEMATICS

Before reflecting on the juxtaposition of common sense and mathematics, we interject here that the Mi'kmaw elders and teachers we engaged in conversation are not the only educators to note the significant change in children's engagement with everyday needs. Dewey (1907, pp. 22-24), whose reflections on education were not situated in Aboriginal communities, but rather in the colonizers' world, noted:

> Those of us who are here today need go back only one, two, or at most three generations, to find a time when the household was practically the center in which were carried on, or about which were clustered, all the typical forms of industrial occupation. The clothing worn was for the most part not only made in the house, but the members of the household were usually familiar with the shearing of the sheep, the carding and spinning of the wool, and the plying of the loom. Instead of pressing a button and flooding the house with electric light, the whole process of getting illumination was followed in its toilsome

> length, from the killing of the animal and the trying of fat, to the making of wicks and dipping of candles…There was always something which really needed to be done, and a real necessity that each member of the household should do his own part faithfully and in co-operation with others.

We find the commonalities between the reflections of the elders and of Dewey quite striking. They even seem to be obsessed by the same technical marvel—light wired into households powered by electricity.

We connect elders' and teachers' frequent reference to "common sense" as distinct from the kind of mathematics done in a world of convenience. How much wood would they haul home for fuel? "Enough." How did they know how much to bring? "Common sense." By contrast, we might consider a school mathematics word problem that asks, "Bob's wood pile for a week of fuel is about 2 x 5 x 3 feet. What would the dimensions of the pile be for two weeks of fuel?" It is easy to imagine a child in school answering 4 x 10 x 6, doubling each dimension. But it is hard to imagine someone who is cutting, hauling, and burning the wood making the same error.

The person who needs wood for fuel draws on common sense, which includes a sense of the situation, a sense of the family's needs and a sense of the work it takes to meet these needs. In such situations, the answer to our mathematical questions can be "enough." How many potatoes would you cook? "Enough. That way you didn't waste any." These kinds of answers may seem unmathematical because we may wonder how much enough is. But a typical mathematical word problem answer, like "9 potatoes are needed for a family of 6," ignores the reality of variance in potato size. For the answer to the potato question, a gesture showing an imagined volume (roughly spherical) accompanies the elder's "enough." Likewise, for the wood-fetching question, the elder marks a height off with his hand as he says "enough." The natural gesture, which is part of his answer, does not tell us how much wood was needed, but it does show us that he knew how much enough was. This concept enough values estimation (which was central to the first part of the conversation) because estimation responds to human needs instead of precision.

"Enough" implies a sense of what is needed. For this kind of sense, the question needs to be situated in a problem—a real problem. Children who have everything they need at their fingertips cannot have a sense of necessity. To ground classroom mathematics in such necessity, we, like D'Ambrosio (1998), suggest that class activity begin with an issue faced by the children's community. We share with D'Ambrosio the value of understanding the centrality of mathematics in cultural practice, but our point here goes further: without grounding mathematics in local problems and questions that require answers, students could not apply their common sense to their mathematics. With mathematical activity that begins in local issues, students can begin to use their mathematics to exercise their intentions within these issues. This kind of personal (and communal) agency is different from agency that arises in classroom contexts in which the mathematical starting points relate to other people's concerns.

This strong connection between local concerns and mathematics relates to the call for connecting number to quantity, as articulated by Wagner and Davis (2010).

They advocated for an increased attention to quantity sense in school mathematics curricula with activities that connect quantity to number operations, and claimed that the separation of quantity and number is a relatively recent mathematical phenomenon: "As number is slowly but surely abstracted from context, students become numb to the meaning of the numeric symbols they learn to manipulate" (p. 40). They have suggested that this abstraction has supported colonialism by promoting numbness to critical quantity sense. We think that the elders in our conversations, who like Wagner and Davis, valued mathematical activity connecting to context, saw their appeal to remembering common sense as a way of resisting forces of colonization.

Mi'kmaw common sense is a form of resistance to abstraction, which Balacheff (1988), for example, characterized as central to mathematical action with its decontextualization, depersonalization and detemporalization. The Mi'kmaw elders expressed reluctance to support anything that creates numbness to context. Mi'kmaw culture strongly values awareness and connections to the land and to each other, which are connections that can be lost in the abstraction that is often associated with mathematics.

When their mathematics is not grounded in their experience, students cannot apply common sense. They need something else. Perhaps this something else is what some educators call spatial sense and number sense. It seems to be expected in typical curriculum structuring that children learn to understand space and number before addressing their community's issues. The Aboriginal elders who we have been interviewing seem to be saying that this is backwards. Mathematics should *begin* with common sense. Brown (1996) asserts that in mathematics education the emphasis should not be "on students re-creating the teacher's intention but instead…on students' production of meaning in respect to their given task" (p. 64). We suggest that students' production of meaning should rather relate to their tasks as humans, addressing community needs.

Lisa recalls from her teaching experience a lesson in which she invited grade 10 students to think about the increasing population in their community and to analyze available data using regression analysis. She recalled that students were very engaged and extended the learning by asking meaningful questions about how the community would be able to provide for this increasing population given a fixed land mass and limited number of employment opportunities. The students chose to examine how the population density would change as the population grew and also compared these population density calculations to large urban areas. While her intention may have been to simply use meaningful data, the students' response to being able to address important community decisions took the lesson in a positive and productive direction, one that addressed community needs and prompted the students to stretch their mathematics to meet these needs.

Typical questions relating to population growth often focus on growing bacterial cultures or earning interest on an investment; such questions are outside the experience of most grade 10 students. When contexts seem contrived and removed from the experiences of students, how can they draw on their experience to make meaningful connections to the problem? Such problems do not help to build a sense of common sense. In fact, Gerofsky (2004) argued that the genre of mathematics problems seems to be designed to lead children to ignore context rather than attend to it. Thus they are led away from common sense.

As we reflect on distinguishing between a grounded, contextual common sense and abstract mathematics we are reminded that this distinction is perhaps related to the fact that there is no Mi'kmaw word for mathematics. We note here that there is also no English word for mathematics; rather the English language has adopted the Greek-based Latin word. Is this an indication that the English culture had no mathematics prior to learning of its existence from the Greeks? Did the mathematical practices of the English not have value until identified as mathematics? Or is it rather that the English chose to adopt this word because they saw connections between mathematics and practices that already existed within their own cultural experiences? We wonder about the conditions that created the necessity for English mathematical practices to develop. Did these practices arise as a result of a common sense approach to solving problems? If so, does the same issue exist for majority Canadians (English speakers)? Is mathematics that is disconnected from necessity also equally devoid of a connection to common sense for all students?

What may be a distinguishing factor between the experiences of English-speaking Canadian students and those of Aboriginal students is that the English culture has had the power to choose to pull mathematics into their cultural practices whereas many indigenous cultures have had mathematics pushed on them by colonizing school curricula. Doolittle (2006) has argued against the approach of looking for the mathematics in indigenous culture, as in the "defrosting" described above, which he called pulling out the mathematics. He has equally argued against the practice that pushes mathematics into the culture as when demanded by school curricula. Rather he suggests that the best approach is to allow communities to have agency to decide what and how mathematics might be pulled in to the community. Such an approach involves community members deciding for themselves how mathematics might fit within their own cultural practices and community needs. In our closing reflections we consider an example of a community-initiated mathematics project.

STUDENT WORK IN THE TENSION

While the elders and teachers in the conversation seemed to distinguish between school mathematics and common sense, and to lament the loss of common sense in their community, they and others in the community also recognized and continue to recognize the importance of their community's children succeeding in school mathematics as it is (lacking in common sense). Interestingly, as reported by Lunney Borden (2010), the rationale given for success in school mathematics is that it prepares students for higher education that equips them to bring skills into the community. The need for success, even in a system that is seen as too abstract, is articulated as addressing the community's future needs. Necessity still reigns.

The students of the community live the tension between common sense and mathematics. When given tasks that seem to be divorced from their experiences, they struggle to apply their common sense, and thus struggle to understand the mathematics. We advocate for asking two questions of mathematical experiences to understand better the tension between common sense and mathematics faced by students: First, what does a task necessitate the student doing? For this question one should look for necessity on the surface and follow the student's choices along the way and the resulting necessities. Second, what mathematics is the student doing when addressing these necessities? In this section we apply these questions to student work in the Show Me Your Math (SMYM) event, which came into being as a result of our initial reflection on the conversation with elders and teachers, and with further consultation among additional teachers and elders.

Many projects related to necessity in terms of survival needs like building canoes for travel, examining traditional tools used for hunting and gathering. Basket making was examined by many students for their SMYM project. Modern basket making is often seen now as a craft more so than a necessity, but historically the baskets were important items for survival. They were used to carry and store food and water among many other uses, as well as being an important part of the economic life of the community—often traded and later sold for goods needed in the community. For the basket maker, functionality of the basket was absolutely important; for the students who may have learned to make baskets as part of their research for their projects, such functionality was not as crucial. They operated with different needs.

The baskets in student projects had to look like the traditional baskets but did not need to meet their traditional requirements for functionality. In our ethnomathematical conversations with elders and others in the Mi'kmaw communities, we were told stories about their learning to make baskets as youth. Their elders would often take their basket apart many times until it was done properly to address the necessary functionality. This ripping apart and remaking was not evident in the basket making described by students who investigated basket making for the SMYM event. Nevertheless, their baskets *needed* to look like traditional baskets, which means that they should be similar in proportion and design. Thus, much of the mathematics would be similar. Likewise, when the elders were youth learning to make baskets, their initial baskets did not need to be functional either. Their elders patiently guided them to redo the baskets again and again until their baskets became functional.

Also, the students participating in the SMYM event *needed* to describe the mathematics in their work, which is something that didn't *need* to be done traditionally. The example demonstrates, at the surface, that working with community artefacts does not address necessity as much as we might imagine. Similarly, Lisa's work with her class studying demographics and community planning needs did not have the same stakes as the work done by the leaders who were actually making the decisions and writing the proposals. But the students' contributions were well received by the leaders who then made good use of some of the arguments from the students.

Despite the complexity of the students' context, and the impossibility of high stakes necessity in a learning environment, we advocate for experiences such as these for mathematics students. We are not suggesting that the mathematics curriculum be replaced by ethnomathematical investigations, but rather we suggest that beginning with these investigations can help students to root their mathematics learning in their own ways of knowing. Furthermore we feel it holds promise for students to move toward connectedness in a way that resists colonization. As Wagner and Davis (2010) pointed out, students should engage "the tension between abstraction and groundedness in order to make number work more meaningful" and we would extend this to all mathematics learning.

We believe that it is important to question where students are being led to and led from when planning mathematical tasks. What is the cost of participation in a system of learning that leads students away from common sense, away from community needs, and away from survival of their community culture and traditions? How might a critical awareness of the role of common sense and necessity help teachers to better support Mi'kmaw learners, and all learners, in their classrooms? How might establishing authentic rather than contrived needs for mathematics invite more engagement from students? We agree with Diane Toney that knowledge of school mathematics is important for children's future educational and career goals but we see that drawing from needs, from questions that are important for the survival of a community, a nation, a global village, "might be good for their common sense."

NOTES

[1] Mi'kmaw people have lived on the coastal lands that are now known as Canada's east coast for many generations before European settlement.

[2] The names, except Diane Toney's, are pseudonyms. The question of whether to use pseudonyms is challenging. We want to honour the knowledge of elders and leaders yet with our mediating and interpreting their words feel anonymity is warranted.

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ILDIKÓ PELCZER & VIKTOR FREIMAN

ASSESSING DIFFICULTY LEVEL IN MATHEMATICAL PROBLEM SOLVING IN INFORMAL ONLINE ENVIRONMENTS

Case of the CASMI Community

CONTEXT AND PROBLEM STATEMENT OF THE STUDY

Since high-speed Internet access became an everyday asset in many Canadian schools and homes, educators have started to look into the possibility of creating virtual spaces where children could have the opportunity to get involved in a less formal process of learning and sharing knowledge. Mathematics and sciences often figure among school subjects in which students have difficulties; therefore, many educators are interested in creating Web spaces where children will be confronted with a different approach to these subjects. The explicit goal of this project is to reach out to as many students as possible and to offer enriching experiences through the possibility of solving interesting and challenging problems.

A number of educational systems are moving toward inclusive learning and teaching opportunities like New Brunswick, Canada (Mackey, 2006), where a variety of educational resources are becoming available in order to meet the particular needs of learners. ICT (information and communications technology) can play an important role in providing differentiation in inclusive learning environments. Kennewell (2004) lists several approaches making ICT use valuable in supporting special learning needs such as differentiation by task (like giving different roles to students working on the same project), by response (allowing able students to go beyond the basic learning objectives by making and testing their own conjectures), by support (adjusting to the student's level of understanding), and by resource (allowing the preparation of a range of resources, each of which can be produced and adapted to meet particular learning needs).

Palloff and Pratt (2005) analyze the concept of online collaboration, which helps to reach different outcomes: deeper levels of knowledge production; promoting initiative, creativity, and critical thinking; allowing students to create a shared goal for learning and building the foundation of a learning community; addressing all learning styles; and helping to create a more culturally sensitive classroom. The combination of all these factors may lead to a more efficient, in depth, and complete learning process, which makes this potentially beneficial for fostering mathematical culture in its largest sense.

K. S. Sullenger & S. Turner (Eds.), New Ground, 129–152.

While the work of assessing the educational impact of innovative approaches enhanced by technology is just beginning, there is already an important body of research evidence of several successful patterns. Nason and Woodruff (2004) studied computer supported collaborative learning environments based on model-eliciting problems that provide a rich context for mathematical knowledge-building discourse, which in turn enables students to adequately represent mathematical problems and facilitates student-student and teacher-student hypermedia-mediated discourse. Among others, virtual tools help students generate diverse solutions and solution processes for the same mathematical problem and communicate both synchronously and asynchronously diverse solutions to others.

Math Forum is another example of rich online mathematical resources spread out over a million and a half pages with a variety of services including the Problem of the Week, Ask Dr. Math, and Teacher2Teacher sections (Renninger & Shumar, 2004). The research about the success of this community shows that aside from this huge amount of resources, a particular culture of learning is being created collaboratively by all of the participants: schoolchildren, students, pre-service teachers, classroom teachers, and math and pedagogy experts. In fact, the participants are not only passive users of resources but also active contributors to the co-construction of a new (informal) mathematical learning community. Moreover, results from several studies suggest that interactivity and communication regarding mathematical problems are the key advantages technology can offer in fostering connections to serious mathematics content, engaging learners into questioning and finding solutions, as well as providing them with models for working with challenging problems and topics.

Mathematical enrichment by means of virtual learning communities has been studied within the framework of the NRICH project (http://nrich.maths.org/public/) whose main impact on the pupils was in terms of "helping them to gain a wider appreciation of mathematics and raising the profile of mathematics as a subject that could be interesting enough to pursue either within or outside school or for further study" (Jones & Simons, 2000, p. 108). The structure of communication and discussion available within virtual learning communities enables young people to look deeper into more complex and philosophical questions. For example, the *Agora de Pythagore* project in which middle school students were puzzled with several geometric construction problems asking what could lead mathematicians of antiquity to explore them in depth. Web-based discussions between pupils led them to several explanations like the simplicity of a straight line and circle, the role of symmetric configurations constructed with a compass and ruler, as well as the simplicity and shared acceptance of these two basic tools by all members of mathematical and non-mathematical communities. Pallascio (2003) argued that all these discoveries were possible because of the learning context that is favourable in this way to developing higher order thinking abilities.

Originated from the Chantier d'Apprentissages Mathématiques Interactifs (CAMI) website (Freiman & Vézina, 2006), the CASMI (Communauté d'apprentissages scientifiques et mathématiques, www.umoncton.ca/casmi) virtual community offers online problem-solving opportunities in mathematics, science, chess, and recently in literacy and human sciences. In our analysis, we focus on mathematical problems that are developed based on the Problem of the Week model in a similar way to the MathForum site (mathforum.org). Four problems are posted every two weeks and can be freely chosen and solved by registered participants who may then submit their solutions electronically. Personalized e-feedback is provided by pre-service teachers for each participant. The most interesting solutions and the names of successful problem-solvers are shared with other project members via a common e-space. Teachers can also opt to integrate problems in their own way in and beyond the classroom.

An Internet search for “problem of the week in mathematics” using Google produces 2,610,000 links (15 May 2010). Creators of such an amount of content for all kinds of problem-solving activities expect their problems to be attractive, interesting, rich, and challenging while addressing a public that can be specific (access is restricted to certain groups) or general (resources open to all). While choosing the content, people who create these problems rely on specific learning objectives and goals, but also on their experience in and outside the classroom, on their life-long work with students of all kinds of backgrounds, and on their own understanding of what a problem should look like in order to reach those groups.

However, in some cases, these content choices do not acknowledge that interpretations of experts and users may vary. Namely, teachers who pose problems and students who try to solve them could perceive the same problems very differently. This possible gap between two perceptions and the question of how to deal with it motivated us to explore the issue more in depth.

According to our goals, for this case study, we formulated the following research questions:

- How do we characterize a problem from the CASMI site and how do problem characteristics and ratio of correct solutions relate to each other?
- What is the relationship between the characteristics and the patterns of perceived difficulty (PPD)?
- What is the relationship between the PPD and the ratio of correct solutions?

THEORETICAL AND METHODOLOGICAL FRAMEWORKS

In our previous articles on the CASMI project, we discussed its impact on different groups of participants: teachers, schoolchildren, and pre-service teachers (Freiman, Vézina, & Gandaho, 2005). We also discussed the opportunities for more challenging teaching and learning (Freiman & Vézina, 2006), for enrichment (Freiman, 2009; Freiman, Lirette-Pitre, & Manuel, 2007), for creativity (Manuel, 2009), for pre-service teacher training (LeBlanc & Freiman, 2008), and participation patterns (Sullenger & Freiman, 2011).

In this paper, we focus on problem difficulty as a perceived and measured characteristic of the problems. The problems for the analysis were selected from the CASMI database, which contained in 2009 more than 300 mathematical problems, more than 20,000 solutions from more than 5,000 school children who made more than 50,000 visits to our website (Freiman & Lirette-Pitre, 2009). New problems are posted every two weeks and participation is open to everybody. Since June 2008, after submitting a solution electronically, participants, who are schoolchildren and pre-service teachers, have been asked to assess problem difficulty on a three level scale: *not difficult at all*, *a bit difficult,* and *very difficult.*

A FRAMEWORK FOR PROBLEM CHARACTERIZATION

Solving problems is an important part of our everyday life. Wenke and Frensch (2003) distinguished between simple and complex problems: some problems have clearly defined goals and may be solved easily and quickly while other problems may require many "mental steps" in order to "overcome barriers between a given state and a desired goal state by means of behavioural and /or cognitive, multi-step activities" (p. 90). The authors argue that complex problem-solving "implies the efficient interaction between solver's cognitive, emotional, personal, and social abilities and knowledge" (p. 90). Not surprisingly, they mention a huge variety in problems and thus the existence of a dozen of ways to "meaningfully define and classify problems" (p. 88).

In mathematics and mathematics education, problems and problem-solving play a central role. Schoenfeld (1992) conducted an in-depth analysis of the literature on problem-solving in which he divides problems into three "themes": as *routine exercises* in which one follows a technical procedure (algorithm) prescribing steps that lead (nearly automatically) to the correct solutions; as *mental exercises* requiring the application of several skills that can be practiced and mastered by individuals, thus enabling them to develop efficient problem-solving techniques; and finally as *art* of solving problems of a "perplexing and difficult kind." According to the author, mathematicians see this last kind of problem in contrast to the first two as the "heart of mathematics" and a human endeavour (p. 14).

In order to characterize a problem, we start with some common aspects from several problem-solving models. Even if problem-solving models differ in the level of details, context considered, and so on, they all refer to a stage of *problem understanding*, a stage in which some kind of plan is elaborated for the solution (*make a plan* phase, according to Pólya, 1945), and finally one in which that plan is executed (*carry out the plan*). We shall focus on these three stages and associate them with some problem characteristics.

Every mathematical problem contains data, which have connections between them (these are the given facts or what is known), and, in most cases, ask the problem-solver to derive information. In the case of problems that are formulated textually, the problem-solving usually begins with a phase in which the text must be read, understood, and interpreted. The interpretation of the text can mean that, on the one hand, the situation described by the text has a meaning for the reader and, on the other hand, that the reader of the problem is able to transcribe that situation into mathematical terms (if it is needed).

Take for example a problem that speaks about an igloo and the quantity of ice blocks required for building it. This situation can easily be interpreted as valid (though not yet as a solution) by someone who has seen an igloo; however, this is not the case for someone who cannot really imagine an igloo (even if the word is known). In order for such a situation described textually to trigger an inquiry, it has to fit into the world known by the child. We shall call this particular aspect of the problem "familiarity." A problem shall be considered as familiar if the situation described by the text is one that the child knows from everyday experiences. Admittedly, what is familiar may be culturally or environmentally dependent.

Once the given elements are extracted from the situation, a transition toward a more formal representation by means of structures, schemas, symbols, sometimes with the use of mathematical terms may be necessary. For example, if the text of a problem speaks about the area of an L-shaped garden, then the child needs to make an abstract representation of that garden as a schematic drawing. While doing so, the child should try to find a way to reduce its complexity by applying some representation methods and tools known to him or her. We say in this case that the problem requires the construction of a *mathematical model* with an adequate mathematical representation of the problem. In our example, a simple drawing of the garden as an L-shaped image would not be enough. Some other kind of abstraction (de-contextualization) is needed to transform it into the parts (squares, rectangles) for which students have ready-to-use formulas to calculate their area.

This transition from a real-life situation to a mathematical situation using mathematical language can be difficult (Linares & Roig, 2006). Even if a problem is given in formal terms it could need a model. This mathematical model would require the problem to be reformulated in such way that it would already contain the idea about how to solve it.

The solution process can begin once the text has been interpreted and the problem has been transcribed with the help of a model (if need be). This process starts with elaborating a plan. Sometimes, the plan is predetermined by the way in which the problem was understood. Consider a problem that, once translated into mathematical terms, asks for the value of a variable from a linear equation. In such a situation, the plan is automatic and consists of solving the equation. Therefore, at this point, we look at how formal the proposed solution procedure may be; this is an *algorithmic approach*. Of course, it can vary according to the age of students whom we address, as well as level of schooling.

The last aspect we want to look at is how the plan is carried out. The main issue that interests us here is the possibility of "playing out" cases, which is to say adopting a *step-by-step approach*. In this instance, the student would identify all of the possible cases for a situation and try to reach a solution by looking at each particular case (Zhu, 2007). Many problems do not permit the use of a step–by-step approach, in which case we need a more general approach. An illustrative case of a step-by-step problem is the one that asks for all of the possible combinations of a small number of objects. If the number of things to combine is large, the problem needs a general approach.

In practice, we can find problems with all kinds of combinations, but it is also possible to have some interdependence between them. A larger and more systematic study would be necessary in order to detect the dependencies, if there are any. We leave this aspect for future investigation.

APPLICATION OF THE FRAMEWORK: EXAMPLES OF CLASSIFICATION

In this section we give examples of problem characterizations. We chose problems with different combinations of characteristics in order to illustrate our categories.

Consider the following problem:

Problem 1

The students from Mr. Thériault's class decorate pumpkins for Halloween. Each team should put an item on the head, on the body, and inside the carved head. For the head, they can choose a witch hat, a straw-hat, or a helmet. For the body, they can use paint or straw. For inside the head, three coloured candles are available: red, orange, and yellow. If, in order to be considered as decorated, at least one decoration for each part is needed (head, body, and inside the head) in how many different ways can we decorate the pumpkins? Don't forget to explain your reasoning.

The problem describes a familiar situation: pumpkin decoration. The students are therefore *familiar* with this situation. Each element to be considered is given and the question is about the number of combinations possible. Since the problem only has a small number of elements to combine, the participants make up the possible combinations. No formalization is required in order to give the answer, so the problem does not need a *model*. Since we have a well-known routine for making these combinations, the problem has the *algorithmic* characteristic. Finally, these combinations can be carried out by using a *step-by-step approach*. These four characteristics are reflected in the solutions submitted by students (see the following example).

Solution 1 (loosely translated from French)

Answer: we can decorate 18 pumpkins.

Hat body inside
Witch painting orange
Witch straw yellow
Witch painting red
Witch straw orange
Witch painting yellow
Witch straw red
Straw painting orange
Straw straw orange
Straw painting yellow
Straw straw red
Helmet painting orange
Helmet straw yellow
Helmet painting red
Helmet straw orange
Helmet painting yellow
Helmet straw red
I made a table and I made all

Straw straw yellow	*the combinations for the head, body and the inside.*
Straw yellow red	

Looking at this solution, one can see that there is no model, the solution is direct and consists of an enumeration.

The second problem we look at is different:

Problem 2

We have the following game:

1. *I think of a number*
2. *I multiply it by 2.*
3. *I add 8 to the result of step 2.*
4. *I divide the results from step 3 by 2.*
5. *Subtract the initial number.*
6. *Your final answer is 4.*

Try out the same game with other numbers. What do you obtain as a final answer? Can you explain mathematically why the game works like this?

The first thing we notice is that there are numbers and operations together. Since the question of the problem asks for a general explanation of the result, a *model* of the problem is needed, which is done by describing in symbolic terms the operations employed. At the same time, given that it is a "mental game," it does not represent a *familiar* context. However, the operations to be performed are clearly stated and can be carried out sequentially; therefore, it is an *algorithmic* problem that allows a *step-by-step approach*.

The following is an example of solution that was submitted.

Solution 2 (loosely translated from French)

Regardless what number we use, when multiplied by 2 it gives an even number: 3x2=6, 1111x2=2222, 2x2=4 etc.+8 (divided by 2) =+4. My number is 3; it is as if I would be doing 3+4-3=4. The 2 times 2 and division by 2 serve to hide that this is not a simple operation.

Even if the student did not use a completely algebraic way of writing, he describes the procedure semi-formally. He models the process to follow in an algorithmic fashion. His final argument highlights that the core of his reasoning consists of both the *model* and the *algorithm*.

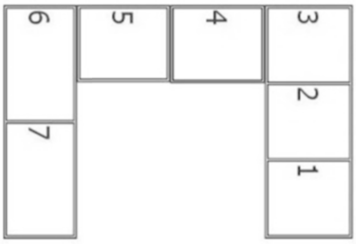
Consider the following problem.

Problem 3

> *The Doucette family invites their friends to celebrate Remembrance Day at a restaurant. The tables in this restaurant are square shaped and at each side of the table one person can be seated. We can arrange the tables under different configurations, but each time at least one side must be touching another table. Beside the 4 members of the family, they are expecting 12 guests. What is the minimum number of tables needed?*

The situation is *familiar*: arranging tables according to instructions. By having done this before, one can imagine possible arrangements. Even if this understanding helps to have a clear view of the situation, it is not yet a solution. Still, we do not need special mathematical knowledge in order to deal with this problem. At the same time, we do not have a ready-made *algorithm*. Additionally, a *step-by-step approach* is not efficient, since the number of possible combinations is high. Consequently, the problem has the following characteristics: *familiar*, *no model*, *no algorithm,* and *not step-by-step*. The efficient solution comes from an iterative construction. The following solution illustrates these ideas.

Solution 3 (loosely translated from French)



> *If the tables are put together, no one can sit there. That is, at the first table there will be three people and at the rest two, until the last table where there will be three people again. The digits are representing the number of the table.*

The main argument presented: if they are aligned side by side no one can sit at that side. Once the solution is found (the correct configuration is identified), it can be written as an equation. However, here the equation doesn't constitute a *model* of the problem, but rather a formalization of the solution.

In this section we looked at the first question we formulated: the identification of a set of problem characteristics. We defined four characteristics of mathematical problems, each linked to an aspect of the problem-solving process. These factors were: *model*, referring to the necessity of using mathematical knowledge for the transcription of the information given in the problem; *familiarity*, referring to understanding the problem based on everyday life experiences; *algorithmic*, meaning the availability of an algorithm or standard procedure in a given situation;

and *step-by-step,* referring to the way in which the solution method is performed. After defining these aspects, we gave three examples of problem characterization along with a solution that was submitted. In each case, we underlined the links between the solution and problem characteristics in order to better illustrate our ideas.

PROBLEM CHARACTERISTICS AND DIFFICULTY LEVELS

The concept of difficulty level appears already at the stage of choosing appropriate problems for students. There are benefits of doing this at the planning stage: it gives the possibility to select problems that take into account the anticipated student's previous knowledge and then, by gradually increasing the difficulty, it serves to keep the student motivated (Newman & Kundert, 1998).

Research related to the difficulty of mathematical problems can be grouped as follows. First, there are studies that search for measures of difficulty that do not depend on any given field. Gronlund (1981) defined difficulty as the ratio between the number of correct and total number of solutions. He introduced the term *item difficulty ratio* (IDR) for this concept that is still one of the most widely used measures. Second, there are the studies in which the authors look for factors that affect success in problem-solving and therefore may influence its difficulty level. For example, Lane (1991) found that difficulty of algebraic word problems depends on such factors as the number of intermediate results to be obtained, the necessity to reformulate results into one short sentence, and the familiarity with the context of the problem. A third line of study focuses on problem categories and the difficulties they create. Researchers in this line define frameworks to classify problems and then associate difficulty with categories. The difficulty in question can be a subjectively perceived difficulty (Craig, 2002) or represented on a researcher-made scale based on the degree of solution correctness (Galbraith & Haines, 2000).

Our exploratory study belongs to this last line of research. However, rather than working with *a priori* defined problem categories, we search for combinations of characteristics related to IDR. Later on, we look at subjective perceptions of difficulty on a three-level scale (from easy to difficult). Instead of using the levels of individually perceived difficulty, we look for patterns of perceived difficulty (PPD) in order to relate them to sets of problem characteristics. There are some benefits to doing this. First, by relating problem characteristics to IDR, we obtain a more general way to assess difficulty. Second, by using PPD, we make it possible to include variations of perceived difficulty (this is important since the appreciation of difficulty will vary from student to student) and redefine categories of difficulty based on these patterns. Third, relating PPD to a set of problem characteristics, we have the advantage of identifying aspects that make the problem more difficult. Last, studying the relationship between IDR and PPD, we have an insight into where differences arise.

DATA ANALYSIS

Problem Characterization and Ratio of Correct Solutions

For the present work, we considered 34 problems given on the CASMI website, between May 2007 and October 2008. Table 1 synthesizes the results of the characterization along with the ratio of correct solutions for each problem. While a "+" sign means that the problem presents the characteristic, a "-" sign means that it does not. F1=model, F2=familiarity, F3=algorithmic, F4=step-by-step, NRS=number of submissions, NRC=number of correct solutions, and IDR=item difficulty ratio.

Table 1. Problems and their characteristics based on the proposed framework

Problem	F1	F2	F3	F4	NRS	NRC	IDR (%)
Pb06_01	+	+	-	+	81	24	29
Pb06_02	-	+	-	-	112	12	11
Pb06_03	+	+	+	-	286	161	56
Pb06_04	+	+	-	+	163	94	57
Pb06_05	-	+	-	-	187	52	28
Pb06_06	+	+	+	-	239	39	16
Pb06_07	-	-	+	+	179	83	46
Pb06_08	-	+	+	+	314	260	83
Pb06_09	-	+	+	-	402	54	13
Pb06_10	+	+	+	-	355	232	65
Pb06_11	-	-	+	+	342	251	73
Pb06_12	+	+	+	-	296	73	25
Pb06_13	-	+	+	+	435	297	68
Pb06_14	+	+	+	-	112	12	11
Pb06_15	-	-	+	+	253	210	83
Pb07_01	-	+	+	+	66	48	72
Pb07_02	+	+	+	-	93	62	67
Pb07_03	-	+	+	+	57	35	61
Pb07_04	-	+	+	+	115	95	83
Pb07_05	+	-	+	+	69	48	70
Pb07_06	+	+	+	-	114	31	27
Pb07_07	+	-	+	-	176	76	43
Pb07_08	-	+	+	+	349	253	72
Pb07_09	+	-	+	-	236	101	43

Problem	F1	F2	F3	F4	NRS	NRC	IDR (%)
Pb07_10	-	+	+	-	308	133	43
Pb07_11	-	+	+	-	318	131	41
Pb07_12	+	+	+	-	350	128	37
Pb07_13	-	+	-	-	120	25	21
Pb07_14	-	+	-	-	339	126	38
Pb07_15	-	+	-	+	85	69	81
Pb07_16	+	-	-	-	254	155	61
Pb07_17	+	+	-	-	249	83	34
Pb07_18	+	+	+	-	272	115	42
Pb07_19	+	+	+	-	380	167	44
Total: 34	17	27	25	13			

The table reveals that there is no immediately detectable relationship between characteristics, total number of solutions, and number of correct solutions. However, according to our theoretical framework, we can expect that problems without the *step-by-step* or *algorithmic* factors will have lower IDR. We present the analysis in the next section.

Analysis of Solution Rates: Relationship between Problem Characteristics and Item Difficulty Ratio

We performed a variance analysis by considering each of the problem characteristics defined in our framework as independent variables. The results of the analysis are given in Table 2. Each line corresponds to the results of the factor analysis on the factor written in the first column in relation to the element written in the second column (dependent variable). The first column contains the factor we study in explaining differences in the means. The second column is the element dependent on the factor. The third column is the mean value of the dependent element for the problems that have the factor.

For example, the first row, third column is the mean of the total number of solutions from problems having the *model* factor. The fourth column is the mean of the dependent element from problems that do not have the factor from the first column. In these terms, the purpose of the factor analysis is to determine whether the differences in these means are explained by the factor. The last column contains the probability value at which the difference is significant or, in other words, the probability that the differences in means are due to random effects and not due to the factor.

Table 2. One-way ANOVA test on the factors - Effects in bold are significant at p < .05

Factor	Dependent Element	Mean group 1 factor present	Mean group 2 factor missing	Probability
Model	Total number of solutions	225.81	248.81	0.83
Model	Ratio of correct solutions	133.37	105.56	0.34
Familiarity	Total number of solutions	234.03	215.57	0.70
Familiarity	Ratio of correct solutions	111.5	132	0.19
Algorithmic	Total number of solutions	250.16	198.75	0.09
Algorithmic	Ratio of correct solutions	132.62	80	0.07
Step by Step	Total number of solutions	196.21	255.10	0.12
Step by Step	Ratio of correct solutions	**129**	**106.15**	**0.00003**

Interpretation of Results

First, we look at the *model* factor. From the analyzed problems there are 17 that need no mathematical model to find solutions. The results show (based on the probability value in the last column) that there is no significant difference in groups at 0.05 percent level for the two studied dependent elements (see values from first two rows). It would be premature to say that the factor is not making a difference; more statistical data analysis is needed in order to properly identify the role of this factor in relation to number of solutions.

The *familiarity* factor appears in 27 problems. Again, the statistical analysis shows no significant difference in the total number of solutions or in the ratio of correct solutions at the 0.05 level of probability.

The *algorithmic* factor is missing only from nine problems and shows significant difference on the studied dependent elements at 10 percent level. In other words, problems that are algorithmic in our categorization received a significantly higher number of submitted solutions than those that are not. Although this is an interesting result, we have to proceed carefully with the conclusions, because the number of submitted solutions can depend on variables that are out of the control of those who propose the problems, like holidays or weather. At the same time, the result makes sense: it might be that students who read a problem and think that they have a way to solve it (there is an algorithm available) will submit a solution to it. For this reason, this is a result that is worth further investigation.

The *step-by-step* factor is present in 13 problems that have scattered categorization on the other factors. There is no statistically significant difference on the number of submitted solutions; however, there is a strong statistical significance (at 0.001 percent level) on ratio of correct solutions. This means that problems that allow a step-by-step approach will yield a significantly higher ratio of correct solutions than those that do not have the factor. This is a good reason for studying what kind of problems allow a step-by-step approach.

From an initial overview we can say that these are usually problems that also have the *familiarity* and *algorithmic* factors present (see problem characteristics in Table 1). An important aspect to analyze is the relationship between a step-by-step approach and mathematical knowledge: do these problems require formal mathematical knowledge? In case of an affirmative answer, we need to look into the type and complexity level of the required formal knowledge in order to correctly describe the particularity of the step-by-step approach in problem-solving.

The problems analyzed in this preliminary phase of our research are targeted for young problem-solvers and, in most of the problems, after breaking it down with the step-by-step approach, the solution is immediate. It would be very interesting to see what happens with more complex problems. As we said in the description of the factors, the *step-by-step* factor reflects the way in which the solution is carried out. Such a definition includes the cases in which the problem is solved after it is broken down into particular cases. Often, identifying cases to examine is itself a challenging issue; therefore, it is possible that the above results are not reproduced by more complex problems. Nevertheless, as a preliminary conclusion, the *step-by-step* factor is one that explains the ratio of correct solutions, whereas the *algorithmic* factor does so for the total number of solutions.

The above analysis refers to the study of possible links between problem characteristics and solution rates. For those who prepare the problems, it can be interesting to find such relationships since they may explain the difficulties students face during problem-solving. However, solution rates do not necessarily match subjective perceptions of difficulty. Even if students miss a problem, it does not mean that they see it as a difficult one. Consequently, it would be interesting to look for PPD and problem characteristics. This can bring up at least two types of insights. First, it can direct attention to the common points among solution rate, perceived difficulty, and problem characteristics. Problems which are showing a consensus in the two perspectives exhibit characteristics that are interpreted similarly by educators and children. Second, problems showing different difficulty perceptions are interesting, because they direct teachers and educators toward characteristics that students find make problems difficult.

Perceived Difficulty

In order to treat our second question, we look at the 18 problems (out of 34) that had information about perceived difficulty. Table 3 contains the information submitted by the participants. Columns 6-8 (Easy, Average difficulty, and Very difficult) show the percentage of the evaluations submitted by the participants, with the highest value shown in bold, for easy identification. The last column refers to the cluster of perceived difficulty and later in this section we explain how it was identified.

Table 3. Subjective perceptions of problem difficulty, along with problem characteristics, for the problems used in the analysis

Problem	F1	F2	F3	F4	Easy	Average difficulty	Very difficult	Cluster
Pb07_01	-	+	+	+	**0.79**	0.15	0.06	1
Pb07_02	+	+	+	-	0.41	**0.48**	0.11	3
Pb07_03	-	+	+	+	**0.54**	0.34	0.12	2
Pb07_04	-	+	+	+	**0.82**	0.13	0.05	1
Pb07_05	+	-	+	+	**0.52**	0.39	0.09	2
Pb07_06	+	+	+	-	0.36	**0.50**	0.14	3
Pb07_07	+	-	+	-	**0.56**	0.33	0.11	2
Pb07_08	-	+	+	+	**0.53**	0.38	0.09	2
Pb07_09	+	-	+	-	0.40	**0.47**	0.13	3
Pb07_10	-	+	+	-	**0.66**	0.28	0.06	2
Pb07_11	-	+	+	-	**0.57**	0.36	0.07	2
Pb07_13	-	+	-	-	0.39	**0.46**	0.15	3
Pb07_14	-	+	-	-	**0.59**	0.36	0.05	2
Pb07_15	-	+	-	+	**0.68**	0.25	0.07	1
Pb07_16	+	-	-	-	0.27	**0.42**	0.31	3
Pb07_17	+	+	-	-	0.50	**0.41**	0.09	2
Pb07_18	+	+	+	-	0.45	**0.48**	0.07	3
Pb07_19	+	+	+	-	**0.57**	0.35	0.08	2

Identification of Difficulty Patterns

Difficulty terms are subjective: “very difficult,” “average,” or “easy” are perceived differently by users. Often, students relate difficulty with their own ability to solve a problem and not with the characteristics themselves. The scale with the highest percentage can show huge variations; a pattern that has a very high value on “easy” and low on the other two illustrates a different case from one that has a more uniform distribution, even when the “easy” category still has the highest value. Also, for comparative issues, it is interesting to detect what kind of features cause differences on evaluation. We shall look for patterns of difficulty and try to connect each pattern with a combination of problem characteristics. In this case a difficulty pattern is a vector with three components, corresponding to the easy, average and difficult percentages.

In order to define the patterns of difficulty assessment we applied the *k*-means algorithm. This is a non-hierarchical iterative method that uses similarity measures in order to group data into a previously defined number of clusters (*k*). The algorithm considers data as an *n*-dimensional vector; therefore it searches to delimit parts of the space that contain similar data vectors. Similarity is assessed by a user-defined metric. Between the commonly used distances are the Euclidian, city block distance, and Manhattan.

The algorithm starts by choosing the *k* cluster centres and grouping around the data to minimize in-cluster and maximize inter-cluster distances. After each cycle, the centres are repositioned and distances are refreshed. The procedure is repeated until the centres have a small change between two iterations. We used the algorithm with k=3 clusters.

Figure 1 shows the centres of each cluster (remember that the centre is a vector with three components representing the percentages on "easy," "average difficulty," and "difficult" categories). Clusters can be characterized roughly as follows: the first has very high values on "easy" and considerably lower on the other two (marked with Cluster_1 in the figure); the second cluster has comparable average values on "easy" and somewhat difficult categories (Cluster_2); and the third has the highest value on "average" difficulty (Cluster_3). The original data (Table 3) shows that in general the "very difficult" category had a very low percentage. In Table 3, the column cluster shows how the problems are distributed among these three clusters. In order to refer more easily to them, we named the first cluster as "very easy" problems, the second as "easy," and the third as "intermediate" problems.

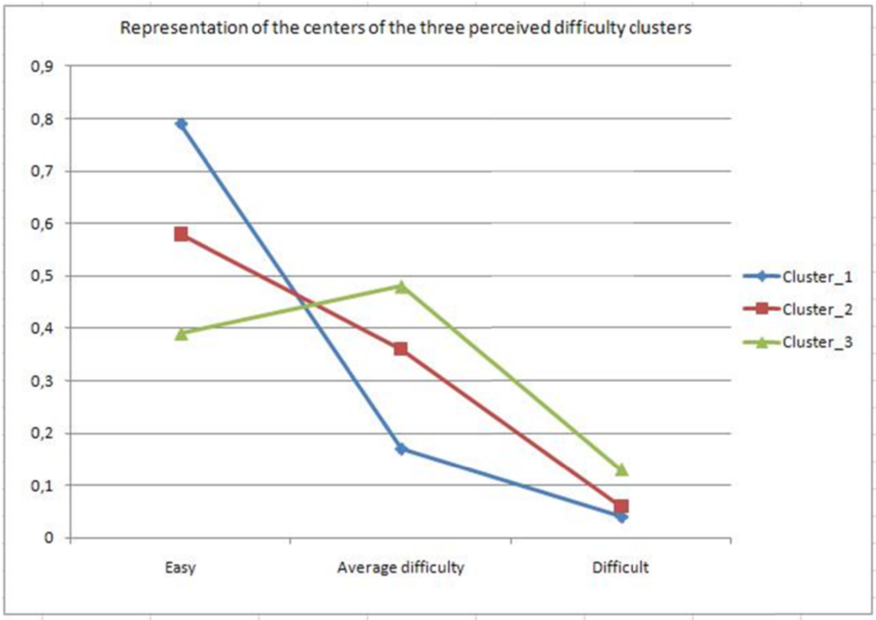


Figure 1. Difficulty patterns of Manchot problems

Once we identified the clusters of perceived difficulty, we looked for a relationship between problem characteristics and the clusters in order to answer our third question. We searched for this relationship in the form of a decision tree. A decision tree is induced by an algorithm that searches for relationships between factor values and a class value. In this instance, the factors are the problem characteristics and the class variable is the cluster to which the problem belongs. To find a relationship between these meant assigning a cluster to a particular combination of factor values (problem characteristics).

Since this relationship is statistically induced it is not perfect, that is, it might happen that a problem is identified as belonging to a cluster to which it does not, in fact, belong. In other words, the accuracy of the tree doesn't need to be 100 percent. A decision tree is represented in the form of a tree; the factor that splits the problems more accurately is at the root. In order to "read" the tree, you start from the root and read the factors along with the values marked on the arrows until you arrive at a leaf on which the cluster value is marked.

Figure 2 shows the induced tree. The nodes represent decision variables with the value 1 corresponding to the presence of the characteristic and 0 to the lack of it. For example, one rule would be: If the problem has the *step-by-step* characteristic (left branch from top node, called root), the *familiar* characteristic (second left branch), and the *algorithmic* characteristic (left branch again), then it will be considered as a "very easy" problem (leaf with value 1 means that the leaf belongs to Cluster 1).

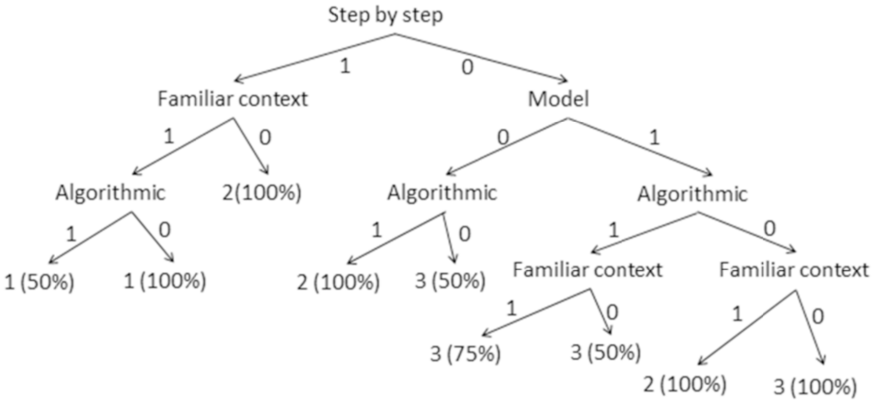


Figure 2. Decision tree based on problem characteristics and PPD

Cluster 1 (marked with 1 on the leaves) contains the "very easy" problems. This is clearly described by the problem features *step-by-step* and *familiar context*. On the other hand, Cluster 3 is the one that has the "intermediate" problems and Cluster 2 has the "easy" problems. All of these problems are on the right branch (they do not allow a step-by-step approach), do not have the *algorithmic* or *model* characteristic, or are not in a *familiar* context. It is interesting to see that the feature "familiar context" comes at the end of the branches, so its role is not as important as "model" or "algorithmic." In addition, problems perceived by most as “intermediate” (Cluster 3) can be identified as the ones that, though they allow a step-by-step approach, are not in familiar context. Another alternative for this pattern is to have *algorithmic* problems.

Comparing Item Difficulty Ratio and Patterns of Perceived Difficulty

We turn now to our fourth question: the comparison between item difficulty ratio and PPD. The relationship between item difficulty ratio and problem characteristics was discussed in the previous section. Table 4 shows the problems used in the analyses, but are ordered by their clusters of perceived difficulty. The item difficulty ratio (IDR) was added to the table.

Table 4. Comparative values of ratio of solutions and perceptions of difficulty

Problem	IDR	Very Easy	Intermediate	Very difficult	Cluster
Pb07_01	0.72	**0.79**	0.15	0.06	1
Pb07_04	0.82	**0.82**	0.13	0.05	1
Pb07_15	0.81	**0.68**	0.25	0.07	1
Pb07_02	0.66	0.41	**0.48**	0.11	3
Pb07_06	0.27	0.36	**0.50**	0.14	3
Pb07_09	0.42	0.40	**0.47**	0.13	3
Pb07_13	0.20	0.39	**0.46**	0.15	3
Pb07_16	0.61	0.27	**0.42**	0.31	3
Pb07_18	0.42	0.45	**0.48**	0.07	3
Pb07_03	0.61	**0.54**	**0.34**	0.12	2
Pb07_05	*0.69*	**0.52**	**0.39**	0.09	2
Pb07_07	0.43	**0.56**	**0.33**	0.11	2
Pb07_08	0.72	**0.53**	**0.38**	0.09	2
Pb07_10	0.43	**0.66**	**0.28**	0.06	2
Pb07_11	0.41	**0.57**	**0.36**	0.07	2
Pb07_14	*0.37*	**0.59**	**0.36**	0.05	2
Pb07_17	0.33	**0.50**	**0.41**	0.09	2
Pb07_19	0.43	**0.57**	**0.35**	0.08	2

Table 4 reveals that problems from Cluster 1 (“very easy” problems) have a high percentage of correct solution rates, leading to a correlation between the item difficulty ratio and PPD. The analysis of both difficulty indicators with problem characteristics (IDR and problem characteristics in the first section; PPD and problem characteristics above) showed that the *step-by-step* factor is essential to identify a problem as very easy and having a high ratio of correct solutions.

Cluster 2, however, shows a lower degree of agreement between cluster interpretation and ratio of correct solutions. The ratio of correct solutions varies from 0.33 to 0.69. The interesting part of these results appears when we look at the problem characteristics: those with low IDR (less than 50 percent) are the ones that don't have the *step-by-step* characteristic. A main characteristic of Cluster 2 (shown on the decision tree) is that a majority of the problems lack the *step-by-step* factor while simultaneously the *familiar* factor seems to be important. In these terms, there is again an agreement between difficulty measurements (IDR and PPD) and problem characteristics. However, problem 5 and problem 14 are particularly interesting (shown in italics in Table 4).

Data from Table 1 show that these two problems have opposite categorization on each factor. As these two problems suggest, it might be that some children perceive these problems as somehow difficult, because they lack a *familiar* context of formulation or because the problem does not allow a *step-by-step* approach. The lack of at least one of these characteristics can also increase the probability of error, which can explain the variation in the ratio of correct solutions.

Cluster 3, with "somehow difficult problems," mainly shows an agreement between the PPD and the ratio of correct solutions. In general, solution rates are less than average. The interesting part is that these problems lack the *step-by-step* factor and, as was shown in the first section of this chapter, this factor is the main variable that influences the ratio of correct solutions as well as being the most important factor in the decision tree. In the analysis of the decision tree, we also saw that the necessity of a *model* is the second most important factor in deciding the cluster in which the problem will find itself. In this regard, the decision tree complements the information coming from the analysis of the correct solutions ratio. It shows that problems having the *model* factor but not the *step-by-step* factor will be perceived as "somehow difficult" and will show lower than average correct solution ratios.

In conclusion, problems that can be solved with a *step-by-step* approach are more easily handled by the students, especially when the problem is *familiar*. Difficulties start when the familiarity of the context is missing and, even more, when the problem needs a mathematical *model* and a solution plan that goes beyond the *step-by-step* approach. These findings could be useful when designing problem sequences or problem fields. By changing the problem characteristics in the order identified in the decision tree (and factor analysis at the beginning), educators can try to keep students motivated by slowly adjusting the difficulty level (due to the changes in the problem characteristics). A further study needs to be conducted to confirm these conclusions.

DISCUSSION AND CONCLUSIONS

In the present paper we aimed to investigate the following three questions:

- How do we characterize a problem from the CASMI site and how do problem characteristics and ratio of correct solutions (or, in other words, item difficulty ratio: IDR) relate to each other?
- What is the relationship between the characteristics and the patterns of perceived difficulty (PPD)?
- What is the relationship between the PPD and the ratio of correct solutions?

In order to investigate the first question, we developed *a framework for problem characterization*, by defining four aspects: *familiarity of the problem, model construction, using a (known) algorithm*, and using a *step-by-step approach*. Every aspect may be linked to one particular stage of the problem-solving process. More precisely, we claim that the *first* aspect, *familiarity* of the problem, refers to the degree to which the situation described in the problem might be known to the student from everyday life experiences. This may be directly related to the correct understanding of the problem. The research is not conclusive on how *familiarity* can affect problem-solving performance. While some authors argue the benefits of relating mathematical problem-solving to the real world (De Corte, Verschaffel, & Greer, 2000), others have found that "familiar contexts neither enhance children's problem-solving performance nor decrease problem difficulty" (Huang, 2004, p. 278). Also, dealing with the context requires well-developed language skills in both language and mathematics, and lack of such skills can lead to an increased difficulty level (Irujo, 2007).

The *second* aspect refers to the necessity of using a *model*, which is a more formal, symbolic representation of the problem, in order to solve it successfully. Some authors claim that representing problems symbolically reduces problem-solving difficulty (Luna & Fuscablo, 2002). Our analysis of CASMI problems follows the line of research in mathematics education emphasized by Goldin (2002). It reflects the need to build "a shared, scientific, non ideological, framework for empirical and theoretical research in mathematics learning and problem solving" in which "representation, systems of representation and, the development of representational structures during mathematical learning and problem-solving are important components" (p. 198).

The *third* aspect expresses the possibility of applying a well-known procedure (or *algorithm*) to the problem, once the model is constructed (or is already available as ready-to-use) by the problem-solver. According to the latest development in mathematics education, direct application of algorithms is not considered as problem-solving unless the problem demands construction (re-invention) of an algorithm by the learner (Wilson, Fernandez, & Hadaway, 1993). However, the authors recognize that at some point in the problem-solving process some problems may require the use of well-known procedures, like, for example, calculating the area or the diameter of a circle.

The *fourth* aspect refers to the problems that allow the *step-by-step* construction of a solution by listing directly and explicitly all cases. Often, such problems do not require the use of any mathematical concepts or procedures, but ask for careful and systematic search for all possibilities. We found that this aspect is similar to the well-known trial-and-error problem-solving strategy using informal methods or experience (Wu & Adams, 2006).

The second question was explored in the section *Analysis of solution rates: relationship between problem characteristics and ratio of correct solutions*, where we investigated possible links between problem characteristics and ratios of correct solutions. We applied ANOVA over each characteristic identified by the first question. This was applied to two variables: the total number of submitted solutions and the ratio of correct solutions. The results show a significant difference in correct solution rates between problems having or not having the *step-by-step* factor. The particularity of such problems is that the cases treated separately are simple enough so that no special algorithm or model is required in order to solve them successfully. Since this particular factor might be linked to the fact that the problems analyzed are from the *Manchot* (Penguin) section of the website, it is seen by the authors as the easiest level. It would therefore be necessary to repeat the analysis with problems of various levels of difficulty (for example, from other sections of the website) before considering these results as a general trend.

While it is true that these problems seem to have the highest success rate and thus can be considered as the easiest ones, it does not mean that we should exclude them. On the contrary, these problems can be a good informal introduction to complex problem-solving for learners who would be in the ZPD (Zone of Proximal Development) in the Vygotskian sense (Vygotsky, 1978). The next developmental step would not necessarily be the use of a problem that does not have the factor, but of a problem that still has it and is more complex. This would eventually motivate students to gradually develop some patterns and make generalizations (e.g., an equation that should be treated differently for pair and odd numbers, but for each case algorithms would be available) thus developing superior problem-solving abilities (Krutetskii, 1976).

Before answering the third question, we looked for patterns of perceived difficulty (PPD) in the *Identification of difficulty patterns* section. A k-means clustering method was applied to the data, represented by vectors of three components. Each problem was described by the distribution of percentages on students' perceptions about each of the three components: *easy*, *average*, and *difficult*. We identified three clusters, each of them representing a particular distribution of percentages over these three components. Based on the values of the dominant component we called these three clusters: *very easy, easy,* and *intermediate*. In order to explore the relationship between the newly identified clusters and the factors analyzed in the second question, we applied an algorithm to induce a decision tree. One of the main results obtained in the section was that *very easy problems* all had the *step-by-step* factor and the *familiarity* factor. This could be useful for ordering problems by level of difficulty.

The problems that have the *step-by-step* factor and are not familiar belong to the *easy* cluster, along with those that are not *step-by-step*, but are at least *algorithmic* or *familiar*. We hypothesize that an algorithmic problem is considered by some as easy, because they might have the feeling that at least they have some tools available or, in the case of familiar problems, they can have the impression that their familiarity reminds them of their everyday life experiences.

Based on this finding, we can suggest the following questions as potentially promising for further research: (1) Do students perceive familiar problems as being (at first sight, before solving them) easier to solve, and would this be attributable to the fact that familiar problems remind them of everyday life where, in most cases, we have practical solutions to problems? (2) How does this perception vary after trying to solve the problem, especially when looking at the student's expectation regarding a problem's solvability?

Since expectation has strong influence over the perception of personal success and failure, we realize that the familiarity factor could be much more influential than we may have first thought. Qualitative research methods could give some insight into this very provoking suggestion, especially in relation to contradictory messages from the research field mentioned above.

Last, the problems that were perceived as *intermediate* can be characterized, in general, as not having the *step-by-step* factor and, for most, as having the *model* factor. Although the presence of a model sometimes can help to have a clearer vision about the problem and can even hint toward a solution, building one can be difficult. This finding is rather consistent with the literature (see above).

The relationship between the PPD and the ratio of correct solutions is described in the section *Comparing item difficulty ratio and patterns of perceived difficulty.* We observed that problems perceived as *very easy* also have high ratios of correct solutions. In this sense, there is an agreement between the commonly used measure of problem difficulty and its subjective perception. The second cluster, represented by PPD as *easy*, also shows relatively homogeneous ratios of correct solutions, whereas the ratios in the case of intermediate problems are evenly split. Between the problems of the third cluster, we find problems with an average ratio of correct solutions as well as low values of correct solutions.

Such a finding highlights another interesting aspect: some problems are perceived as being easier than they are, because the solver fails to recognize its complexity and to give a complete solution or because his solution, in fact, doesn't apply to the situation (e.g., there was a misinterpretation of the problem formulation). Another possible explanation is that the solver might feel that the problem is easy, but doesn't have the tools to solve it. In both cases, the situation shows that the student has some difficulties with problem solving that need to be addressed by teachers in more formal settings.

These results stem from a preliminary study of the *Manchot* problems, the easiest problems offered on the CASMI website. A much larger study is needed in order to verify the generality of the reported conclusions, in both senses: over a much larger sample of problems of the same level and problems of different levels of difficulty. However, we consider that the preliminary results are promising and can be of interest for educators and researchers.

Researchers might find the definition of a framework for problem characterization useful, especially when the characteristics are linked to phases of the problem-solving process. Along the same line, the question of sufficiency needs to be addressed: are these characteristics enough to describe all of the problems that we can usually find in school mathematics? Another important aspect is about mistakes. Based on the review of submitted solutions, we hypothesize that there are different types of mistakes linked to the phases of the solving process and, consequently, linked to the characteristics.

In our paper we explored the relationship between problem characteristics and difficulty (measured or perceived). However, there is a special interest in identifying aspects of a problem that can make it challenging and engaging, which suggest another interesting line of research for educators involved in developing material for websites that promote mathematical problem-solving and investigation.

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THE CHALLENGE OF UNDERSTANDING YOUNG LEARNERS' EXPERIENCES IN INFORMAL SETTINGS/CONTEXTS

A New Approach

Over the past several years, we have struggled to find strategies that examine young children's understanding of science experiences in informal settings, such as our most recent involvement in a summer science camp. Our own teaching and research experiences in classrooms meant we had a collection of strategies we used with children. We interact, engage in discussions, and assess their learning, but found we had limited success in gathering rich data about their experience using school-based methods. Since the early 1900s, educational researchers such as Jean Piaget and John Dewey have been researching the lives of young children, recording their words and actions and asking them questions in attempts to better understand the culture and processes involved in children's learning. Many different research approaches have been designed and practiced in an attempt to delve more deeply into the understanding and meaning these children make of experiences. If we are to provide an education that is appropriate to children's developmental levels and interests, we must find ways of gaining better insight into their perceptions of formal and informal learning experiences.

A number of definitions of informal learning exist, in particular in relationship to the learning of science. For the purposes of this paper, we use the following definition: "Informal learning refers to activities that occur outside the school setting, are not developed primarily for school use, are not developed to be part of an ongoing school curriculum, and are characterized by voluntary as opposed to mandatory participation" (Crane, Nicholson, & Chen, 1994). Wellington (1990) describes informal learning as learning that occurs outside the classroom in an unstructured environment, and noted that there is no assessment and few expected outcomes. Normally, informal learning is learner-centred, and somewhat open-ended. It most often engages the participants in relevant and hands-on learning. The learning that takes place during summer science camp activities may best be described as "structured informal" (Vadeboncoeur, 2006) and led by camp instructors, guiding and designing science exploration.

This paper describes new strategies we developed to gain insight from young children, aged six and seven years old, during a summer science camp program in an attempt to better understand the meanings that this experience held for them in this setting, considered more informal than traditional schooling. We focus on

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strategies developed to collect evidence of scientific language and understanding based on their experiences in the camp in an attempt to better understand what the experience of camp means to the children. We share what we know/discovered about children and their learning, about informal learning contexts, and about interviewing to create new approaches to understanding children's experiences in informal science settings. Solving the challenge of interviewing children in their own world will help us gain information about the culture of summer science camps, children as competent narrators of their own experiences, what kinds of things children can understand about science, and grapple with this nontraditional approach to summer science camps and studying informal learning contexts.

CONCEPTIONS OF CHILDHOOD

The way in which we conceive childhood shapes the way we approach research involving children and their experiences. Indeed, the extent to which researchers embrace or reject the idea of children as "different" shapes the nature of their research. Childhood is primarily a relational term, grounded in its relationship of difference with adulthood (Jenks, 1982). Socio-cultural research (Lewis, Encisco, & Birr Moje, 2007) is, of course, not exempt from these pressures.

A great deal of research exists from a psychological perspective where children have been examined in experimental settings. Fewer studies exist from a socio-cultural perspective (Lewis, Encisco, & Birr Moje, 2007) where attempts are made to a) create a more natural setting in which to research the children; b) find alternate ways for children to provide information; c) prompt children for additional information without altering or directing their narrative; d) seek a variety of ways for children to provide information; and e) allow researchers to access information children have that they are unable to share due to a lack of vocabulary, for example.

An increased interest in the search for understanding of children's sociological and cultural worlds has resulted in research processes that focus on children as objects of the sociological gaze. New sociological and cultural approaches to understanding childhood suggest that rather than viewing children as future adults-in-the-making, we should focus upon children's lives, perceptions, and activities. This entails a shift away from the idea of a child as "becoming" an adult to the "being child," conceptualized as an active social agent (Qvortrup, 1994).

James, Jenks, and Prout (1998) argue that children should be understood not as beings lesser than adults, but as having different competencies that the researcher must address. The recognition that children can actively participate and communicate their ideas in research challenges the belief that children are somehow less competent than adults. A socio-cultural approach can encompass this perspective about childhood.

Socio-cultural studies focus on seeking to enable communities of practice that are legitimate in the sense that they are meaningful and familiar to the participants (Wenger, 1998). Rogers and Fuller (2007) describe socio-cultural research with participants. In their study, they ensured that the setting of the research was not only familiar but that consideration of the participants' previous experience should be included in the research design. In our study, we sought to design the interview process so that it would be linked with the children's experiences during the science camp as well as their everyday experiences as children.

A great deal of the research that involves children is psychologically based and focuses on an experimental design using structured formats. Few examples of interviews with children that are open-ended and not psychologically based exist. Children can provide real insight for researchers about their experiences if the interviews are conducted in a risk-free environment of trust and allowing children to participate in ways that are culturally relevant to them. The summer science camp is a challenging context in which to explore the experiences of young learners. The camp provided the young scientists with a natural setting for engaging their curiosity and their interest in the way that scientific rules and procedures work. By allowing the children to imagine themselves in stories and situations as young scientists participating in a science camp, and by inviting them to extend these narratives, we have been able to gather rich data about the meaning they attach to their experiences during the science camp.

In this section we have made the critical argument that how we conceive childhood is crucial to how we think about understanding children. A psychological approach that does not consider the social nature of learning in these early years is not an appropriate model for this research. A socio-cultural model is important to consider and reminds us that using an open-ended approach in a culturally relevant, risk-free environment is important, especially if we want children to talk openly and for extended periods of time. Trust is crucial and, because language is such a challenge in researching young children, we need to find other ways of interacting than those offered by traditional interviews.

A NEW APPROACH TO INTERVIEWING/INTERACTING WITH YOUNG CHILDREN

Traditionally, interviews range from open-ended to structured and are heavily dependent on interrogatory language that is often or can be overwhelming/ confusing to young children. The new approach we propose mimics conversations young learners have during play or firsthand learning experiences with others. As such, it offers an opportunity to create a trusting context in which children are willing to share their thinking about their experiences for extended periods of time.

Interviews are frequently used in a variety of methodological approaches and offer the researcher many benefits (Marshall & Rossman, 1999). Benefits can include the ability to collect a large amount of data quickly, to provide clarification, and to allow for immediate follow up. The most important aspect of the interviewer's approach is to convey the idea that the participants' information is acceptable and valuable. This is particularly important when the research participants are children (Sherman, 1995). Corsaro (1981) warns about the fragility of the child's world and the possible instability of peer interaction in the classroom, warning the researcher to use caution when entering the world of the young child as a participant-observer or as an interviewer, lest they disrupt the balance young children exhibit between self-absorption and a natural curiosity of the world around them.

Interviewing children takes special consideration and planning for several reasons. Children are a vulnerable population and anyone wanting to research them must be prepared to consider carefully the power differential that exists in the interview context. Children often demonstrate a certain transparency that we lose as adults and it is this transparency and honesty that interviewers of children must learn to tap into without taking advantage of the children's naiveté (Grumet, 1988). Interviews allow the researchers to "qualify" what they hear through the eyes of the participants, rather than "quantify" through the screen of the observer as is the case with other traditional psychological systems where behaviours are coded and recorded. This is particularly important when the informants are children. "Upon entering the children's world, researchers focus on how they as adults understood the experiences that children receive and exchange. From this perspective the child is the experienced member of the child's culture and the adult is the stranger" (Spindler, 1963, p. 211). If we are to understand the children's experiences and perceptions of those experiences, we must attempt to interview them with a perspective that is open to making sense of the world of the child (Sherman, 1995).

It is essential that interviewers of young children develop a trusting relationship based on honesty. Children can quickly identify a lack of sincerity in an adult and will not engage to the same level of conversation if trust is lacking. Questions that are neutral can also be used to establish a comfort level with children at the beginning of interviews (Bear, Manning, & Shiomi, 2006). Spending time with the participants prior to the interview can also establish a level of rapport that will facilitate discussion during the interview (Baer, 2005). In this study, the interviewers worked with the children as camp leaders throughout the camp, assisting them in the activities and developing rapport with them.

At the same time, it is important to work with a degree of informality (Buldu, 2006). Informality can allow the children to feel comfortable with the interviewer allowing the interviewer to go beyond introductory questions to gain clarity of the children's thinking. Using prompts that extend children's answers is also important when interviewing young participants. As is the case with many adults, children also respond well to semi-structured, open-ended questions (Phan, 2005). This allows the children to respond in ways that are not directed by the interviewer, leaving open a greater range of possible answers. By simply asking a second time with an extension question such as "Why *else* should we do that?" children can add to their original response (Bear, Manning, & Shiomi, 2006).

Interviewers of children have begun to use prompts in the form of scenarios (Bear, Manning, & Shiomi, 2006) where an activity is depicted and then questions are asked about what the children hear in a story. Cohen, Manion, and Morrison (2007, p. 375) argue that there is promise in using what they refer to as "projection techniques" such as pictures to elicit a verbal response from children. Such approaches have shown promise in that they have helped to elicit detailed descriptions without inadvertently giving the child verbal cues that may bias their response. In another study (Baer, 2005), figures were presented to children and they were asked to suspend reality and place themselves within the scene. Lewis (2005, p. 222) has reported a similar approach in which she explored the use of stylized cards to prompt uninterrupted narratives from children with moderate learning difficulties. However, little evidence exists of situations where children are asked to complete a story or add to it beyond what is given to them in the interview. Our study seeks to extend these described approaches by involving children in adding narrative complexity to situations that are closely connected to recent situations from their science camp experiences (e.g., picture of a child looking through a microscope and showing surprise).

Some researchers prefer to combine the interviewing of young children with observation periods (Plowman & Stephen, 2005) as this can allow for some triangulation of what the children are describing. However, observation of children needs to be done carefully. Participant observation is often accepted as a strong research approach to use with children; however, Harden et al. (2000) suggest that participant observation is problematic in a culture where children are used to seeing adults as different and are, therefore, unlikely to be prepared to accept them as one of themselves or to ignore their presence. In the case of our study, camp leaders worked together with the children in the days prior to the interviews and recorded observation data.

During the interviews, when possible, the camp leaders were encouraged to help a child talk through a misconception. This style of talking with a child is based on research (Myhil & Warren, 2005) that demonstrates that a careful guide can help children talk through their thinking about a particular subject. Because the focus of the interviews described here was to, in part, examine children's understanding of science, this process was included in the interview strategies. Interviewers of young children have also developed questioning strategies that prompted the children to describe their thinking, in essence, to develop a metacognitive awareness of what they are describing (Jacobs, 2004). In this paper, the research was conducted by asking children to advance their descriptions in ways that explained why they had used particular examples in their responses.

SUMMER SCIENCE CAMP

At a local university, the Science faculty members offer children in the area the opportunity to attend a week-long science camp in either July or August. Provided at a relatively low cost, these camps are well attended. Seven week-long camps are offered each year to children of a variety of ages. Two camps are offered to six and seven year olds and approximately 50 participants attend the camps.

During the summer camp, children participate in informal science activities presented by a group of leaders who are university students. The children participate throughout the day in a series of science-related activities that include laboratory experiments and other activities that take place outdoors. The students work with lab partners and always wear goggles and lab aprons as they are encouraged to work like "little scientists." The children write in journals and also participate in large group discussions. The culture promotes engagement, participation in activities, risk taking, and the asking of questions. Children are encouraged to talk about what they are doing with each other and with the camp leaders.

The science camps are part of a larger project funded by a CRYSTAL (Centre for Research on Youth Science Teaching and Learning) grant sponsored by NSERC (Natural Sciences and Engineering Research Council of Canada) and intended to examine perspectives about the learning of science through informal outreach projects which support school science curricula but take place outside of regular school hours. These projects support student learning and the science curriculum in out-of-school locations, and during out-of-school times.

At the end of each camp week, the students were interviewed individually by one of the camp leaders. The camp leaders were used intentionally as interviewers because of the level of familiarity they had established with the camp participants. The camp leaders had worked during the week with students one-on-one and had also worked with small groups of children. The camp leaders worked hard to establish a friendly relationship with each participant, ensuring they knew each camper's name.

This study occurred during the second year of the camp. During the preceding summer, (the pilot year of this research) four week-long camps were held and six- and seven-year-old students were asked to fill in a written survey and participated in focus group interviews. Several problems arose with these research approaches. Although the questions were simple and used large primary print, most of the children's answers were what we considered to be stifled and very short. The children's lack of reading comprehension, spelling and writing skills hindered the use of surveys. Alternately, in the focus groups, one or two children dominated each discussion so it was decided that we should change the interview approach as well. Our change in research approach was meant to help overcome and compensate for the length of time children needed to read and interpret questions, then compose and write out answers. We believed that by allowing children to freely speak their answers, the quality of the data would be improved greatly. Children would not have to interrupt their thought process to think about spelling or letter formation.

HOW CAN RESEARCHERS EFFECTIVELY ENGAGE CHILDREN IN BOTH SCIENCE CAMP AND INTERVIEW SETTINGS?

We entered this research study with the perspective that children's own understandings of their life experiences are as valid as any other. This is consistent with the view of Cohen, Manion, and Morrison (2007) who argue that it is important to understand children's worlds from their own perspectives rather than from the perspective of an adult. With this in mind we sought to build connections with children through incidental interactions with them in the context of the science camp activities and then again in the context of informal conversations (i.e., interviews) that followed the science camp activities and sought to allow children to give us insights about their perspective of the science camp experience.

Morrow and Richards (1996) have identified power relationships as the greatest challenge that researchers face when interviewing children. Mauthner (1997, p. 20) argues that researchers can address the intrinsic problem of power imbalances by focusing on children's subjective experiences. For instance, encouraging children to take the lead in interviews, by offering them opportunities to engage in storytelling and drawing pictures about their science camp experiences, allows them to take more control during the interview then might otherwise be the case in a question and answer approach seeking pure information transfer (Cohen, Manion, & Morrison, 2007, p. 349).

A science camp for children is a messy and chaotic place to conduct research that seeks to understand how children are thinking about their experiences in a high activity setting. The culture of the camp is one of exploration, interaction, examination of ideas and activity. During interviews in this setting, the researcher is faced with the challenge of engaging children who are primarily focused on experiencing phenomena from the science camp activities rather than on responding to a researcher's invitation to talk about the meaning those experiences have for the child. However, subsequently engaging a child in a structured interview can be equally complex in that the validity of the child's comments may be compromised by removing the child from the setting and asking questions that do not fully connect with the socio-cultural experience being examined. We have sought to address these challenges by engaging the interviewers in a meaningful way (i.e., as camp leaders) with the participants in the days leading up to the interview. In addition, we sought to structure the interview experience in such a way that it would be a natural extension of the culture of the science camp activities for the children. The children were asked to participate in ways that mimicked the camp. Osborne and Dillon (2007) warn of the challenges in examining informal learning environments, given the intrinsic nature of research. They suggest that the formal structure of the research process creates a disjuncture with the informal context that impedes the collection of data. However, Lom and Sullenger (2010) suggest that the research process can provide an alternate context that retains the main influences of the informal learning context. In our study, the daily activities of the children are within an informal setting, and although the interviews might be considered semi-structured, we attempted to create each stage of the interviews with a purposeful informality that enabled the children to engage with the interviewer in an extended conversation in a way that was comfortable and mimicked their interactions in the camp. We intentionally worked to elicit data without leading the children, within a culture and context that was familiar to them. The familiar context fits within a socio-cultural approach that is contextually specific rather than a psychological approach with an artificial context. We designed interview strategies that prompted the children's thinking by sometimes creating a problem for the children to solve or by initiating a narrative. Extending the narrative was intentional and we believed it would help us gain greater insights into the thinking of the children.

The child-centred interview strategy took place over a period of two days so that all children whose parents had provided written consent could be interviewed.

Each interview took between 20 and 30 minutes and was videotaped. The interviews included a set of four activities each child was asked to complete. The children had already been invited to participate in individual activities at times throughout the camp and so being asked to do this was not out of the ordinary. The four-protocol interview strategy was developed after assessing the level of success during the previous year's surveys and interviews. The camp offered explorations in different topics in science including chemistry, physics, biology, and geology, so it was also important to consider this when devising the strategies for eliciting responses from the children.

The four protocols of the interviews included an activity where children were asked to examine three photos of a familiar experiment. One step of the experiment was missing and the children were asked to describe and/or draw the missing step and then describe it fully to the interviewer. The children were then asked to look at drawings of a four-step scientific process, that they were introduced to during the camp. The four steps were presented out of order and the children were asked to shuffle the photos and place the steps in the correct order describing what happened during the actual experiment as they sorted the photos.

The children were also asked to complete a series of story starters. Short paragraphs, each describing a scenario, were read to the children. In some cases, the children asked if they could read the scenario aloud by themselves and they were encouraged to do so. The children were asked to complete the story by talking about the things that might happen next. In each story, science played a significant role. Children used this opportunity to use some of the vocabulary they had been introduced to during the science camp. They also used their imaginations to describe possible conclusions to the start of the story. Finally, children were asked to complete a drawing of a creature who had only a few beginning lines drawn. After completing their version of the creature, the students were asked to describe what they drew and justify different aspects of the creature they created. They were asked why the creature was covered with fur, feathers, or whatever the children have chosen to use. They were asked how the creatures transported themselves and what they ate. The children also had the opportunity during the interview to draw molecules they had learned about in the science camp.

The interview protocols were not presented so that one protocol led to the next; however, it was intentional that photographs were used in the first two protocols and not in the last protocols. The four protocols flowed in a manner that was meant to increase the opportunity for the children to use scientific vocabulary and share new knowledge they had gained. The visuals were used as a way to prompt discussion and allow the children to talk about something that had recently become familiar to them, as in the example of the photographs of the experiments the children were asked to re-order or add steps to. The photographs were used in the first two protocols as a jumping off point for conversation, but the order of the two protocols utilizing photographs did not matter. It was the fact that the photographs were used as a prompt in the initial parts of the overall interview that we believed to be important. This was done because the photographs gave the children a talking prompt and provided something that was recognizable. Also, during these protocols the children didn't need to use a great deal of imagination. It was successful in getting them to use scientific language and helped the flow of conversation get started. The latter two protocols, with the story starters, provided more opportunity for imagination to play a role in what the children described for us. These were the protocols where a real extension of the narrative occurred and where the locus of control in the discussion shifted more toward the children. This shift in control enables children to draw on their own learning to a greater extent than when the control remains with the adult. When the adult remains in control of the conversation with children we often see children attempting to please the adult or give an answer they believe the adult is looking for. When the children control the conversation, they make more decisions about what is included in the conversation.

CHILDREN'S INSIGHTS INTO THE SUMMER SCIENCE CAMP EXPERIENCE

At the outset we argued understanding young children's experiences learning science in informal contexts required strategies that were open-ended, risk free, and examined what they did each day in camp. The child-centred interview strategy developed was successful in extending conversations and developing trust. This approach provided extensive data compared to the previous year's approach. Moreover, using the child-centred interview strategy, we gained better insights into their experiences and the understandings of scientists and their thinking than any other strategy we have tried.

Studying Young Children's Experiences Using Child-centred Interview Strategy

In reviewing the video recordings and reading the transcripts of the interviews with the six and seven year olds it is apparent the children were comfortable with the interviewers and they were willing to reveal information they were asked about. Because the children were familiar with the interviewers, they appeared relaxed and were, generally, quite talkative in the interviews. Each child was seated at a table with his/her interviewer and the photographs used in the interview were placed on the table in front of the child.

The children laughed and talked as they moved the photos into the order they believed to be the correct one. The photographs were large, 8 ½ by 11 inches, and easy for the children to manipulate. The photos gave the children something to focus on during the interview and provided a task they could engage with while discussing their thinking about science. Each of the activities provided a focus to the discussion the children were involved in. While we sought to focus each child's discussion on science, the activities were intentionally designed to be open-ended.

Comparison of Child-centred Interview Strategy to Previous Year's Approach

As the research was completed, we analyzed our approaches to the interviews with deliberation. We have been able to ascertain a great deal more information about each child by using this four-step interview process. We compared the results from the previous year's interviews with the kind of data we were able to collect during this study and noted several distinct improvements. By removing the written component and focusing on the children's verbal ability, the interviews lasted longer, not only because we had more questions to ask, but largely because each child appeared much more relaxed and was more verbose during the process, providing lengthy, detailed responses. We learned that when children are given the opportunity to use their imagination and create their own narrative portrayals of their experiences, they can provide real insight into their understanding, demonstrating their competence. It has been a challenge to find ways to engage the children for any length of time. Because of the way we presented the activities within the interview protocol, the children were more engaged in this set of interviews and able to demonstrate their abilities with regard to describing their experiences. In the pilot study, the children would sometimes ask when they could return to the camp. No one asked to leave during the interviews in this study and they were more engaged in the interview process, appearing eager to participate.

The interview activities were presented in such a way that children were prompted to share more information with the interviewers than in the previous year. The camp participants were better able to demonstrate their scientific vocabulary and build on the prompts provided with obvious elaboration and enthusiasm.

Young Children's Descriptions of Scientists' Ideas and Thinking

Using the story starters created some of the most creative answers from the children. They used the story starters to describe scientific processes, to describe the role of scientists, to place themselves within the context of the story, and to develop the story through to a positive end. The story starters were specifically designed to create opportunities to make contextual connections for the children with the science experiences of the camp. The following examples are intended to illustrate the rich nature of the talk that occurred during the interviews.

The children wove their scientific knowledge throughout the stories they built from the story starters. One story starter used began with a young girl "flipping a switch and finding herself starting to shrink." One participant continued the story by saying:

> She knew they were made of atoms, but wondered what they looked like. She flipped the switch and suddenly felt herself shrinking. She imagined herself as a little atom walking around connecting to other atoms trying to form something else.

While the notion of atoms connecting with something else to form a new substance is rudimentary, it is a complicated concept for a six year old and this student was able to weave this idea into a story that was not directly focused on atoms. The student was able to do this because the story starter was open-ended and allowed the child to take the story in any direction she wanted, adding scientific knowledge she had as she told the story. This relates to the locus of control shifting to the child, allowing the child to control what is included in the narrative.

It was also evident from the children's stories that they were able to introduce some of the science-related vocabulary used during the camp.

> Donnie: I think she's, as you can see, she's looking in a microscope so I think she's looking at, it's her first time looking at an atom or something.
>
> Researcher: Can you tell me a bit more?
>
> Donnie: I'm gonna try. She runs over to tell people what an atom looks like but then maybe it was a photon she might have seen because nobody ever saw a photon before. Photon is like light so she didn't have to tell them she saw an atom, because people have seen atoms but if she saw a photon she would be amazed.

Again, this student added his knowledge of atoms and photons to the story without the prompting of the interviewer. This seven year old introduced his own scientific knowledge and the language used at the camp into his explanation. The power in this is providing children with the kinds of opportunity where they can weave their own knowledge into a larger narrative. In this case, the story starter has allowed a child to share with us an important feature of his understanding of the culture of scientific inquiry and the nature of the feelings that a scientist might experience in the moment of discovery. Providing children with a creative opening to extend a story embedded in a scientific context to which they feel they have developed a connection (in this case, through science camp experiences) seems to better enable them to effectively share their understandings with researchers.

In the final portion of the interview, the children were asked to complete a drawing of an imaginary creature. Before drawing the creature they were told that they would be asked a great deal of information about the creature after the drawing was completed. They were told they would need to tell us where the creature lived, what they ate, how they moved, etc. The children, for the most part, drew creatures that might be described as "typical"; however, the children were able to describe, with some accuracy, how the creature might move across a variety of terrains, how it took in its food, and why it ate the various foods they described.

> Researcher: What can you tell me about your creature?
>
> Marie: She lives on another planet called Zortex and she eats the rocks. That's why her teeth are flat. The rocks keep breaking them off.

The children were able to build narrative extensions that were logical and exhibited scientific thinking. They described the characteristics of their creatures with confidence and with elaborate descriptions at times that related to the kinds of things they had learned about animals during the science camp.

DISCUSSION

Socio-cultural approaches to exploring young children's experiences are the most effective way to gain insight into their understandings as attested by this research. Such a research approach extended talk between the researcher and the interviewed children and allowed us to shift the focus of the talk from a one-way dialogue from adult to child to a focus on a discussion that is more like the conversation between children.

Both the child-centred interview strategy and socio-cultural research approach can encourage and enable the children to explore and explain science phenomena in ways that draw on their natural curiosity and on their natural playfulness. An informal learning context such as presented through the science camps reveals much about how children engage with science when researched in a manner that allows researchers to connect with the children's understanding of their experiences. By using a socio-cultural approach to the interview process, we provided a flexible template in which children's narrative could be explored and extended.

The child-centred interview strategy shows considerable promise as a socio-cultural approach in that an essential feature of this open-ended approach shifted the locus of control in the research discussion more toward the child. We will continue to modify these interviews as we seek to increase future success, filling the gap identified earlier by Lewis et al. (2007). Additional and extended strategies may enable us to find ways to engage even further with the young children.

It is essential that we continue to examine socio-cultural approaches to interacting with young children in ways that are meaningful to the children and are generative of rich data. Children have important ideas to offer researchers about the way they experience learning and how they understand those experiences. These ideas from children can help enable educators to continually assess and improve the learning contexts they provide for children. In order to gather this type of information from children in a meaningful way, we must continue to examine and develop interview processes that are open to better understanding the socio-cultural world of the child.

The research described here just scratches the surface and we need to continue to do more to understand the culture of the camp and the way it affects the children's understanding of their experience. We have shown that children are capable of contributing to the conversation about their learning in these informal settings and can provide detailed and thoughtful responses when approached in a manner that is relevant and familiar to them. Further research can help to expand what we can learn about the children, from the children.

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TEACHERS' EXPERIENCES DEVELOPING AN INNOVATIVE SCIENCE PROGRAM

A Look at Professional Growth

In 2005, the Natural Sciences and Engineering Research Council funded five Centres of Research into Youth Science Teaching and Learning (CRYSTAL) across Canada in response to their concern that few Canadian students were choosing to pursue science careers. Each CRYSTAL had a specific theme. CRYSTAL Atlantique had the theme exploring the culture of science, mathematics, and technology across the Atlantic provinces with an initial focus on informal learning. Science in Action was created to study the impact of an innovative, afterschool science program on elementary and middle school students' attitudes towards and understandings of science.

By innovative, we mean a concept that generates improvement by moving outside of the status quo (Education Innovator—Office of Innovation and Improvement—U.S. Dept. of Education). Fullan (2000) warns that professional development is not innovative if it merely alters some language and structures, but does not alter the practice of teaching. Furthermore, innovation is also "the process of bringing new problem-solving ideas into use" (Amabile, 1988; Glynn, 1996; Kanter, 1983) by including idea development and implementation (West, 2009).

Science in Action is innovative in its conception of science, its development and implementation, the nature of its research design and composition of its research team and, most importantly to this paper, the level at which program development and the research process began. The afterschool program portrays science as an enterprise, that is, something a group of people do to study things of interest to them and the ideas they generate as a result of their studies. We treat science as personal, practical, theory building, social, political, and financial. The focus is on understanding the lives and work of the people involved in science rather than merely the ideas they have generated—what is traditionally referred to as knowledge. We want students to understand more comprehensively what a day in the life of a scientist looks like and determine whether they would be interested in pursuing such a career.

In developing and implementing Science in Action, we planned for a longitudinal study over four of the five years of the CRYSTAL grant. Upper elementary students from grades three through five and middle school students in grades six through eight were invited to participate in the multi-aged programs. To allow students to participate throughout their years in upper elementary or middle

K. S. Sullenger & S. Turner (Eds.), New Ground, 167–183.

school, the program curriculum was developed in three-year cycles. At the same time, we believed that students needed to know what it was to have expertise, to understand something in depth, and to commit to studying something over a long enough period of time, that is to gain insights into the kinds of expertise demanded of scientists.

Science in Action is also innovative in its research design and composition of its research team, particularly the latter. Using Reason's (1989) model of co-operative inquiry, we created a research team with three key criteria. First, everyone in the project was considered to be part of the research team unless they chose not to be. Second, each member chose the role(s) they wanted to play in the research process knowing that these roles could change as their interests and/or life circumstances change. Third, within the broad timeframe of the project the research process would be driven by the people involved. Members of the research team were drawn from schools, school districts, community-based science organizations, community colleges, and the university. Over the course of the project we ranged from 34 to 24 participants involved in the research team.

We began program development at ground level—no materials or resources other than the concept of an afterschool program that would engage students in studying science differently. At the outset, we sent out brochures to school districts describing the project and inviting teachers in middle schools and their feeder elementary schools to apply to participate. Teachers from the middle and elementary schools had to agree to participate for the entire project, four years, and act as facilitators for the two afterschool programs being developed. These teachers became part of the planning, design, development, critique, and implementation process. We referred to this stage of curriculum development as the alpha level of testing, a term we adopted from software developers who use the term to refer to software that is only developed well enough for the developers to test it themselves. Our goal was to develop a program and curriculum guide for a beta level of testing which would mean piloting it with groups of facilitators who had no previous interaction with Science in Action.

In addition to spending one-and-a-half to two hours facilitating one of the weekly afterschool programs, teachers met with the entire research team at bi-monthly meetings held over the course of the school year. These full day meetings were used to critically review past sessions, refine curriculum for upcoming sessions, practice upcoming activities and using equipment or resources, ask questions, share experiences, and arrange schedules for upcoming rounds of data collection. In June each year, the research team met for an intensive, three-day work session to review and revise that year's program and broadly plan the next year. As the project progressed and we were ready to share what we had learned, the teachers also participated in making conference presentations. Other than travel expenses and keeping the equipment, materials, and resources developed or purchased for the two programs, teachers received no financial remuneration for their involvement in Science in Action.

TEACHER-FACILITATORS

The teacher-facilitators are the face of Science in Action to the participants. We wanted to present a different way of studying science based on a philosophical approach that involves teachers acting as facilitators of learning. The teacher-facilitator has a role in this program that is different from their usual experience as a classroom teacher and curriculum deliverer. Teaching in this program is not the sole responsibility of the leader. Similarly, learning in this program is not the sole responsibility of the students but a complex process with many interacting variables. The teacher, who is a variable in the classroom context, as a facilitator is charged with the function of acting as an intermediary between the activities of the program and the students to assist them in their learning. Therefore, the function of being an intermediary means the teacher has the role of creating a context to facilitate student learning. Fulfilling the functions of a facilitator means that the teacher is also actively engaged in learning about themselves and most importantly learning about their students and ways of enabling them to grow and develop. Furthermore, teachers saw themselves as learners alongside the students to report on successes and failures of program implementation.

Whooo Club (Elementary School) Facilitators

There were six elementary school teachers who volunteered to participate in the Whooo Club. Each one has an undergraduate degree as well as a degree in education. Three of them had been teaching for less than three years, while the remaining three had up to 12 years of teaching experience. While most were responsible for teaching science to their classes, only one had studied science in their academic background.

EcoAction (Middle School) Facilitators

There were seven middle school teachers who volunteered to participate in EcoAction. Each one has an undergraduate degree as well as a degree in education, but only three have some science in their academic background. All of them had been teaching for between five to 25 years. Each of them is responsible for teaching science (as well as other subjects), including two who teach French Immersion.

As we worked with these teachers in developing the program, it became clear that the approach we were using in Science in Action was influencing how teachers thought about teaching science. Moreover, it was this interest in what we were seeing and hearing that led to our research focus initially on professional development and later on professional growth.

RESEARCH ON PROFESSIONAL GROWTH

In 2003, Essie Lom, a doctoral student, joined the research team and brought with her an interest in professional development from her perspective as a former teacher. It was this interest that prompted us to examine the project as a form of professional development resulting in professional growth.

A review of the literature revealed that what constitutes professional growth varies with researchers seeking to define, model, or characterize it. The representations range from a holistic view to include personal growth to a narrower focus for teacher assessment purposes. Early on, Hargreaves (1992) suggested that professional growth can be seen as the way a teacher changes as a person and as a professional. Similarly, Bell and Gilbert (1994) argued that professional growth was based on both professional knowledge and development of the teacher as an individual. They posited that teacher learning could be characterized as teachers developing their beliefs and ideas, as well as developing their classroom practice. From that perspective, they identified and described three main types of growth: personal, professional, and social. Similarly for Lieberman (1995), an essential part of learning that characterizes teacher growth is the struggle for personal and intellectual growth.

Other researchers created models of professional growth that focused on teacher knowledge. Kagan (1992) was the first to create a model of professional growth, referring to "changes over time in the behaviour, knowledge, images, beliefs, or perceptions." Grossman (1992), finding Kagan's model too limiting, added the acquisition of different perspectives and ideas and the incorporation of a wider vision of what teaching involves, referring to "teachers' expanded vision of their professional roles and their awareness of broader issues in education" (p. 61). For Clarke and Hollingsworth (2002) teacher learning is an integral component of professional growth. Their model of professional growth focuses on a process of constructing a variety of knowledge types (content and pedagogical knowledge) by individual teachers in response to their participation in the experiences provided by the professional development program and through their participation in the classroom. For them, teacher learning, both personal and professional, is an integral component of professional growth.

More recently Borko (2004), fuelled by current reform movements in education and the emphasis on accountability, has narrowed the characterization of professional growth to measurable and identifiable changes in professional knowledge or practice for the purpose of teacher assessment. Based on the notion that professional growth is determined by student achievement, there has been a growing proliferation of "how to" instructional models such as the growth plan developed by Peine (2007)—a systemized plan to foster and then evaluate the effectiveness of teacher professional growth. Thus, the contemporary practice of evaluating the success of professional development focuses on student achievement rather than professional growth.

Therefore, in an effort to identify best practices, researchers have focused on the link between effective professional development and professional growth. A review of the literature on professional development reveals that professional growth is a concept identified by others about teachers. In his exhaustive review of research on the effectiveness of professional development, Guskey (2009) claims that "professional development remains key to educators' progress and professional growth" (p. 226). Other researchers (Elmore & Burney, 1997; Fletcher, 2003; Guskey & Huberman, 1995) assert that the importance of professional development is it promotes a change of practice by enhancing the quality of teaching. Circumstances that lead to professional growth are believed to be an intentional process (Guskey, 2000) centring on the teacher as learner (Ball & Cohen, 1999; Hawley & Valli, 1999; Little, 1993) as well as ongoing, lasting a teacher's entire career (Hargreaves, 1992).

According to these studies, professional development that fosters professional growth is life-long and expected to lead to sustained change in teacher classroom behaviour. Based on this extensive review of the literature on teacher growth it is evident that the process of teacher growth can be seen as one in which personal, professional, and social development is occurring, with teachers addressing their feelings associated with changing, and one in which development in one facet cannot proceed unless the other facets develop as well.

METHODOLOGY

Since an essential characteristic of Science in Action is collaboration, we felt that the methodology used to determine teacher growth should be faithful to the philosophical approach which guided the collaboration. The research collaboration is guided by Reason's (1989) co-operative inquiry model and Connelly and Clandinin's (1990) field experiences strategies. This research process is particularly suited to collaborations where people come from different groups with diverse concerns and questions. In this approach, all members of the collaboration are members of the research team, and specific roles can change over time. Thus, the model is also suited to studying research contexts like schools where teachers may change assignments, schools, and positions. Everyone participates in the study, choosing roles that vary from design and implementation of teaching strategies to data analysis and a full spectrum of knowledge transfer activities. The more experienced researchers work with other team members who want to develop research skills. Clandinin and Connelly's (1994) personal experience methods are ideal for teaching novice researchers how to move from field experiences and notes to research data and findings.

Participants

The Science in Action implementation-research team consists of 25 educators from eight elementary and middle schools. It is important to note that the group of participating teachers was not static; rather, the program allowed for movement of teachers to leave, join, or re-join the program as circumstances dictated. This is a unique opportunity for members of these diverse communities to work together.

For example, despite the fact that one middle school and elementary school shared the same building, the teachers had never worked together on a common project. As a result, the conversations within the collaborations provided opportunities for teachers to share individual concerns, realizations, and expertise within their practice.

The schools which hosted the Science in Action project also provided a variety of student populations. Two of the schools were situated in a small town whose students were bused in from surrounding rural communities. Another two schools were located in larger urban centres whose surrounding population was from lower socio-economic circumstances. As a result, the students who participated in Science in Action came from a wide variety of backgrounds.

Along with the 13 teachers, the collaboration included representatives from two community-based science organizations. They were invited to participate because of their proximity to the schools and their involvement in the local science community. Their representative provided access to their facilities and contributed to the development and implementation of the curriculum. The remaining members of the collaboration were volunteer graduate students and their advisor, a regional university educator, who was the project organizer and supervisor.

Data Collection

Many decisions about data collection were made resulting from the nature of the collaboration. We were accustomed to a wide range of discussions in our meetings and felt that conversation would be a natural extension of the atmosphere of the collaboration. Since researchers were also the sources of data, we chose to implement interviews as opposed to surveys. These interviews had to take place over the phone due to the lack of time available for these busy teachers. Furthermore, we felt that an interview strategy would provide an opportunity for teachers to expand and reflect on their responses. All the interviews were transcribed. Teachers were interviewed at the end of their first year of participating in Science in Action as well as at the end of the third year. We were interested in learning about the teachers' backgrounds, their motivations for joining Science in Action, its effect on their teaching practice, what they learned, whether they considered the experience to be professional development, what effect the experience had on participating students, and what challenges these teachers faced participating in the project.

In an effort to involve the teachers further in the research process, we decided to involve teachers in a second round of data collection by having the research team, including the teachers who were initially interviewed, read through and conduct a preliminary analysis of the transcripts. The team was divided into three groups of four or five and each given a complete set of interview transcripts. In addition to looking for patterns across the transcripts, each group was asked to reflect on what they learned from the analysis. These discussions were audiotaped and transcribed. After reading through the interview transcripts, each group was asked to discuss what had been said about Science in Action as professional development and what reaction members of the group had to these statements. In addition, each group was asked to discuss what we had learned that would be of help or of interest to other researchers, teachers, or members of science-based community organizations and the pros and cons of Science in Action being delivered as an extended school activity.

Data Analysis

We began the analysis of our data by coding relevant phrases and comments made in the interviews. Using Stauss's constant comparison model (Corbin & Strauss, 1990), we coded teachers' responses that represented their thoughts about involvement in Science in Action. We looked for examples and reflections about their experiences. Each set of teachers' responses was coded individually. Next we searched within each set of interviews for patterns across interviews. Then we compared patterns across the two sets of interview data comparing across questions and categories for consistencies, inconsistencies, and new ideas. Thus the data for this paper comes from the original interviews as analyzed by the two authors and from the group analysis conducted by the research group as a whole.

FINDINGS

What we learned when we interviewed the teachers was they thought overall participating in Science in Action was a new, though positive, experience and had had an impact on their teaching science. Even so, they reported challenges that others should be aware of if they were going to consider a similar experience. Moreover, it didn't seem to matter what their science background was or their years of teaching experience, participation was by turns rewarding and disappointing, enlightening and confirming, as well as extraordinary and usual.

A New Experience

The new aspects of participating in Science in Action were overwhelmingly: the opportunity to interact with other people they would not ordinarily get to meet; to be able to interact with them over such a long period of time; to have opportunities they had never had before; and to participate in developing a curriculum so directly. However, teachers also described different understandings of students, access to resources, and changes in their attitudes towards and confidence in teaching as new outcomes of their experience as well.

The teachers reported they had never had an opportunity to interact with other professionals including scientists for such a long period of time. One teacher said that even the times commuting back and forth from the bi-monthly meetings offered time to share information and experiences with colleagues. Still other teachers argued the interaction "gives you a wider scope" than you get from focusing on your own classroom and school. Learning how others approach teaching, such as the community-based science educators, gave them different perspectives. Not only did the community-based science educators work with the students as part of the program, they were an integral part of the research team working on the program teams with teachers to review, plan, and develop the program during the bi-monthly meetings.

Teachers also talked about learning from scientists alongside the students. One teacher said, for example, he learned from watching the scientists that he had been teaching sampling wrong all these years and wished he had had the opportunity to work with scientists more during his career. Another teacher said he "saw science in a different light." Teachers talked about scientists becoming part of their network. Some of the teachers added additional visits and extended activities to the afterschool program. One teacher said,

> Being able to speak directly to scientists and learning different ways of approaching and teaching science opens your eyes to all sorts to different methods.

Others asked the scientists to visit their schools and work with their students in their science classes.

Teachers had an opportunity to share what we had learned with others outside the project as well:

> For some of the people in my school it's helped or they have identified me now as being somebody who has a bit more knowledge in the area. So when they have questions they will often come and ask.

Being able to attend international conferences with other science teachers and presenting was not only a new experience, it was far beyond what one teacher expected as possible,

> I don't think I would have attempted it had I not been involved with the Whooo Club.

For the first time in their schools, they were being seen as "science people" where other faculty were asking their advice on science matters and school administration was taking action on their suggestions for new resources.

However, the most significant new experience teachers talked about was having such direct influence and impact on the program curriculum itself. They talked about being "expected to have expertise" and take responsibility for having ideas, for contributing to the program's design and development. According to these teachers, this project was not their usual passive PD experience where they were expected to listen to and implement others' ideas. One teacher's comment captures this sense of new responsibilities/way of participating,

> This is the first time I've ever seriously sat down and done planning and it's that sort of collaboration that I find has made me a better teacher.

Impact on Their Science Classroom

For all of these teachers, this was a totally new context in which to experience teaching science; they had a different role as facilitator and new ways in which to experience teaching science such as group activities, learning in an outdoor environment, and activities directed to the students as problems and challenges. Teachers told us they were getting different ideas for lessons and how to approach things in their classes. A number of teachers used the orienteering, which we taught students as a team building skill and so they would feel more confident exploring their piece of land, with their own classes. One group of teachers even extended the notion to doing geocaching with the global positioning system (GPS) units we provided.

Some teachers indicated that they got to know their students who participated in EcoAction in different ways that translated to how they saw them in their classroom. They got to see students doing things and interacting with other students that they did not see in the science classroom. They also got to interact with them differently and build more of a rapport with them. Teachers also mentioned they got to interact with students whom they had not taught. Another teacher indicated she liked working with the students in Whooo Club better than her science classroom. She felt she had fewer students with problems. However, it was interesting that all three Whooo Clubs had about one-third of students who were labelled struggling by their classroom science teachers.

Teachers noted they also had access to resources that were not available in their classrooms such as projecting and stereo microscopes, video cameras hooked to their computers, a resource library, and GPS units. They were able to use the equipment and materials with their science classes as well. Most notable to them was just being able to expand the teaching strategies and activities they could provide their students.

Perhaps the most interesting thing teachers told us was that participating as facilitators had given them another way of seeing how to teach science. They also told us their attitude towards science had changed. One teacher told us, “It made me a better teacher.” Another said they “had to think differently.” Teachers were more confident in their science teaching and doing more activities and group work in their classes.

Challenges

We asked teachers if they would recommend other teachers join the Science in Action program. They raised a number of issues and challenges to participating in such a groundbreaking, program development project as Science in Action was. These included issues concerning time, workload and expectations.

Time, or lack of it, was the most challenging aspect of participating in Science in Action over the four years reported these teachers. They found themselves with more to do in the same amount or even less time than they have had in the past. Aside from their teaching duties, they participated in a variety of planning, evaluating, and learning activities that required them to spend time outside the classroom—"It's all about time and fitting everything in," according to one teacher. Just having time to meet with their colleague to plan each week's meeting was a challenge, they told us. As one teacher said,

> I would like to have that extra time, that prep time, that one extra prep period a week to prep for science club. Unfortunately I don't get it.

As the project progressed we learned that these teachers are the busiest in their respective schools, volunteering to oversee at least two more afterschool programs. These additional programs would not be offered in these schools if they did not sponsor them.

Workload was another major factor that challenged these Science in Action teacher-facilitators. Sometimes, teachers needed to make adjustments to accommodate students with special needs. For example, on occasion, teachers found that the language used in the planned presentation of the activities was too sophisticated for the learners they taught; one teacher told us, "We had to change the lingo to adapt it to kids." Even though teachers were made aware of the commitment their participation would involve, when it came to actual amount of work required, these teachers expressed surprise as this teacher did: "I was surprised probably number one by how much work it is." Teachers reported that at times, the scheduled activities and preparation to present them to their students added to their stress:

> It's stressful but only just because I'm involved in so many other extracurriculars that sometimes all of them together combined were kind of taking over my life.

One teacher suggested that the demands of the program may be so extensive as to deter others from participating.

Finally, when invited to participate as researchers, the teachers often cited an overloaded workload as their reason for being unable to take on an additional role, as this teacher did:

> I would say based on my work load right now, I would not participate in that aspect of it. Something like that, perhaps, in the summer time but not during work hours or during a regular working year. I wouldn't have any time unfortunately for that.

Even when there was a desire to participate as researchers, the teachers felt overwhelmed by the tasks they needed to do, as this teacher described:

> I'm not quite sure where I'm going to fit more things like transcribing and conferences into an already hectic schedule, So I'm not looking forward to that, I wasn't aware that that was part of it at the beginning.

For these teachers, this was such a new experience that they did not have a sense of how to judge either the time commitments or workload responsibilities.

A third issue raised by the participating teachers was the expectations of the program that conflicted with the reality of their daily classroom experience. Some felt that the number of activities they were expected to prepare per session was unrealistic:

> It's the frustration of noticing everything laid out, all the activities and not having enough time. So, needing more time, and for every lesson have two weeks rather than just one week.

Other teachers suggested that the number of activities they were expected to complete was also unrealistic, as this teacher told us:

> We found through the project that there's just too much to get covered in an hour, way too much. We have to look at what needs to be covered and choose what we think can be covered in that hour but also keep the interest of the children.

Some teachers expressed concern that these difficulties have a negative impact on the number of children who continue in the program. Some children drop the program when the activities are not presented as planned. Despite the fact that teachers participated in designing and developing the activities during the summer, finding time to prepare for them with the number of other teaching responsibilities they had was overwhelming and in some cases impossible.

DISCUSSION

What is a career in teaching about if not to grow as a professional? For these teachers, it was reflecting on their experiences participating in Science in Action—the ways they had benefited and changed—that led them to determine the experience was professional development. In most literature, professional growth is depicted as an outgrowth of professional development; in this case, professional growth was used as an indicator of professional development.

Professional growth according to these teachers' experiences is multifaceted. Not only did they change their thinking about the value of certain pedagogical practices such as group work or "hands-on" activities, they created new social networks, became resources for their colleagues, and, most importantly, significantly changed how they thought of themselves. These teachers' experiences with professional growth are similar to those identified by Day (1999) in his research on continuous professional development (CPD). Teachers not only acquired new skills and knowledge, but also developed "critical friendships" that we termed networks; "vision statements" that link theory with classroom practice; and "personal efficacy," such as the increase self-esteem they derive from being known for their expertise. At the same time, they bring into question the narrowing of professional growth to only be reflected in or valued through changes in classroom practices.

Not only did these teachers remark on their professional growth, but their personal growth as well. Many noted that their confidence as science teachers grew as a result of this experience. They became known in their respective schools as experts and had the opportunity to present at conferences. The importance of personal growth was noted early on by researchers (Bell & Gilbert, 1994; Hargreaves, 1992; Lieberman, 1995). However, with the current focus on professional development for teacher assessment, the concern for a teacher's personal growth has become less important, because it is difficult to evaluate.

In some sense, each of the aspects or facets of professional growth we draw from these teachers' descriptions is an illusion. None of them exist or were developed independent of one another. While it may be important to tease apart the various facets to recognize the complexity and richness of professional growth, we argue doing so could lead to particular facets becoming criteria for demonstrating professional growth. If professional growth is to continue as a benchmark for professional development, then we need criteria that are more inclusive and ways of demonstrating growth beyond the classroom.

Professional growth is fostered by context. In 1971, Schön argued that teachers are usually implementers and managers of a curriculum designed by "experts"—little has changed in the almost 40 years since. We argue that it is the context created by Science in Action that promoted the kinds of professional growth we noted in three ways. First, the context was ongoing, longitudinal; second, it allowed and valued choice; and third, it made the "familiar unfamiliar." We suggest that the multiple ways in which teachers depicted professional growth directly result from their active participation in all aspects of the project and program.

An Ongoing Context

The Science in Action teachers did not merely construct their own learning resources for use in their clubs, but were integral decision makers and planners. Teachers attributed some of their growth to this novel position. As collaborators, they grew as communicators and discovered that they had much expertise to offer—increasing their estimation of self-worth. In addition, they were no longer relying on others to provide the knowledge on which to base curriculum decisions. They were offered opportunities to be more than receivers of documents and resources and they chose to accept and become part of the developers and decision makers. As these teachers noted, it was being able to meet with colleagues over such a long period of time that allowed interactions to develop into critical friendships and networks. Similar to the findings of Hargreaves (1992) and Birman, Desimone, Porter, and Garet (2000), these teachers cited that their professional growth was enhanced by their ongoing participation in Science in Action. This opportunity allowed them to learn new strategies, practice them in a classroom setting, and critique them with colleagues—a unique experience in the realm of professional development (Wilson & Berne, 1999).

Choice with the Context

The co-operative inquiry model guiding Science in Action (Reason, 1988) encourages trust between participants, promoted through freely negotiated involvement, roles, and democratic decision making. Such a context is about choice—choosing to participate, choosing roles, and choosing to change roles as personal circumstances or interests change. Such a context is also about the choice to be a decision maker, a choice which brings with it the expectation to know things and contribute.

Choosing to participate, to be a decision maker, fosters reflection, a critical element of professional growth or development (Lieberman & Miller, 2001). Schön (1983) emphasizes the importance of this critical reflection in teaching, in his notion of teachers as "reflective practitioners." We recognise the value of experience and reflection as contributors to the knowledge base of educators, which in turn, contributes to "ways of knowing" (Brandenburg, 2005) which develop over time. For example, during the regular meetings when teachers met with other members of the research team, it was common practice to discuss what worked or didn't in the previous period of club time. It was in these moments of reflection that teachers began to reveal that program strategies, such as grouping or sampling, were affecting their own teaching of science. While reflection and decision making are common practice for teachers, it was their work in the Science in Action project that made it visible. This revelation supports Wilson and Berne's (1999) warning that teacher learning should not be "delivered" but rather "activated"—a note of caution supported by our teachers.

A Context that Makes the Familiar Unfamiliar

The Science in Action context allowed teachers to "make the familiar unfamiliar." By that we mean that acting as facilitators instead of the more traditional "information deliverers," and shifting the emphasis from knowing what scientists have learned from their studies (knowledge) to understanding who scientists are and what they do, made the familiar act of teaching unfamiliar. Being able to juxtapose the learning experiences of many of the same students they see in science class allowed them to compare what worked and what wouldn't across the two contexts. Trying things in Science in Action they would or had not in their classrooms provided them with the unfamiliar context from which to reflect on the more familiar context.

Researchers in teacher development theories put the teacher as learner at their centre (Ball & Cohen, 1999; Hawley & Valli, 1999). Likewise, our teachers confirmed that as facilitators they were asked to take on a different role. They learned to approach teaching in a new way, different from their past experiences. Slepkov (2008) and Inman (2009) both found that for teacher learning to be significant, it must be in an authentic context which, for them, was the classroom, for us, the Whooo Club or EcoAction. Because they had several years to practice the approach as facilitators, our teachers were afforded a rare opportunity to "test drive" this different approach to the role of the teacher. Despite the discomfort that comes from change, these teachers reported enjoying the chance to step outside of their own boundaries and to make what was previously unfamiliar, familiar.

We are not alone in arguing for the importance of context. Birman, Desimone, Porter, and Garet (2000) specifically propose three structural features that set the context for successful professional development: form (the structure), duration (amount of time given toward the program), and participation (the composition of the participants). Our findings support this model. Participating teachers recommended the interactive structure of Science in Action, which provided a context for them to confer with colleagues, learn from scientists, and most importantly experiment with new strategies without the pressure of formal teacher assessment in a three-year project made up of participants from diverse backgrounds. These teacher/researchers recommend professional development with extended duration of activities, having content focus, active learning opportunities, and coherence to foster the greatest discernible teacher growth.

In contrast to Guskey (2000), we propose that professional growth is not necessarily purposeful. It is something that happens on the way to doing something else. Would we have learned the things about these teachers' experiences with Science in Action if we had set out to study them from the beginning? We think not. The very formalizing of the participation to accommodate data collection would have destroyed the opportunity for teachers to act as collaborators and not subjects. The very aspects of the context that promoted professional growth would have been diminished and perhaps destroyed. We find it interesting that studying professional growth may have shades of Schrödinger's cat—the act of studying it may destroy the context in which it is fostered.

IMPLICATIONS

This research demonstrates the importance of teachers playing a central role if professional development is to foster professional growth. These Science in Action teachers did not play an add-on role: they were not just part of the curriculum implementation, as often is the case, but rather had an active, authentic role in all parts of the project. In addition, what contributed to the innovation of the project is that these teachers not only volunteered to participate, but were offered the choice of how to participate, thus fostering the potential for effective professional growth (Beatty, 1999). Through this work we were able to identify some of the challenges and many of the benefits teachers encounter when they participate in such an innovative project. We also recognize that because teachers are unaccustomed to be the planners and developers of a curriculum as well as researchers, they need additional support to feel comfort in these new roles. Despite the discomfort that occurs when working in unfamiliar areas, research (Eraut, 2004) shows the learning that ensues is most significant and transformative. Consequently, there needs to be a balance between the guidance that could be provided and the independence that would allow for honest, significant contributions.

Subsequent thoughts concerning the professional growth these teachers experienced left us with further questions. Evidence from this research suggests that professional development situated in a context that makes the familiar unfamiliar may be effective in facilitating teacher understanding of new instructional practices. While it was evident from teachers' comments that Science in Action had a significant impact on them and their practice, we were left wondering if this change was a lasting one. We wondered whether, without the opportunity to meet and collaborate with colleagues, their professional growth will be sustainable? There was clear evidence that during the project, teachers were reflecting on practice, constructing new knowledge about teaching, and making positive instructional shifts. However, when no longer involved in the project, they will return to their traditionally isolated role of classroom teacher, without the aid of the collaboration that fostered their professional growth. Each teacher has his or her own unique approach to the demands of their chosen career. This reinforces the importance of a continuous program of professional development with multiple opportunities or junctures in time for teachers to re-embark on their journeys of professional growth. Thus, the challenge for future research is clearly whether professional growth can be sustained without the support of the collaboration. In addition, future research several years later could reveal how long-lasting these changes in their thinking and practice are.

Finally, research on professional growth in informal contexts is problematic in itself. This approach to professional growth and learning by teachers is significantly different from other currently used methods of delivery of professional development. Rather than predetermining what the expected outcome of any individual professional development opportunity ought to be for every teacher, informal contexts provide opportunities sufficiently broad to enable the teacher to construct knowledge, gather practical skills, and grow personally in ways that are meaningful to him or her at that particular moment in their professional life. As a result, greater value is given to traditional forms of professional development that are provided for teachers. These teachers expressed a preference for the informality of the project and its subsequent professional development over forms they previously experienced. However, it was clear that while they were permitted to participate in Science in Action, it was on their own time and effort outside of their regular duties. In addition, there was no sanctioned credit given for the professional growth they experienced. This led us to wonder how systems driven by economy and accountability can establish a means to recognize and value the personal and multifaceted forms of professional growth derived from informal contexts. Despite these concerns, this research does contribute to a greater understanding of the challenges to and "optimistic premises" for teacher growth through similarly innovative, collaborative, informal projects.

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Section III: Alternatives to Science in Schools

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INTRODUCTION

Informal learning is often defined as something that takes place outside of formal and non-formal education. Formal education commonly refers to the institutional ladder that is usually compulsory, hierarchical, implementing a prescribed, state-regulated curriculum with explicit goals and evaluation mechanisms that lead to the granting of diplomas or certificates for admission to the next grade or level or the formal labour market. Non-formal education often refers to programs outside the formal school system that is usually short-term and voluntary, such as driving lessons, tennis courses, or cooking classes. In contrast, informal learning is not part of an educational institution with its prescribed curricula. Often museum science centres are viewed as informal learning opportunities; however, they are, in fact, alternatives to academic, or school learning. The learning is limited to a specific curriculum and tends to be designed more for fun than real learning. Unfortunately, the learning that occurs in informal learning situations is not recognized by formal educational institutions or the workplace. However, as seen in this section, it is in this sphere where most of the significant learnings that we apply to our everyday lives are learned.

The first article in this section, “Pedagogical tools that help pupils pose and solve environmental problems,” examines the impact of informal environmental science programs on students in three countries. Pruneau revealed that students were able to utilize the problem-solving strategies they discovered in the informal science program in their own school experiences. By learning strategies in posing and solving problems, these students would be able to transfer these skills to a variety of contexts.

In the second article, “Studying science afterschool: Middle school students’ experiences working with field botanists,” Sullenger and Peck reflect on the impact that participation in an informal science program can have on students. The authors recognize the significance of interaction with scientists in “real work” situations as having an impact on students’ perceptions of scientists and their work, which can lead to students’ increased belief in their ability to learn science.

In the third article “Informal learning and the problem of disengagement in science: A small success story,” Sullenger and Turner reflect on the levels of engagement students experienced while participating in an informal science program. The authors refer to the disengagement toward science courses that students exhibited in an extensive international study (Schreiner & Sjøberg, 2004). In contrast, Sullenger and Turner revealed that student participants in an informal

K. S. Sullenger & S. Turner (Eds.), New Ground, 187–189.

science program exhibited overwhelmingly positive and impactful attitudes toward science and scientists.

What becomes clear when reading the three articles is that informal learning opportunities present aspects of learning not afforded in non-formal education and schools. These three aspects are the social nature of learning, student-controlled learning, and voluntary participation. In combination, these three aspects not only positively impact student engagement in learning, but also result in encouraging students to extend their learning beyond the limits of the informal learning situation.

One aspect that is common to the informal learning opportunities studied in these three articles is the social nature of learning. Students and their facilitators/educators in these articles participate in the learning experience together. Sullenger and Turner recognized that what made the Science in Action program engaging for students was that they were able to interact with peers as mentors and helpers. Sullenger and Peck identified the interaction between students and botanists in the students' own context as making the learning significant for both students and scientists. Finally, Pruneau identified student social interaction in problem-solving as the factor that enabled students to pinpoint aspects of the problems and solutions they did not recognize as individuals. While schools are convenient places for students to meet, the learning outcomes are measured by individual testing, counter to the social experience in these articles that authors acknowledge to enhance engagement and student learning.

Another aspect common to the informal learning opportunities in the three articles is that students can control the depth and breadth of learning. The three articles identified learning situations in which students were able to penetrate deeper into content than in their science classes. The contexts, described in these articles, created by working with scientists, solving real-life environmental problems, and designing experiments to better understand their world, not only increased student engagement with the learning situation, but also led them to consider other potential ways to apply their learning. Students in all three articles took their learning of science beyond the limitations of a state-approved, school-based curriculum.

Finally, the third aspect common in these three articles is the voluntary nature of informal learning. The students in all three articles participated because they were curious, interested, and/or wanted a new learning experience. Each of the articles emphasized the integration of students from a variety of academic levels and abilities. Many of the participating students were not considered to be the most academically gifted or successful, and often surprised themselves and their teachers with their levels of achievement and learning in these informal learning situations. Schools, conversely, group students by age and/or ability and don't take into account interest and attitudes.

So what can we learn from these three articles? It is clear that given the opportunity to be masters of their own learning, students tend to seek greater complexity and depth than is offered in their formal education curricula. These three articles demonstrate that informal learning can push the boundaries of what schools understand learning to be. However, there is much work left to be done. Research into informal learning is still very haphazard and difficult because of the unstructured nature that is inherent in such situations. These three articles demonstrate how little we understand about the significance of informal learning and the need for more programs and research.

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PEDAGOGICAL TOOLS THAT HELP STUDENTS POSE AND SOLVE ENVIRONMENTAL PROBLEMS

INTRODUCTION

In the literature, most environmental problems are deemed complex and multidimensional (Foladori, 2005; Sauvé, 1997). According to Jonassen (2000), a complex problem possesses a large number of characteristics, functions, and variables. Furthermore, many relationships exist between the elements of this type of problem. Bardwell, Monroe, and Tudor (1994) attribute three dimensions to environmental problems. The first dimension is multidisciplinarity, a dimension that reinforces the necessity of calling on knowledge and experts from several fields (social, technical, scientific, etc.). Foladori (2005) considers that the existence of many of the causes of environmental problems requires a multidisciplinary approach to problem solving. The second dimension refers to the possibility of analysing these problems from different angles. According to Bardwell (1991), the way that an environmental problem is posed will lead to various possible solutions, according to the element on which one is focusing. The third dimension lies in the uncertainty of the information taken into consideration by the solver. The information on environmental problems is not always available or accessible to learners, due to their complexity or because of the learners' own limited capacity to evaluate the relevance of certain information.

Since 1977, the advantages of environmental problem solving by learners were brought to the fore in environmental education (EE): all EE objectives, as defined at the Tbilissi Conference—awareness, knowledge, state of mind, skills, participation (UNESCO-PNUE, 1986)—could be reached, and young people could maybe transfer their problem-solving skills regarding open and complex problems to various environmental topics. In the educational projects that they observed, Chawla (2002) and Hart (1997) noted that young people had been able to propose some relevant solutions to environmental problems. But, what exactly is a young person's capacity to solve environmental problems? Moreover, can young people see themselves as having responsibility for or the possibility of making a contribution to solving environmental problems? Despite the current success stories and the great educational value given to problem solving (Stapp, Wals, &

K. S. Sullenger & S. Turner (Eds.), New Ground, 191–223.

Stankorb, 1996), few researchers have described and analyzed this capacity among young people in the environment.

The international research program that is discussed in this article deals with young people's capacity to solve environmental problems. Specifically, we were interested in describing how students spontaneously pose and solve environmental problems and to help them to do better. Our team worked in a perspective of solving problems creatively, along the lines of the Osborn-Parnes model (Osborn, 1998). Our study is based on the belief that young people can bring new and effective solutions to environmental problems, progressively contributing to the transformation of contemporary lifestyles. The research agenda first consisted in observing the way young people spontaneously accomplished two steps of environmental problem solving: posing the problems and finding solutions. After describing the strengths and weaknesses of young people during these steps, we identified, in the fields of creativity and cognitive science, the educational strategies that could help them succeed in the problem-solving process. Then, we tested some of these strategies to check if they actually improved young people's capacity to find adequate and original solutions.

In this article, we summarize the work that was done with youth from three countries: Canada, Romania, and Colombia. The study presented here is not a comparison among the capacities of Canadian, Romanian, and Colombian students for solving problems. In fact, the students that we involved in local problem solving were neither of the same age nor did they work on the same environmental issues and did not live in the same environmental, educational, and socio-cultural context. Due to limited access to schools, especially in Romania and in Colombia, we were not able to control these variables. Since it was difficult to carry out comparisons, our team opted for a progressive and exploratory study of young people's way of posing and solving environmental problems. We observed how the students spontaneously experienced the process and then gradually experimented with educational strategies to help them improve their performance. What we learned is that young learners can become better problem solvers if they are introduced to effective problem-solving strategies and if they study problems within their own communities with scientists and other experts. However, we raise questions about the kinds of problems that should be submitted to students, about the approaches that could be used to build their self-efficacy when they are involved in finding solutions and about the creativity strategies that could be efficient with different kinds of problems.

OVERVIEW OF THE STUDY

This first phase of the study began in Canada. The first year, we asked three groups of Canadian students (ages 8, 11, and 13) to pose and solve environmental problems while we observed them. The results obtained enabled the research team to note the strengths and weaknesses common across the age groups and to propose educational strategies to improve the students' success in problem solving. Some educational strategies that could improve the young learners' problem solving skills were found in the cognitive sciences literature. During the subsequent experiments (in Canada, Romania, and Colombia), we asked the students to solve local problems again, but this time using cognitive problem-solving strategies. We asked them to visually represent the problem (in all three countries) and other heuristics, like observing the problem in the field, discussing the problem with their family, searching the Internet, etc. (in Romania). For the third phase of our study, we looked at the literature on creative problem solving for strategies that would allow young learners to develop their problem solving even further. A final educational experiment was carried out in Canada, using creativity strategies to help the students find more original and effective solutions. Table 1 presents the three phases of the research program.

Table 1. The three phases of the research program

Phases	*Location*	*Experiments*	*School's cultural context "before the experiment"*
Phase 1	Canada (New Brunswick)	Observing how students spontaneously pose and solve environmental problems.	Traditional
Phase 2	Canada (New Brunswick), Romania, and Colombia	Students are invited to solve local problems again, but this time adding a visual representation of their problem. In Romania, they are also presented with some problem solving strategies.	Traditional
Phase 3	Canada (New Brunswick)	Using creativity strategies to help students find more original and effective solutions to an environmental problem.	Traditional

REVIEW OF LITERATURE

Since we found no research describing the problem-solving process within the field of environmental education, we looked to the fields of cognitive science and creativity, which have studied the act of problem solving in depth.

Posing and Solving Problems

The concept of *problem* is often associated with notions of deficiency or an element "that needs improvement." Mayer (1992) defines a problem based on three elements: an *initial state* (considered as unsatisfactory), a *desired state* (different from the starting situation), and *obstacles* that intervene in the path from the initial to the final state. However, problems should not always only be perceived negatively.

Solving a problem consists in seeking a path to reduce the gap between a current situation that is unsatisfactory and a situation that is desired (Proulx, 1999). Problem solving could be summed up in an initial situation, a desired situation, and a group of operations enabling a path toward a solution—that desired state. The *cyclical* process of problem solving generally happens in eight principal operations: identifying a problem, posing a problem (represent and define it), finding solutions, evaluating and choosing a solution, planning an action, carrying out the action, and evaluating the action and the process (Higgins, 1994). Among these operations, *posing a problem* is the most important because it is central to all the other steps. The next most important operation is finding solutions because it requires considering all the information and identifying all the possible ways of addressing the problem—it requires thinking "outside the box." It is these two most important aspects of operations of problem solving that we wanted to explore with respect to the capabilities of young learners in solving environmental problems.

The advantages of *posing* a problem well are as follows: having a specific idea of what one is seeking, identifying relevant information more easily, reducing the feeling of disorientation when faced with a new situation, and finding effective and sustainable solutions. Figure 1 illustrates how our research team conceives the operation of posing a problem in the problem-solving process.

In Figure 1, problem solving is presented as a cyclical process consisting in a constant back and forth motion between the problem space, the solution space, and the action space. Learners identify a problem, explore it, question themselves, investigate, and pose the problem, exploring its various elements: sources, causes, stakeholders, places, impacts, time related information, obstacles to action, desired situation, etc. This allows them to formulate solutions and choose one that they will apply after planning their action. During the process, learners constantly go back and forth between the various operations. If they discover new elements of the problem, they go back to the problem space to reformulate it. If they find too few solutions, they pose the problem again. If they see that it is not possible to carry out the chosen action, they seek other solutions. The whole process takes place in a metacognitive space, since individuals observe and constantly adjust how they are working on the problem. The solutions as well as the procedural knowledge acquired are used again by learners in other problems. Experiencing a successful process reinforces the learners' feeling of auto-efficacy and encourages them to solve other problems. Finally, the ideal problem-solving process takes place within a community of learners who help each other to accomplish the various operations.

The operation of *posing* a problem happens many times during the problem-solving process. Posing a problem first and foremost consists in formulating the problem to better solve it (English, 1997). Stoyanova (2000) explained that, during this operation, students interpret the problem by using their own words, rearranging the information related to the problem, and repeatedly reformulating the problem in order to clarify it and reveal its obstacles and goals. The learners formulate it in a way that helps them find a solution. This is a difficult task to accomplish. To pose a problem, students use their knowledge, associate ideas, reason, generate

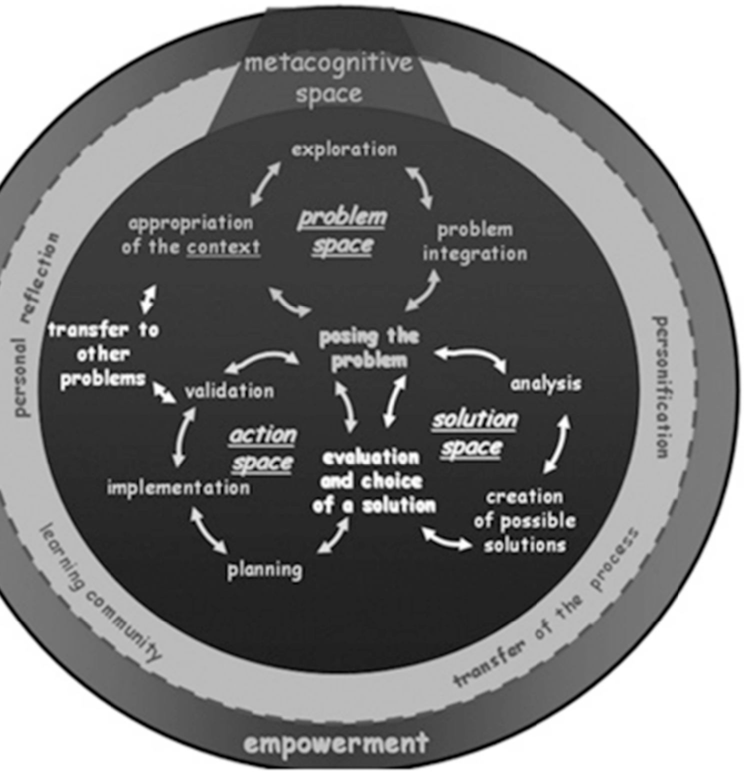

Figure 1. Representation of the problem-solving process (Pruneau, Freiman, Langis, Baribeau, Liboiron, & Champoux, 2007)

abstractions, observe themselves, ask questions, evaluate, and visualize. They must be able to determine the various characteristics associated with the problem (Hauslein & Smith, 1994), choose the words to describe the current situation and the desired situation (Jones, 1995), as well as repeatedly summarize the problem (Michalko, 1991). Thus, when students *pose* a problem, they synthesize, they simplify, and organize the information related to the problem (Schacter, Herl, Chung, O'Neil, Dennis, & Lee, 1997). They decode its linguistic and mathematical elements, they represent it in a form favourable to solving it, and they establish links between its elements (causes, places, impacts, obstacles), their previous knowledge, and other available information (Gregg, 1997).

Problem-solving Strategies

Various factors influence the students' ability to pose and solve a problem well: motivation, the feeling of self-efficacy, perseverance, ability to reason in depth, past experiences with similar problems, and enriched knowledge of the problem at hand. The student must also be able to use various *problem-solving strategies* throughout the process (Hayes, 1989). These strategies consist in different means employed by the individual to define and solve a complex problem, as is the case with environmental problems. They primarily include various visual representations: drawings, graphs, maps, tables, and so on. Green (1993) maintained that visual representations make it possible to enrich a problem visually, verbally (with words, sounds, phrases), numerically (with numbers to specify the extent or importance of the problem), sequentially (with representations of its development phases), conceptually (with symbols, theories, or analogies), and affectively (by expressing feelings and opinions relative to the situation). Cheng, Lowe, and Scaife (2001) also claimed that visual representations make it possible to take advantage of the paper space in order to improve the representation of the phenomena. Visual representations help relieve the memory and facilitate information sharing between solvers. In addition, according to Cox (1999), the construction of visual representations helps to increase learners' metacognitive speech by forcing them to consider several ways of conceiving the information. When they seek to visually represent a problem and when they share these representations with their peers, learners tend to engage in private speech (about how they approach and solve the problem) and to observe their own comprehension. Visual representations are used to visualize important elements of the problem (initial state), connections between these elements, actions to accomplish, possible limits to these actions, goals to reach, and the importance of the problem in one's life. Visual representations help students gradually build their internal representations of the connections between the elements of the problem and the approaches that are available to solve it (Stoyanova, 2000).

Other problem-solving strategies are also beneficial to good solvers: immediately testing possible solutions, working backwards (finding solutions to make the problem worse), repeatedly simplifying and reformulating the problem, dividing the problem in many small goals, working forwards and backwards, and so on (Horak, 1990; Wheatley, 1995). Several researchers (Goldberg, 1975; Kantowski, 1977; Kraus, 1982; Schoenfeld, 1983) found that teaching students these kinds of strategies improved their problem-solving skills. Knowledge and use of these strategies is however insufficient to turn students into excellent solvers (Hatfield, 1978; Lester, 1983). Other studies (Jensen, 1987; Thomas and Grows, 1984) revealed that students must also develop metacognitive skills, which means learning to observe and control their problem-solving process—among others, learning to choose the appropriate strategies to use and constantly evaluate their efficiency (Lorenzo, 2005; Sternberg, 1985).

Finding Original Solutions to Problems

Bauer, Heatherly, and Keller-Mathers (2003) defined creativity as a person's ability to create new, original, and useful products during the creative process. According to Starko (2005), two major characteristics can be attributed to creative products: novelty and relevance. Lubart (2003) considered that a product's novelty is expressed by its originality and its high level of unpredictability. The second characteristic consists in the *relevance* of a creative product or in its excellent adaptation to a context. Lubart explained this adaptation by saying that a creative product must satisfy different context-related constraints. This characteristic includes a cultural dimension to creativity, but also the value and usefulness of the creative product. If we apply this idea to EE, the solutions brought forth by the students while creatively solving environmental problems should be original, feasible, and agree with the community's cultural values. The following evaluation criteria can be beneficial to analyze the creativity of the students' ideas: *fluidity* (ability to produce several ideas), *flexibility* (ability to produce several categories of solutions), and *originality* (aptitude to generate ideas that are statistically rare).

Bauer, Heatherly, and Keller-Mathers (2003) and Sauvé (1997) found that creative problem solving could offer the necessary conditions to tackle complex problems, such as environmental problems. The classic problem-solving process is different from one that involves creativity. Classic problem-solving targets well-defined problems, whose solutions are relatively simple and often predetermined (Kim, 1990), whereas creative problem solving principally deals with situations that are either ambiguous or lack structure.

The Osborn-Parnes Model (Osborn, 1988) is an important model in *creative* problem solving. In this model, the solver experiences a process during which two phases are continuously alternating: the divergent and the convergent phases. The *divergent* phase consists in formulating several either hare-brained or realistic solutions, without any judgement limiting the production of ideas. In the *convergent* phase, ideas are evaluated, improved upon, and combined before becoming applicable. Since the birth of the Osborn-Parnes model, many strategies have been invented and successfully applied to help solvers propose a greater number of original ideas for complex problems that are lacking in structure. These strategies, which have been tested in the fields of industry or publicity but not yet in environmental education, can be categorized as follows: strategies aiming to create analogies or forced connections between elements of the problem and other elements (connected or not); strategies to widen the problem in order to find new solutions; strategies aiming to stimulate mental images (i.e., image streaming); strategies seeking to redefine or divide the goals of the problem (list of attributes); strategies in which the problem is modified by inversing it, multiplying it, etc. (SCAMPER); and strategies consisting in various organized and structured representations of elements of the problem (mind mapping).

State of Research in EE

To our knowledge, in environmental education, few researchers have described young people's ability to pose and solve environmental problems. Some research has tackled students' conceptions regarding less familiar problems (i.e. Pruneau, Langis, Richard, & Albert, 2003), but not the ability of students who have studied a problem and who were asked to solve it.

In science education, a field related to EE, research on solving scientific problems has mainly consisted in a comparison between the abilities of experts and novices. It would seem that experts manage to solve problems thanks to their broader knowledge of the field and because they take more time to analyze and pose the problem (Wilsson, 1995). Experts thus make more drawings and graphs of the problem, consider more carefully the qualitative details, establish more connections between the elements of the problem, connections that are more appropriate, and use analogies. Experts' knowledge has a better cognitive structure and is therefore easier to access for problem solving (Hauslein & Smith, 1994). In this way, it is easier for experts to discern missing information to solve a problem. Finally, their more developed metacognitive abilities enable them to plan and observe the way they approach a problem. Novices, for their part, also make drawings and graphs, but their representations are more incomplete and contain mistakes. These limits stem from their superficial knowledge of the field of the problem. Novices have a hard time bringing out the most important characteristics in a problem (Haulslein & Smith, 1994). They usually work forward (toward a solution) to solve the problem, whereas experts shift their attention forward and backwards, constantly testing their solutions, and considering more the goals of the problem's solution.

PHASE 1: HOW YOUNG CANADIANS POSE AN ENVIRONMENTAL PROBLEM

Canadian students in grades 3, 6, and 8 (ages 8, 11, and 13) were involved in solving a local environmental problem, over a period of three months (from October to December 2005). The class of grade 8 students studied, with the help of chemists, the impacts of pharmaceutical and personal hygiene products (PPHP) in a watershed. PPHP include medications, shampoos, perfumes, and toothpaste discharged into sewers when washing or using toilets. When septic tanks are worn-out, these substances seep into the river, where they have different impacts on water, fish, and shellfish. In this project, such products were found in small quantities in the watershed that was studied. The grade 3 students studied, with the help of biologists and a hydrologist, the impacts of sedimentation on animals in a river. Sedimentation consists of soil elements and plant debris moved from their original place by water and wind and dropped into a stream. Many human activities such as clearcutting and the use of ATVs may worsen it. Sedimentation also has negative impacts on fish and invertebrates. The grade 6 class worked on a traffic problem, a source of pollution, which is harmful to people's health and delays people when they are travelling.

In all three classes the students experienced the same participatory approach to study the problem: visit and general analysis of the state of the river or the city, followed by the choice of the problem. For grades 3 and 8, the sedimentation and PPPH problems were chosen by the scientists who participated in the project. The scientists were personally interested in these subjects and judged that these were important problems related to the river being studied. The grade 6 students chose the traffic problem themselves. Once the problem was identified, the students from all three classes analyzed it in depth. They observed it in the field, questioned, collected, and analyzed information to better understand it, and so on. Activities in the classroom and in the field were carried out by members of the research team. They lasted 50 minutes and were held once a week for a period of three months. The scientists involved in this project visited the students twice, either in the classroom and/or in the field. Their work consisted in collecting, with the students, scientific data on the problem, analysing them, and explaining the results to the students. For their part, the students also sought information on the problem and shared it with the scientists. Throughout the process, most of the problem elements were discussed (causes, impacts, etc.), except for the specific locations where the problem was found (in the case of sedimentation).

Research Methodology (Phase 1)

After this three-month process, in December 2005, students were asked to describe their problem and find solutions within the framework of a questionnaire and individual interviews. The main goal was to identify how the students posed their problem after having studied several aspects of it. All of the participating students answered a questionnaire that began with the task of representing their problem with either a drawing, a graph, words, or a table, according to their preference. Other questions asked them to summarize the problem in a sentence, to express their feelings with regard to the problem, and finally to propose and justify many solutions. Before filling in the questionnaire, students had not yet been asked to give solutions. In fact, because we wanted to observe how each pupil posed the problem and found solutions, we asked them to find solutions only after the three-month period spent exploring the problem. We wanted them to become familiar with the problem before beginning the process of suggesting solutions. After the questionnaire, the students did individual interviews during which they explained both their representation of the problem and their answers. We borrowed questions from Stoyanova (2000) for the interviews, such as: *What is the problem? What do you think of this problem? Is this problem interesting? In what way?*

The data of the questionnaire and interviews were subjected to a classic content analysis (Paillé & Muchielli, 2008) by three research team members. Berelson (1952; in Leech & Onwuegbuzie, 2008) defined classical content analysis as "objective, systematic, and quantitative description of the manifest content of communication" (p. 489). The researcher chunks and codes the data. However, instead of grouping the codes together, the researcher counts the frequency of use

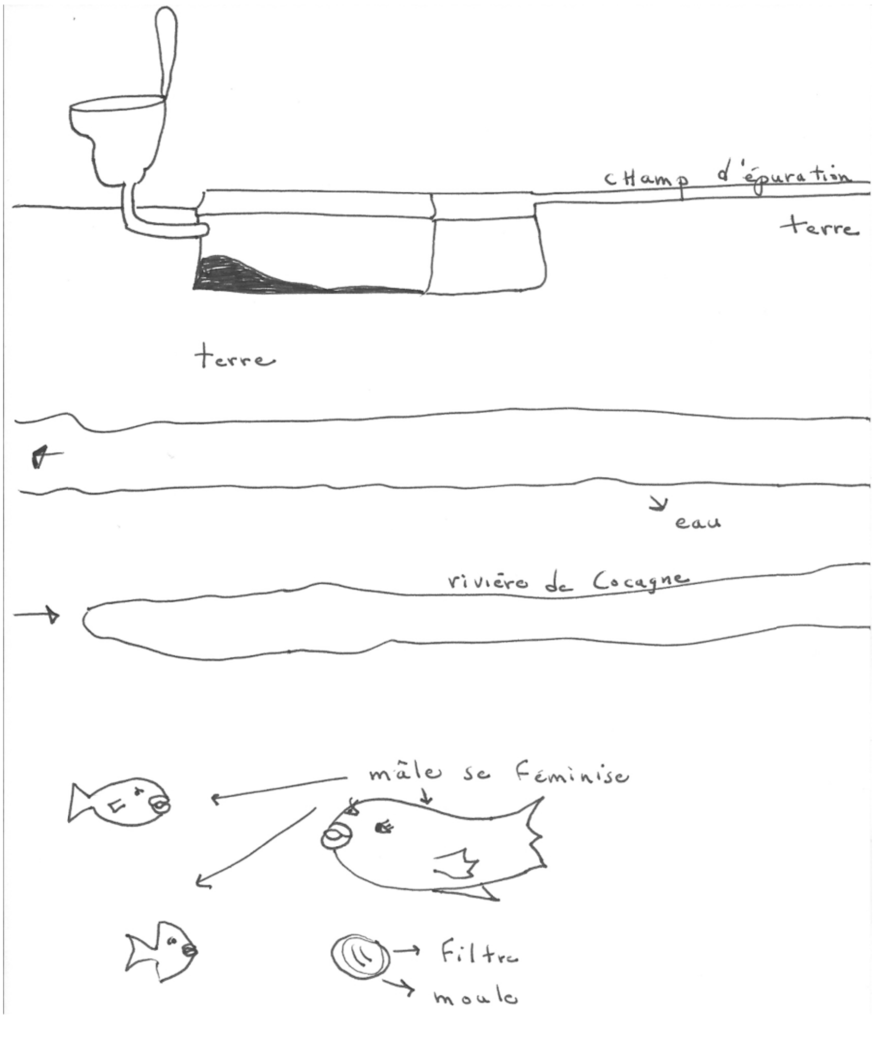

Figure 2. Example of a representation by drawing of the PPPH problem (grade 8 pupil)

for each code. After a first individual reading, the three researchers agreed to analyze the corpus from the following categories (some inspired from the theoretical framework and some emerging from the data): problem elements mentioned by students, types of external representations (visual, written, schematic), spontaneous conceptions regarding the problem, concerns about the problem, and types of solutions proposed. During the interviews, students' drawings were used as prompts and only their comments about their drawings were analyzed.

Phase 1 Results—What We Learned

Almost all of the young participants, no matter their age, illustrated their environmental problem with drawings or annotated drawings. Figure 2 gives an example of a visual representation by a grade 8 pupil who posed the problem of PPPH in the river.

These young learners' perceptions of posing and solving problems were unsurprisingly more like novice than expert problem solvers. Like novice problem solvers, these young people generally neglected to analyze the smaller details of the problem and their way of posing it was centred on the problem and its impacts rather than on the places, accountable stakeholders, desired situation, and obstacles to the action. The impacts of the problem and particularly the impacts on humans seemed to touch them personally, which may explain their tendency to consider impacts more than other elements of the problem. Table 2 shows, for example, the elements of the traffic problem considered by grade 6 students. In Table 2, the students' tendency to particularly look at the traffic impacts is manifest.

Table 2. Problem elements considered by grade 6 students (after studying the traffic for three months)

Elements of the problem considered	*Number of students (n = 26)*
Nature of the problem: too many cars	13
Time: rush hours	6
General impact: destroys nature and pollutes	21
Impact: gas emissions	18
Impact: respiratory problems (cough, asthma, allergies)	12
Impact: bad feelings, like stress, bad mood, tiredness, impatience, and boredom	9
Impact: accidents	5
Impact: long wait	4
Impact: noise	3
Stakeholders: people who drive instead of walking	9
General places: at the lights, downtown, near stores, near my home	17
Specific places: streets	5
Cause: lack of roads to exit the city	4
Cause: people don't know the impacts	2

Young people were also rather skilled in creating networks of cause and effect, which illustrates their ability to visualize the impacts of environmental problems. They identified a source or a cause of a problem, explained how it was expressed, and finished with the impacts. Thus, a grade 8 student wrote:

> Pharmaceutical products can end up in the sea if you put them in the trash, in the toilet, in the sink. It can affect animals which live in the sea (fish, mussels). It can affect them because mussels filter water. If there is waste in

> the water, they keep it in their body. It can make them sick and we can eat them.

The relationship chains generated by young people were, however, limited because it is difficult for one student to consider all of the elements of such a complex problem.

In addition, after three months, a minority of the students had retained or built non-scientific conceptions about the problem, conceptions that hindered the quality of the proposed solutions. For example, for five of the grade 8 students (n=20), pills thrown in sewers remain as they are, can be seen floating in the river, and are eaten by fish and mussels. For four grade 3 students (n=19), sedimentation is caused by boats that move water and for six other students from the same group it consists in waste thrown in the water.

The solutions put forth by grade 3, 6, and 8 students were occasionally adequate, but sometimes they were less plausible, particularly when they were tinged with their less scientific conceptions. Here are several solutions to the sedimentation problem proposed by 3rd graders:

> Not to allow ATVs into the water, stop mowing the lawn too short near the river, keep boats from stirring up the river bottom, etc.

Notice that the last solution of the list is influenced by students' spontaneous conception that boats produce sedimentation by stirring the water while boating. In this same list, we also notice that the solutions proposed by the students are not original and are very normative: not to do this, to prevent a cause. The solutions do not directly involve students in environmental actions. For them, other people aside from themselves have to stop doing this or that. It is also important to note that the students had not had the chance to ponder on solutions long, since it was the first time that they were asked to propose any.

Finally, the motivation to be involved in problem solving depended on whether students were directly affected by the problem or not (students themselves or animals they care for) and on their locus of control, internal or external, which refers to their personal feeling of being able to make a difference. At the beginning, it was difficult to convince the young people in the participating classes that people of their age could actually get involved and manage to improve a situation.

Thoughts after Phase 1

After obtaining these results, we pondered the following questions: *Did the participating students pose their problem in the best possible way? Could they be empowered to find better solutions?* We wondered whether learners this young could be taught to be more expert problem solvers? Could we teach them problem-solving strategies and even if we did would they be able to implement these strategies to solve environmental problems in their own communities? Could they see themselves as having solutions to environmental problems?

To our knowledge, in environmental literature, no rules dictate at what time the solver has finished posing an environmental problem in order to solve it properly. Does the solver need to bring out all the elements of the problem? Do we have to emphasize the causes to prevent the problem from happening again? Should we aim to reduce the impacts? Should we define the goals of problem solving? We believe that all these aspects are important. In the case of students, they cannot necessarily act on all aspects of the problem. For example, grade 3 students could work on a cause like educating ATV drivers who send sediments in the river when going through it. As well, they could work on the problem itself, by replanting riverbanks to limit the sedimentation that gets into the river. It seems like students should pose the problem in the most complete way possible in order to have several options they can use to improve the situation. In the same way, choosing specific goals for problem solving is essential to us in order to set attainable goals. Do we want to reduce the amount of sediment already in the river? Do we rather want to reduce the sediments brought into the river by farm animals? The analysis of the problem's social factors (community's socio-economic situation, ways of life, citizen needs, etc.) also seemed important to conduct if we want to establish sustainable solutions. We feel that in a systemic approach to problems, linking the different elements of a problem is also important.

For Phase 2 of the project, we identified specific problem-solving strategies we felt learners at this age level could grasp and implement. We expanded the study to include learners from three countries: Canada, Romania, and Colombia.

PHASE 2: TEACHING STUDENTS PROBLEM-SOLVING STRATEGIES

From the Phase 1 results, we chose an educational project that would help students better analyze and pose an environmental problem. We chose to teach students certain problem-solving strategies as well as the systematic inclusion of activities that encouraged students to share between them their way of posing the problem. The Canadian and Colombian researchers used visual representation tools with the students. The Romanian researcher used the same tools but added other strategies: surfing the Internet, finding solutions proposed by others, observing the problem in the field, speaking of the problem with a family member. We thought that these educational tools would allow students to perfect their representation of the problem, to correct their less scientific concepts, and to propose more effective and maybe more original solutions. We posed the following research questions: *After applying visual and other problem-solving strategies and sharing their definition of the problem with their peers, did the students improve the way they posed an environmental problem? In the same context, did the students' solutions evolve into applicable, effective, and original ideas?*

Phase 2: Experiment in Canada

In Canada, Phase 2 of the research was carried out with the same grade 3 students regarding the problem of sedimentation. As you will recall, students aged 8 and 9 had been asked, for three months (from October to December 2005) to explore, analyze, and pose this problem, as well as find solutions to it. They had expressed their way of solving the sedimentation problem and their first solutions within the framework of a questionnaire and individual interviews. From January 2006, the students used several visual representation tools to enable them to refine and complete their way of posing the sedimentation problem: build a model, design schematic drawings and posters, and write texts. Students were also asked to routinely share their way of posing problems with their peers and another class. Finally, they regularly worked in teams to find solutions.

In June 2006, after using methods of representation and sharing, students were asked to answer the same questionnaire and participate in the same interviews that they had accomplished in December 2005 during Phase 1 of the research. We sought to observe if their way of posing a problem and finding solutions had evolved. The same data analysis methods were also used by the same researchers (see the detailed methods and results in Pruneau, Freiman, Barbier, & Langis, 2009).

As you will recall, at the end of Phase 1, in December 2005, the students had mainly represented the sedimentation problem with drawings or annotated drawings. At the end of Phase 2, in June 2006, they were still using annotated drawings to pose the problem. However, in June, their drawings and comments on them were more complete, schematic, and analytical. Please note the example in Figure 3, in which the drawer presented more details regarding the problem and included more causes of sedimentation.

Figure 3. Representation of the sedimentation problem by a grade 3 student in December (left) and June (right)

Table 3. Elements of the sedimentation problem considered by the students (December 2005 and June 2006)

Elements of the problem considered by the students	*December (n = 20)*	*June (n = 20)*
Nature of the problem: soil, sand, or rocks that get into the river	12	19
Causes: transportation used in the river (ATV, tractors, heavy equipment)	17	19
Natural causes: rain, wind, snow, etc.	13	16
Causes: clear cutting, cutting vegetation near the water	9	17
Cause: stirring the water (human or livestock feet, boating)*	9	2
Cause: road construction near water	0	13
Cause: gardens near the river	0	6
Cause: livestock access to the river	0	9
Place: everywhere in the watershed	18	19
General impact (non-specified) on the fish	1	6
Impact on the sight of fish	10	10
Impact: death of fish	8	7
Impact on fish food and habitat	3	3
Impact on fish eggs	2	2
Impact on fish gills	2	3
Impact on the colour of water	4	3
Impacts on humans: disease, mussel contamination	2	5

* This cause corresponds to a non-scientific conception of sedimentation.

Table 3 shows the problem elements considered by grade 3 students at two data collection points: December 2005 and June 2006. It is possible to note that in June the students took into consideration a greater number of causes and that these were more realistic. Thus, the number of students who falsely believed that sedimentation was caused by the feet of either humans or livestock stirring the water had largely decreased. We note little change in the nature and number of impacts considered by the students.

Finally, in Table 3, we observe that certain elements of the problem were no longer considered by the students. These missing elements could nevertheless turn out to be crucial to solving the problem: specific places where one finds sedimentation, quantity of sediments in different sites, stakeholders responsible for its presence, and the obstacles that could limit actions leading to improving the situation.

As for solutions mentioned by students, their number increased. In December, the students had essentially mentioned four solutions: avoid driving ATVs in the river, stop mowing the lawn near the water, avoid clearcutting, and keep livestock from walking in the water. In June, the same solutions reappeared. However, 21 new solutions were added: stop building along the river, avoid using heavy equipment, do not expose the soil, write newspaper articles, plant trees along the river, put up educational panels, speak to people, etc. Thus, in December their solutions were mainly normative, but in June the students generated more proactive and more feasible solutions by themselves: make posters, educate people, etc.

Phase 2: Experiment in Romania

The assignment given in Sibiu, Romania was also carried out with grade 3 students (22 students, aged 8-10). The problem studied by the students dealt with the domestic waste that littered the ground in many places throughout the streets of the city. One of the causes of the problem was the privatization of domestic waste management services. In fact, the most disadvantaged citizens did not have enough money to pay for domestic waste pick up. Therefore, they would throw it in the streets, on the sidewalks, and in the parks.

During summer 2006, educational activities were organized. Prepared according to a socio-constructivist paradigm, these activities allowed students to experience the problem-solving process: identify it, pose it, formulate solutions, evaluate solutions, choose one, and apply it. A Romanian teacher led 10 interventions that lasted two hours each, from September to December 2006, with the supervision of a researcher. During the first activity, the Romanian students were asked to examine their surroundings while on a city field trip, when they were challenged to solve an environmental problem of their choice. They opted for the reduction of waste thrown on the ground by citizens. At this stage, in order to supply the students with problem-solving tools, 18 pictograms were presented to them, each representing a problem-solving strategy: navigate the Internet or look at books, draw and write about the problem, observe it in the field, see pictures of the problem in your head, talk about it to a family member or to a pet, take pictures of it, draw conceptual maps, pose the problem in one or two sentences (repeat this many times), look for numbers about the problem, underline aspects of the problem in your journal, get informed about the solutions used by others, play the roles of the people involved in the problem, don't think about it for a while and come back to it later, interview someone (see Figure 4). The students were asked to use these strategies to better pose and solve the problem. Each time they used one, they had to stick the matching pictogram in their reflective journal.

Students were then invited to explore many elements of the problem. They were asked to classify the waste collected during their city visit according to its nature and origin. Three educational activities enabled them to explore the impacts of waste: the multiplication of infectious bacteria and the contamination of groundwater and its consequences on the health and security of humans and domestic and wild animals. Next, two activities led to identifying the stakeholders accountable for this problem: first, collecting their own waste for one week and, second, role-playing the many citizens in their city. During this second part of the project, in order to improve the students' ability to solve problems, two visual representation strategies were applied. This first consisted in building and presenting a model that illustrated several elements of the problem. The second consisted in reading success stories in which students of the same age had managed to improve a situation involving a local environmental problem. At the end of the project, the students kept, in their list of solutions, those that were feasible by students their age. In addition, they finally chose a solution that they actually implemented as a classroom group: write a letter to the mayor to request that money be given to a local waste recycle/reuse project.

Figure 4. Pictograms representing problem-solving strategies that were given to the students

As in Canada, the research part of the project first consisted in identifying how the students posed their problem and examining their solutions. For this purpose, new research questions were formulated: *Does the use of problem-solving strategies (visual representation and 18 others) enable students to pose their problem completely and to find solutions that are effective and original? Do the students use these strategies and are they conscious of their usefulness?* To answer these questions, data was collected in different ways: participant observation, students' reflective journal, questionnaire, and individual interviews. The on-site researcher documented his own observations in a journal. Students had a reflective journal in which they wrote at the end of each activity what they thought of the problem and their solutions. They could also write down their feelings and insert pictograms that matched the heuristics that they employed during the activity or after school. We also administered a questionnaire with open-ended questions and individual semi-structured interviews twice: before and after using visual representation strategies (before activity #7 and activity #9). Triangulation of the data collection tools brought up interesting information while also confirming the credibility of this qualitative research.

Narratives (Berthaux, 2003) were used to reduce the data from the students' reflective journals as well as the questionnaires and interviews. Three researchers built together narratives describing the behaviours of this group throughout the course of educational activities. The narrative grid included the following elements: the students' feelings towards the waste problem, the problem elements considered by the students, the problem-solving strategies that the students claimed to have used, as well as the reasons they did so, and the solutions put forth.

First, we observed in the results (see Pruneau, Freiman, & Therrien, 2006) that the way students posed the waste problem at the end of each assignment was closely linked to the theme of the activity experienced. The students had a tendency to represent the problem by emphasizing the element or elements of the problem that were discussed during the activity that came before the moment they wrote in their reflective journal. However, the predominant element that attracted the students' attention was impacts, mainly the impacts affecting human health.

As a result of the students participating in the series of learning strategies, their thinking/focus shifted from seeing the problem as an aesthetic issue to that of a stakeholder issue. In Table 4, we describe the connection between the theme of the educational activity experienced and the problem elements mentioned by the students in their reflective journals. At the beginning of this process (activities #1 to #4), the students' attention is mainly captured by the problem's sanitary and aesthetic impacts. These elements really affected them. They claimed to be surprised to discover that waste was so present around them and that they had such dangerous consequences for living organisms. Next (activities #5, #6, and #9), they questioned and focused on the causes relative to the presence of waste. The impacts nevertheless showed up again in their journal (activities #7 and #8) when they were asked to spontaneously represent the problem in a model in order to talk about it to students in another classroom. At the end of the process (activities #9

Table 4. Problem elements considered by the students during the various educational activities

Themes of the educational activities (presented according to the chronological order in which the approach was experienced)	*Elements principally considered by the students when posing the problem*
1. Visit a city alley	– Aesthetic impact of waste on the city
2. Presence of micro-organisms in waste	– Impact on the health of living organisms – Spatial scope of the problem
3. Impact on drinking water	– Sanitary impact in specific places
4. Impact on animals	– Impact on the health of living organisms
5. Role-playing	– Human causes of the problem
6. Collection of their own waste	– Personal contribution to the problem (they are one of its causes) – Mathematical data linked to the problem
7. Build a model	– Various impacts caused by the problem
8. Present model	– Various impacts caused by the problem
9. Success stories	– Spatial scope of the problem – Stakeholders involved in solving the problem
10. Choice of a solution	– Possibility of students to contribute themselves to solving the problem

and #10), the students were more interested in the stakeholders and in formulating the solutions.

All along the project, students formulated in teams various solutions to the waste problem. Table 5 presents the types of solutions that stood out the most in each educational activity and provides examples. It is important to note that during activities #1 and #10 the students were never asked to propose solutions to the problem. This explains the dash in the cells corresponding with these activities.

In Table 5, we note the presence of three types of solutions formulated by the students: normative, adaptive, and preventive. The normative type refers to a solution in which a rule is stated: *we must*, *it is forbidden to* or *it is compulsory to*. This type of solution does not make use of the person making the assertion. The *others* are the ones who must be responsible for solving the problem. The adaptive type refers to actions that seek to reduce the problem's impact: act only when the problem becomes apparent. The preventive type refers to the mitigation of the problem's impact before it happens. It is possible to observe in the students' progress that the normative solutions, very present at the beginning, are taken less into consideration toward the end, when the students explore the causes of the problem. This change can be interpreted as follows: after studying the causes, the students became conscious of the origins of the problem and decided to act on this element by proposing preventive solutions. As for the adaptive solutions, they were present throughout the problem-solving process. In Table 5, we finally note that the solutions put forth by the students were adequate, but did not stand out with originality.

Table 5. Types of solutions proposed by the students after each educational activity

Themes of the educational activities (presented according to the chronological order in which the approach was experienced)	*Types of solutions*	*Examples*
1. Visit a city alley	–	–
2. Presence of micro-organisms in waste	Normative Adaptive	– *We must* throw waste in the trash – Pick up waste
3. Impact on drinking water	Normative	– *We must* stop throwing waste on the ground
	Preventive	– Educate the population regarding the problem with posters
4. Impact on animals	Normative	– *We must* keep animals and children from going into dumps
	Preventive	– Educate the population regarding the problem via the newspapers
5. Role-playing	Preventive	– Establish rules that citizens will follow, along with penalties
	Adaptive	– Burn the waste
6. Personal waste collection	Preventive	– Make recycling bins available to citizens
7. Build a model	Adaptive	– Treat people who have been infected by waste
8. Present model	Normative Preventive	– *We must* throw waste in the trash – Inform people
9. Success stories	Preventive	– Talk about the problem on the radio or on television
10. Choice of a solution	–	–

Results show that several students used the problem-solving strategies that the teachers taught them. Some students even used strategies that had not been discussed in class. Table 6 shows the number and percentage of students who used the strategies presented as well as new ones they invented.

During interviews, the students explained that they had used the heuristics presented for various reasons: to improve their understanding of the problem and learn more about it, to remember the important elements, to describe correctly the problem, to find solutions, to find inspiration to generate novel ideas, to find pictures of the problem in order to better imagine it, etc.

Phase 2: Experiment in Colombia

The project in Colombia took place in Medellin, in a marginalized urban area called *La Divisa*, a poor neighbourhood. Medellin is the second largest city in the country with a population of three million inhabitants. A group of 26 students participated in this project: 12 girls and 14 boys, ages 13 to 18 (average age = 15). These young people were in grades 7, 8, 9, and 10, but most of them were in grade

Table 6. Use of problem-solving strategies by Romanian students (n=22)

Strategies proposed by the teacher	*Number of students who claim to have used them (n = 22)*	*Rounded percentage (%)*
Illustrate the problem with a drawing	20	91
Write to better understand the problem	19	86
Make a play out of the problem	18	82
Talk about the problem to someone	18	82
Observe the problem in the field	17	77
Make mental images of the problem	15	68
New Strategies		
Contemplate the results or the problem with or without acting on it	3	14
Get informed on the history of the situation	1	5
Do a project on the problem	1	5
Organize a round table discussion, inviting friends to share their opinion regarding the problem	1	5
Observe the problem with other people	1	5
Show pictures of the problem to other people	1	5

9 (42 percent). This was a heterogeneous group with regards to age. However, they shared a common interest in community and social involvement: most of them were already participating in other groups (disaster prevention, first aid, etc.).

When choosing an environmental problem, the group hesitated between neighbour conflicts and waste management. The group finally chose to work on the latter. This problem consists in the presence of solid waste that accumulates in certain streets and alleys causing unpleasant smells and giving the neighbourhood a negative reputation. Garbage collection occurred twice a week, but many inhabitants did not respect the instructions regarding trash disposal. The places designated for garbage disposal lacked maintenance and domestic animals often ripped and emptied trash bags. In addition, certain truck drivers and bus drivers were accused of particularly harmful practices when they washed their vehicles on public roads or discharged waste in places that were not designated for it.

The educational activities took place between April and October 2007. The lead researcher and a teacher met with these young people once a week for a total of 20 sessions. Since the school did not have appropriate rooms, the meetings took place at the University of Antioquia. The project began with group discussions on the notions of *problem* and *environment*. This made it possible to select common objectives despite the fact that the members of the group presented large differences in age and knowledge. The activity leaders proposed a process in which the group had to take on the role of researchers. Their first task was to explain the problem and pose the research question (pose the problem). They emphasized the importance of this task to the young people. They told the group that only when the problem would be correctly identified would they be able to move on to formulating solutions. These young people went on an exploratory field trip in the streets and alleys of the neighbourhood and were asked to note certain elements. They were asked to observe a) the problem's location, b) the problem components, and c) the people who were affected.

The researchers noticed that the young people had several difficulties expressing the problem and the data collected during their field exploration. For this reason, it was deemed necessary to give them a series of workshops to present some strategies that would help them approach the problem. These strategies included: a) elaborating diagrams, b) designing conceptual maps, c) breaking down the problem, d) picking out the principal ideas in a text, and so on. These activities were carried out using a play-oriented approach, concerning a real environmental problem. It is important to note that, as secondary level students, several of these skills should already have been part of their cognitive tools. However, given that the project was conducted with a lower socio-economic group, several of these skills were missing.

At the end of the project, the researchers organized a workshop with a sanitation engineer, who showed them the basic principles of integrated waste management and recycling. This workshop brought up interesting comments and questions from the young people with regards to the waste problem in their neighbourhood.

In October 2007, the researchers held a meeting to gather data on the way the students posed the waste problem. They asked the students to represent the problem either with a text, a diagram, a drawing, a conceptual map, or a combination of these. After this, individual 10-minute interviews were conducted to check the content and their comprehension of the problem. The representations of the problem as well as the answers and explanations given during the interviews were later subjected to a content analysis.

Once the content analysis was carried out, a final work session was held, during which the researchers discussed and validated the results of their analysis with the group. This made it possible to notice that the categories, in which the different representations of the problem had been placed, corresponded adequately with the students' perception.

Most of the young people (58 percent) chose to pose the problem by using a text, whereas 36 percent of them used a drawing, a diagram or a drawing with a written explanation. Only eight percent of them chose a conceptual map to pose the problem. Table 7 shows the means of representation chosen by the students.

The researchers noted that, on the one hand, most of those who favoured the text as a means to pose the problem confused the problem with the solution. On the other hand, those who preferred using drawings, diagram, or conceptual maps showed a better synthesis of the research problem. Figure 5 illustrates this observation.

Table 7. Means used by the students to pose the problem (n = 26)

Means used	*Participants*
Text	15 (58%)
Drawing	3 (12%)
Drawing + text	3 (12%)
Diagram	3 (12%)
Conceptual map	2 (8%)
Total	**26**

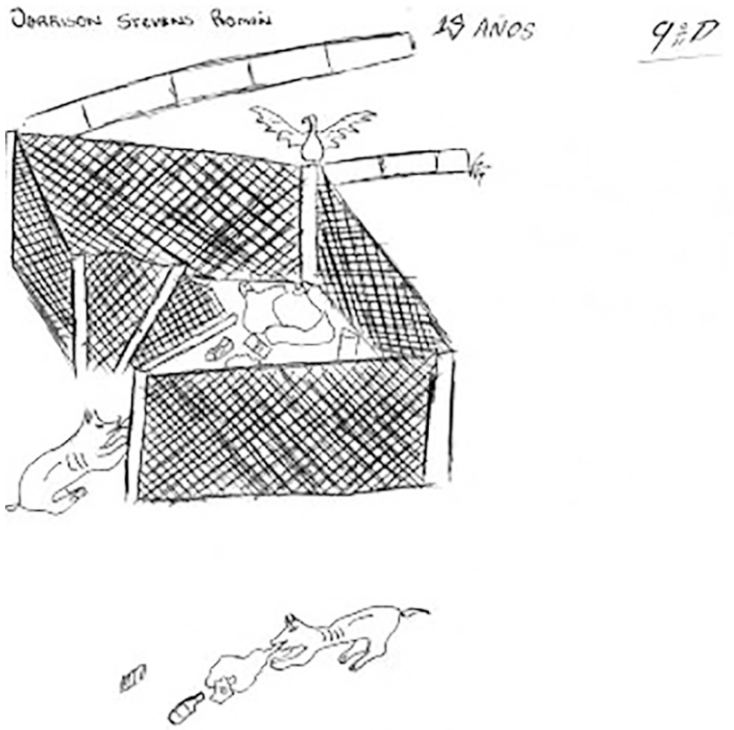

Figure 5. Example of a drawing that represents the waste problem (grade 9 pupil)

The content analysis made it possible to group together the students' explanations of the problem in the following six principal categories: lack of civic spirit and involvement by the population in waste management, lack of information and/or education to adequately manage waste, poor dump site management, conflicts between neighbours, inadequate disposal of garbage, either within households or by other stakeholders, and finally, lack of intervention by local authorities (see Table 8).

Table 8. Students' explanation of the problem and frequency (n = 26)

Categories	*Frequency*
Civic spirit/belonging/community involvement	7
Lack of information and/or education	2
Dump site management	3
Inadequate waste management within households or by other stakeholders	12
Conflicts between neighbours	1
Interventions by authorities	1

Civic spirit refers to a behaviour people have toward garbage management—notably certain undesirable behaviours like throwing waste in inappropriate places (public spaces, streets, alleys, parks, etc.)—and to a person's feeling of belonging to a community. Civic spirit would promote a greater involvement in the community to counter the waste problem. Lack of information and education refers to a lack of knowledge about the effects that incorrect disposal of waste and a poorly developed recycling culture can have on people's health and the environment. Dump site management refers to the inadequate infrastructures for garbage disposal and keeping it out of reach of domestic animals. Conflict between neighbours was mentioned as a cause of contamination, because the owners of domestic animals (cows, pigs, dogs, etc.) may neglect their animals while they are in conflict with their neighbours. Finally, lack of intervention by authorities refers to the lack of investment in material and human resources to counter the waste problem in the neighbourhood.

The most mentioned category was the bad management of waste within households. This mainly refers to taking the trash out on the wrong day, not sorting/recycling at home, and lack of concern when disposing of garbage at the dump. We note that the students posed the problem mainly according to the causes and stakeholders involved, whether individuals, community, authorities, or people from outside.

The researchers also observed a tendency to include the solution (desired situation) when presenting the problem. In addition, the causal relation in the presentation of the problem was less present than expected. It was observed particularly among the young people who used a diagram to pose their problem.

During the presentation of the results from the questionnaire, a lively interest emerged regarding the causes of the problem. The students asked many questions: Why do people throw waste in the streets? Why don't they take out the trash according to the established schedule? Why don't authorities intervene more? These questions were interpreted as future avenues to explore more in depth in order to complete the problem's portrait.

At this point, it is necessary to note that, in Colombia, the questionnaire regarding how students posed their problem was only conducted once the experiment was over. Because of this, the researchers did not have results to compare how the perception and the manner of posing the problem had evolved through time.

The researchers detected several difficulties in the students' analysis capacity, notably concerning the development of skills in using graphic means (diagrams, conceptual maps, problem tree, etc.). They observed that the students who used graphic means (drawing, diagram, and conceptual map) managed to generate a better synthesis of the problem. However, it is important to note that the work was accomplished in a lower socio-economic school where several of the skills were missing.

In addition, the researchers mentioned that these youths formed a very dynamic group whose members were involved in the whole process. They were greatly motivated by the fact that the activity was presented to them as a research project in which they would act like researchers. The students felt concerned by the problem and saw themselves as agents of change.

Thoughts after Phase 2

Our results suggest that young learners across all three countries developed more complex ways of posing problems and finding solutions as a result of being introduced to problem solving strategies. The results obtained from the students aged eight and nine (in Canada and in Romania), as well as from the secondary level students (in Colombia), show the potential of using problem-solving strategies in the classroom, particularly visual representation strategies. The students involved in Phase 2 of the research project definitively posed their problem in a more in-depth and detailed manner than those in Phase 1. These results coincide with those of Cheng, Lowe, and Scaife (2001) and of Green (1993). These authors noticed the relevance and effectiveness of using visual representation strategies in fields other than the environment. The results from Romania also show that young people, motivated to solve a problem, could apply the problem-solving strategies that they were offered.

Despite the students' becoming better problem solvers, we were struck that the kinds of solutions they proposed lacked originality. That is they did not offer solutions beyond those they heard from other adults or sources of information. As a result, we proposed a third phase in which we would introduce students to creative problem-solving strategies to see if this kind of strategy would help them develop their own solutions. The solutions proposed by students in Phase 2, although adequate, nevertheless showed little originality. For this reason, work in our model's *solution space* (see Figure 1) seemed necessary to us.

PHASE 3: USING CREATIVITY STRATEGIES WITH THE STUDENTS (CANADA ONLY)

The last research project, an exploratory one, took place with grade 3 students in Cocagne (ages eight and nine), in Canada. It again concerned problem solving by young people regarding sedimentation in a river. One of the research objectives, however, was new. The idea was to check, with an exploratory approach, if the concomitant use of visual representation strategies and creativity strategies would encourage students to find novel, effective, and creative solutions to the problem being studied. In this way, the use of educational creativity strategies was the innovative element in this final phase of the study.

We organized seven exploration activities with the sedimentation problem in fall 2006, followed by 11 problem-solving activities from January to June 2007. It is during these 11 final activities that visual representation and creativity strategies were used and that the data collection was undertaken. During the familiarization activities, the students were invited to visit the river, to identify the sedimentation problem, and to predict the consequences of the problem on the animal species living in rivers. After this familiarization, in activity #1, the instructor discussed the natural and human causes of sedimentation with the students. The students drew or brought a picture of a place in their community where sedimentation can be found and they proposed solutions to the problem. In activity #2, the instructor worked with the students to sum up what they knew about sedimentation in order to identify the elements that they wanted to represent in a model. The students then presented their model to grade 2 students and finally proposed other solutions. In activity #3, the instructor showed two pictures of a river (a healthy one and one filled with sediments). The students then had the opportunity to observe the sediments in the river and to propose solutions. In activity #4, scientists did a presentation on the sedimentation causes and its effects on fish. The students again wrote solutions. In activity #5, the students individually answered a questionnaire. Then, they participated in an individual interview to communicate their way of posing the sedimentation problem and their solutions. In activity #6, two older students—now in grade 4—came to talk about their experience from the previous year and about the environmental actions they had themselves accomplished to improve the sedimentation situation. The students managed to read other success stories in teams and wrote other solutions. It is in activity #7 that creativity strategies began to be applied.

The instructor explained to the students the relevance of using creativity strategies when trying to find new ideas. She explained the *Why? Why? Why?* strategy that consists in expressing the problem in a sentence and looking for a series of causes for each of the elements involved. She told the students that they would be finding original and hare-brained solutions to the sedimentation problem. She explained to them that even if at first the solutions seemed impossible to apply, they would be later transformed into excellent solutions. The following sentence was written on the board: *All-terrain vehicles (ATVs) cross the river and bring soil into the water.* In teams, the students responded to these four (4) questions on self-adhesive stickers: *Why do people use ATVs? Why do people cross the river in*

ATVs? Why does the soil go into the water? Why do ATVs go into the water? Next, they added another *Why?* to each of their responses and so on for a total of three whys per statement. Still in teams, the students shared the solutions they found on their own. In activity #8, another creativity strategy was used: the instructor wrote the word *sedimentation* on the board, repeatedly, by using various forms of letters. The students thought about other ways of writing the word by writing it on a sheet of paper.

At the same time, they had to think of words, sentences, forms, pictures, feelings, people, causes, and impacts related to the sedimentation problem. The instructor then showed all of the solutions brought forth by the students since the beginning of the project (127). The students were invited to think up new solutions in teams, by combining or improving on individual solutions to formulate other solutions. In activity #9, the instructor placed all of the solutions in a basket and a student chose one that he (or she) wrote on the board. Based on the following questions, the class discussed each solution that was drawn to modify and clarify it: *What does this solution mean exactly? How can this solution be beneficial?* The students answered the following questions in teams: *Do we have to modify it (which means add, take away, or replace something) so that it can become feasible? If so, how can we transform it? How can we write it so that it is more accurate and feasible?* In activity #10, the instructor presented all of the solutions found by the students. She had assembled the solutions into categories. She read the solutions in each category and the students evaluated each solution with stickers to indicate if the solution qualified at two levels: *originality* and *feasibility*.

Four solutions emerged from this process. At this point, the instructor invited the scientists to discuss the potential of the final four solutions. They suggested modifications to make some solutions even more feasible. The students voted by placing two stickers beside the two solutions they preferred. They discussed the process to follow to accomplish an action in relation to the chosen solution. Finally, in activity #11, a questionnaire was administered. The students answered the questions individually and then participated in individual interviews.

Research Methodology

The students' solutions, gathered through the questionnaire, interviews, reflective journal (completed after each activity), and the researcher's journal were subjected to a content analysis by two members of the research team. Two criteria contributed to determining if the students' ideas were original: *fluidity* (capacity to produce many ideas) and *originality* (aptitude to generate ideas that are statistically rare while still being effective).

Phase 3: Results

Introducing creative problem-solving strategies to these young learners along with the visual and peer sharing strategies was an overwhelming success. We noted a significant increase in the number of solutions put forth by the students from the moment creativity strategies were introduced in activity #7. Furthermore, 36 different solutions were found by the students during the questionnaire and the interview in activity #11. Here are some examples of original solutions proposed by these young people and that emerged during the use of creativity strategies: *create artificial ponds and invite ATV drivers to go through these instead of the river, prepare an educational DVD and ask the president of the ATV Club to promote it among the drivers in the Club, create stickers that can be placed on all-terrain vehicles and distribute them among the drivers who want to display themselves as protectors of nature.*

OVERALL RESULTS

In the research project experienced in Canada, Romania, and in Colombia, we wanted to describe young people's capacity to pose environmental problems and to find solutions. We then wanted to find ways of empowering these young people to pose problems as completely as possible and to propose original and effective solutions. Although the various phases of the project were carried out in culturally and socio-economically different settings, as well as with youth in two age categories, they enabled us to conclude that young people, like young experts, can learn to analyze and pose an environmental problem according to several aspects, despite its complexity. However, the process takes time and effort on their part.

The visual representation tools and other problem-solving strategies used were very useful. In the beginning, the students reacted more emotionally to the problem they were confronted with and, trying to sort out what was going on, they mostly considered its impacts, notably the impacts on humans. Older students (in Colombia) seemed more inclined to think about the causes of the problem. By using visual representation strategies (drawings, conceptual maps, models, etc.) with the students, they became more conscious of their own way of posing the problem and of the different way their peers accomplished the same task. They then tended to widen their representation of the problem, shifted their thinking to the larger picture, saw the problem from multiple perspectives, and many corrected their less scientific conceptions. In addition, it seemed possible to give students a number of strategies to improve their observation, analysis, and problem-solving skills. Romanian students in a large majority used strategies that had been presented to them. Finally, the use of creativity strategies seemed to encourage students to formulate novel and original solutions that were adapted to their environment.

If we come back to our team's problem-solving model (see Figure 1), we note that during the first phase of this research project the students had the opportunity to work in the problem space (field trip, exploration, study of the context, problem integration). Analysis of the data collected at the end of this phase revealed that the Canadian students had a rather limited representation of the problem and that a very small number of solutions were put forth. This observation was not dependent on the students' age (grades 3, 6, and 8) or the problem studied (sedimentation, traffic, and chemical products). This result motivated the team to propose problem representation strategies to the students in order to widen their cognitive and metacognitive capacities, with the emphasis always placed on the problem space in Figure 1. This was experimented with in Canada (grade 3, sedimentation) and in Romania (grade 3, waste problem). In Romania, the students' process was also supported by the use of cognitive and metacognitive strategies (metacognitive space in our model, including personal reflection, transfer of the process, and personification). The results showed more flexibility among young people who found a greater number of different solutions. However, the solutions still lacked in originality and were often normative. This is why the team decided to introduce creativity strategies, thus starting to work in the solutions space of the model in Figure 1 (analysis, creation of solutions, evaluation of choices). With the grade 3 Canadians, activities on sedimentation led to an array of more original solutions. We would, nevertheless, need to verify this final conclusion within the framework of a quasi-experimental research, which uses a control group. There is a very large number of creativity strategies used in the business world and in publicity. It will be important to experiment with many creativity strategies and check which work best with each age group and environmental problem. The team has yet to make the students work in the action space of the model (planning, implementation, and evaluation). Another part of our model that will have to be studied is the *empowerment* component of the problem-solving process. How could we convince students that they can successfully bring their own expertise in solving local problems? Working in the action space with students, looking for activities that could empower youth, choosing the right problems for the students' age, and trying new creativity strategies should be part of a research agenda to better understand environmental problem solving with students.

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TOOLS THAT HELP STUDENTS POSE AND SOLVE ENVIRONMENTAL PROBLEMS

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INFORMAL LEARNING AND THE PROBLEM OF DISENGAGEMENT IN SCIENCE

A Small Success Story

In 2005, the Canadian Natural Sciences and Engineering Research Council (NSERC) launched a pilot program on research toward improving science education in Canada. NSERC funding allowed the creation of five regionally based research collaborations across the country. The CRYSTAL collaboration located in Atlantic Canada, CRYSTAL Atlantique, took as its research theme the enhancing of the "culture of science, mathematics, and technology" across the Atlantic provinces. As a further focus for its research, it elected to concentrate on informal science education. As we will argue below, the connection between "the culture of science" and the notion of "informal science education" is a close and important one.

This chapter reports the results of participant-research carried out by one CRYSTAL Atlantique research team headed by one of the authors (Sullenger) in connection with an informal (out-of-school) activity program initiated by her team called Science in Action. Those results are used as a platform from which to discuss larger questions of informal science education, its advantages and disadvantages in comparison to formal school science, and its connection to issues of the public understanding of science. We begin with an overview of current research on informal science education and its relationship to the question of student engagement.

RESEARCH ON INFORMAL SCIENCE EDUCATION

The concept of "informal education" is defined rather loosely in the research literature today. In its most elastic usage, the concept can embrace most forms of acculturation, in which children (or adults) acquire understanding from parents, peers, and the media, as well as from any community institutions and organizations other than schools. Normally, however, the term "informal education" is used in the literature more narrowly to mean organized programs with a quasi-educational purpose that are aimed at young people and exist to supplement formal schooling (Dierking et al., 2003; Osborne & Dillon, 2007). The kinds of informal education extensively studied in the educational literature thus include extra-curricular enrichment programs, apprenticeship and mentoring plans, out-of-school educational programs targeting minorities and at-risk youth, and skills-based

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activity programs (bands, interest clubs, sports activities) that have at least an implicit educational purpose. Particularly in the American educational literature, such "outside-of-school-time" and "afterschool" programs have received much attention lately, in part because of the large public investment that has been made in such programs (Canadian Council on Learning, 2007; Katz, 2001; Martin, 2004; Vadeboncoeur, 2006). Clearly the dichotomy between formal and informal is not a sharp one.

Studies of informal *science* education have covered programs of similar types. Recent contributions to the literature have examined as examples of informal science education the project of a cub scout troop to model erupting volcanos out of baking soda, red food colouring, and vinegar; urban gardening programs for inner-city youth; a university ornithology laboratory's outreach program to involve local bird-watchers in data collection and observing; and an enrichment program of laboratory exercises offered to local high school students by university staff in university laboratories (Renninger, 2007). As this small sample might suggest, university outreach programs in science have attracted much research attention, extending to programs that offer young people apprenticeship experiences on actual research teams. Children's experience in science museums and science centres is also considered an important component of informal science education, and a substantial research literature has grown up around these institutions, their activities, strategies, and objectives, and attempts to measure their impact on visitors (Bettlestone, 1999).

Basic assumptions about informal science education are that participation is more voluntary than in the formal school setting, that learners are freer to set their own goals and level of commitment to the activity, and that the activity is ungraded and hence less stressful than school science. Informal science education often identifies its main objective as promoting enjoyment in science, and hence motivation to continue science learning; in formal science education these goals are usually considered secondary to those of transmitting information or instilling mastery (Melber, 2006; Pedretti, 2006). Because many types of informal science education are experience-based and (sometimes) allow participants to formulate and pursue their own lines of inquiry, they are sometimes lauded as exposing learners to an experience closer to "authentic science" than school science can provide.

Research on informal science learning has been accused of being overly descriptive and often atheoretical (Vadeboncoeur, 2006). Efforts to assess its efficacy in promoting interest and motivation, changing attitudes about science, or altering concepts about the nature of science usually rest on participants' self-evaluation and are open to criticism on that basis. The voluntary nature of informal science education activities also leads to problems of selection bias, which complicates the task of measuring its efficacy in promoting formal achievement. An additional problem with the research is that there seem to be few efforts to compare learning in informal and classroom contexts (Osborne & Dillon, 2007), or to discuss how the formal and informal sectors might co-operate and supplement each other (Stocklmayer et al., 2010).

SCIENCE EDUCATION AND DISENGAGEMENT

The promise of informal science education for many educators has lain in its alleged potential to provide what classroom science normally cannot: a more inquiry- and problem-based approach, an experience closer to that of authentic science, or a context in which enjoyment, interest, and hence appreciation of science and motivation to continue its study both in and out of the classroom would be enhanced (Braund & Reiss, 2006). Today, the need for informal science education, and its profile as a research theme in education studies, may stand on the threshold of an explosive increase in importance. That enhanced importance will emerge as one inevitable product of educators' growing awareness of what we here call the "disengagement problem" in school science education.

Experienced teachers have long been aware that between the age of eight and 16 significant numbers of students pass from a state of enthusiasm and engagement with the study of school science to a state of indifference or dislike for the subject. During the last decade, a growing body of research literature on students' attitudes about school science has begun to show the serious dimensions of this problem, as well as its global reach. The most significant international contribution to research on the disengagement problem has been Project ROSE, which has surveyed and compared the responses of 15-year-old boys and girls in 25 countries concerning their interest in science, their trust in science, their views of school science, and their future career hopes (Schreiner & Sjøberg, 2004; Sjøberg & Schreiner, 2007). When ROSE participants were asked how they liked their school science in comparison to other subjects, there was a 0.92 *negative* correlation between their responses and United Nations comparative national Human Development Index. In short, the more advanced and prosperous a country is, the less its young people are drawn to the study of science, and the less they are inclined to trust and value science. International comparative data, combined with research on the public understanding of science, has also called into question the conventional, tacit assumption that interest and positive attitudes necessarily correlate highly with levels of achievement and factual understanding. Trends in International Mathematics and Science Study (TIMSS) data reveals that at the level of nation-by-nation achievement, degree of achievement is *negatively* correlated with positive attitudes toward school science. Interest in school science and achievement in school science may correlate in local, peer-based studies, but they do not do so at high-level aggregations across national borders, a finding that should be of great significance for the literature on national science indicators (Bolstad & Hipkins, 2008; Canadian Youth Science Monitor, 2010; Murphy et al., 2006; Taconis & Kessels, 2009). This research literature is not without problems; the ROSE data does not trace the change in students' attitudes over time, and other studies that clearly demonstrate declining levels of interest in and engagement with school science over the middle-school years typically do not compare changing attitudes toward science with attitudes toward other subjects. Nevertheless, the research suggests that the disengagement problem is significant in nearly all industrial and post-industrial countries. Students' basic attitudes about science and their personal expectations (or non-expectations) of science-related careers are set very early and are unlikely to be changed later (Osborne & Dillon, 2008; Turner, 2008). The crucial, limiting age seems to be 14, a result clearly indicating the need to refocus attention on the reform of science teaching away from high school, into the early and middle years.

These results, which are only now making their impact felt upon the international science education community, are in one sense not surprising. The decline of interest and engagement with school science during the middle school years, and its inverse correlation with national affluence, closely mirrors results obtained in studies carried out on the (adult) public understanding of science around the world (Bauer, 2007; Millar, 1996; Turner, 2008). That fact suggests that the disengagement problem is a facet of a larger cultural phenomenon that lies beyond science education itself. But the ROSE data also reveal that students in all countries express more positive attitudes and interest toward science in general than toward school science. That finding not only suggests that school science is currently doing little to reverse students' widespread disengagement from science, but also that formal science education may be aggravating the disengagement problem. Asked about what they dislike about school science in comparison to other subjects, students complain about its perceived irrelevance, repetitiveness, fragmentation, and authoritarianism.

Critical educators allege other problems with formal science education. Elementary schools, they charge, devote too little time and too little depth of coverage to science topics. Curriculum approaches at the elementary level typically confound components and attributes of science with pedagogical strategies and approaches (Millar & Osborne, 1998; Osborne & Dillon, 2008) Thus, "hands-on" learning activities are routinely equated to inquiry-learning, and inquiry-learning is conflated with science inquiry (Anderson, 2002); children (and teachers) are encouraged to believe that science is everywhere and everyone is a scientist; and classroom practice assumes that any kind of study of natural objects and natural processes is tantamount to "doing science." Of course, these approaches are intended to promote student interest and confidence and make science accessible to children (and to their teachers). In practice, critics charge, these pedagogical approaches communicate an image of science that is idealized and largely mythical, and they create the sense that science is play.

According to critical educators, the unrealistic expectations about school science created in elementary school set the stage for disillusionment and disengagement as students progress into middle school. There, students encounter more difficult curriculum materials and concepts; schools have less time and fewer resources to devote to "hands-on" activities; and teachers may have insufficient science background to enable them to deal confidently with increasingly complex material. Middle school curriculum programs are frequently disjointed and dislocated from students' home or community environment. Curriculum design typically reflects fundamental indecision about the actual purposes for which science is being taught, especially about whether school science at this level is primarily propaedeutic to preparing students for the study of more advanced science, or is taught for its intrinsic importance in life- or citizenship-training, skills development, or cultural enhancement. By high school, and the end of compulsory science, all these factors, combined with signals from the larger culture of media and peers, have often led to an estrangement from school science on the part of many students. It has led to the polarization, widely reported in the literature, between students who "like science" and intend to study it further, those who "dislike science" and are eager to abandon it, and those who, regardless of their level of interest, will pursue advanced science mainly for career reasons and as a result of parental and peer pressure. The stress placed on promoting positive attitudes toward science in "official" documents like the Pan-Canadian Protocol suggests the reality of the disengagement problem, while research results on students' attitudes suggests formal science education has few effective strategies for dealing with it (Canadian Youth Science Monitor, 2010; Jenkins & Nelson, 2005; Murphy & Beggs, 2003; Pan-Canadian Framework, 2007; Papanastasiou & Papanastasiou, 2004).

We predict that the problems faced by formal science education with respect to students' attitudes and engagement will increasingly occupy educators' attention in the coming decade. We also believe that the disengagement problem will pose issues and opportunities for informal science education as well as set a research agenda. To what extent can educators reasonably expect organized programs for informal science education to remedy the problems of formal approaches with respect to interest and motivation? Can the impact and efficacy of informal programs be reliably measured and assessed? Can informal programs communicate authentic understandings of the nature of science and the nature of scientific work, while remaining enjoyable and interesting enough to retain students' participation and interest?

SCIENCE IN ACTION

From our previous collaborations, we were well aware of these questions, of the disengagement problem in general, and of the challenges that face the design of informal science education programs (e.g., Turner & Sullenger, 1999). With the launch of CRYSTAL Atlantique, one of us (Sullenger) set out to implement a program of informal science education in the province of New Brunswick that would address the problem and test our conceptions of how such a program should be designed.

Science in Action consists of two afterschool programs designed to offer upper elementary and middle school students an understanding of science and science learning alternative to that offered in their formal classrooms. We chose upper elementary and middle school levels because of the dramatic decrease in science interest and attitudes among learners from elementary to middle school and continuing through high school—the "disengagement problem" analyzed in the previous section. The program was based on several specific beliefs about the kind of science understanding students require and the most effective pedagogical practices for introducing those understandings. One of those beliefs was that learners at both these levels are capable of learning and understanding much more than was expected in the current school curriculum. However, we did not know the limits of that "much more."

The guiding principles of Science in Action sprang from our belief that science is an enterprise or culture; it is that thing that scientists do, and so "science" is inextricable from the personal and social role of the "scientist" (Perkins-Gough, 2007). This principle marks a radical departure from many assumptions common in the educational literature. It implies that science is not everywhere and people in general are not scientists—students in school are not scientists. The farmer deciding which fertilizer to use on her field is not "doing science" nor is the chef who is trying to figure out which ingredient to substitute for another. It allows the concept that science is a way of thinking but it does not imply that all thinking, critical, deductive, inductive, or otherwise, is science. So, we argue that as students of science, participants of Science in Action needed to understand scientists, their work, the world in which they work, the kinds of skills they need, and, to a lesser extent, what they learn about the world as a result of their work (what we traditionally refer to as content knowledge). Participants should also understand who else is interested in knowing about scientists and their ideas and how they use that information. For these reasons, we included science educators from community-based science organizations and research scientists to be part of the research team and/or to work with the two programs.

As noted earlier, we believe that many science education researchers confound the work of scientists with pedagogical practices—for example, by suggesting that students are doing science because they are doing "hands-on" activities. It is generally believed using "hands-on" activities is undeniably an important pedagogical practice because students will remember and understand ideas better if they are involved in it themselves as opposed to reading about it or watching someone else do it; but to equate pedagogical activities with science is to set the stage for confusion and disillusionment later. Science and pedagogical practices are also confounded in the recent attempts to merge science-teaching with other disciplines, e.g., science and language arts or mathematics or social studies. In almost every case, the science in these curriculum documents is defined by the topic of study, e.g., trees, forests, space, weather, pollution, or even chemicals, and not by method, technique, or the role of scientists themselves. For example, classroom discussions of pollution as a scientific problem disguise the political dimensions of the pollution problem, a problem to which science and scientists merely make a contribution. This topic approach and the tactic of "making something science" teaches the implicit lesson that science owns the world and anyone talking about the physical or conceptual aspects of the earth or universe is doing science.

In addition to believing that students are under-challenged, we designed Science in Action in light of our belief that there are barriers to understanding science that can make it seem nonsensical and/or make learners believe science is too difficult for them to understand. Before children enter school, they construct descriptions of the world around them that may be different from the descriptions scientists use. Using interviews and observing children solving problems, researchers from a number of countries have developed an extensive literature on the kinds of explanations children develop about their world (e.g. Driver, 1994; Pfundt & Duit, 1994). Those findings make one thing seem clear: even young children are likely to hold on tenaciously to their own explanations about the world despite what they are told in school. Unless students are faced with experiences that challenge their conceptions, they are unlikely to change their models of how things work or accept alternative explanations/descriptions as useful or important (Suping, 2003).

We designed Science in Action in accordance with the belief that students learn science best when they are presented with learning experiences that engage them intellectually, are relevant to their world, and are within their capabilities—that is, that they have the background necessary to study. We also believe that students will remember what they learned more easily if the ideas are connected—cohesive and coherent—and if they grapple with these ideas over a long period of time, much longer than allowed in schools. Furthermore, Science in Action was designed on the belief that students of all ages are social beings who learn best from interacting with others and acting as mentors who teach and/or help others learn new things.

Finally, the Science in Action programs were scaffolded such that ideas, concepts, and skills were presented in a series of gradually more complex experiences. Throughout the year participants completed a series of challenges sent to them by the research team. One of the challenges was a project to be presented at the end-of-the-year event attended by participants from all the schools. We believe that informal science learning can and should incorporate assessment. Our assessment in this program takes the form of expectations and the ability to understand and complete more complex tasks or activities. Moreover, the projects students undertake are not separated into learning or assessment tasks as is the case with school-based instruction. We expected being able to present to peers from other schools and invited guests would be a more compelling a reason to "know what you are talking about" than grades. We believed being able to participate in increasingly complex activities and mentoring others would be a challenge most would find engaging.

Starting from these guiding principles about science and learning about science, we developed two afterschool programs—"Whooo Club" for upper elementary and "EcoAction" for middle school. In designing the two informal science programs, we wanted to know whether upper elementary and middle school students would develop more complex understandings of science if we:

- Engaged them in studies of phenomena scientists study over a long period of time—three years;
- Juxtaposed scientists' ideas and ways of doing science with their own ideas and ways of working;
- Distinguished between the skills needed by scientists and themselves or others who are not scientists, e.g., classifying, record keeping, sampling, observation, or team building;
- Had them interact with scientists, as experts, and others with strong interests in science;

– Allowed them an opportunity to recognize and explain contributions of/role of scientists' ideas in solving everyday and/or locally important problems—explain what they can do because they understand scientists' ideas and methods of working.

Would students participating in these afterschool programs use these guidelines to develop more complex understandings of scientists' work, of their ideas, and of being a scientist? Could these two programs realize the promise of informal science education while avoiding the pitfalls? Could they demonstrate the capacity of informal programs to mitigate if not eliminate the problem of disengagement?

Whooo Club—Upper Elementary Level

The Whooo Club encourages students to develop the investigation skills scientists' use. The theme of the Whooo Club is studying what scientists want to know and learn about animals which they study in a three-year cycle. Year One focuses on animal parts and their functions, especially "bugs." Year Two is focused on animal habitats and what they need to survive, while Year Three looks at life cycles and understanding relationships among animal species using food chains and webs. The role of the scientist as doer and knower is continuously emphasized as much or more than science or science-content itself.

For example, we selected bugs to study because scientists classify and think about insects differently than non-scientists. This discrepancy provided a good way to introduce young learners to the idea that scientists have more experiences than they do and have come to different understandings. To emphasize the skills scientists use, we began with classifying objects like balls and buttons and juxtaposed those with the scientists' classification of bugs. This distinction was to open the way to understanding scientists as having special interests, ways of working, and expertise. There are so many aspects of insects to study that we were able to introduce them to a wide range of scientists and their work.

Other skills students are introduced to include: making observations; how scientists tell one kind of object from another through their properties; how they work in teams; and how they communicate with others what they learned from their studies. We also want students to develop an understanding that scientists are good record keepers. To be a scientist you must keep field notes, sketches, lab drawings, tables, plans, meeting notes, and lab notes, as well as more formal reports and articles. We want to reinforce their writing skills and mathematics skills. Throughout we emphasize scientists as persons and professionals, whose skills and understandings students could emulate and participate in.

Finally, we believe students learn from one another better than from the teacher at times. We want to build multi-age teams so through the years they can teach new students and get them involved in the activities more quickly. We also want them to realize that in science people join and leave teams and that people of different ages and experiences work together. Our aim was to anticipate and defend against the notion of science as forbidding, impersonal, and abstract, a concept to which students become increasingly susceptible at the Whooo Club stage.

EcoAction—Middle Level

The EcoAction program is designed to build on the skills and understandings developed in the Whooo Club and allow students to work with various scientists. The EcoAction theme is studying the critical zone of an approximately one-half square kilometre piece of land (called the EcoAction Research Zone or EARZ) in their community. In Year One students study the plant life within the critical zone; in Year Two the soils, geology, and hydrology of their EARZ; and finally in Year Three the atmosphere and surface water of the critical zone. In addition to enhancing the research and investigation skills developed in the Whooo Club, EcoAction participants focus on the skill of sampling. We chose sampling as a key skill because almost every area of science study is too vast or complex or changing to do an actual count. Learning how various scientists sample and what they do with the data they collect helps create a foundation for more advanced study, and encourages thought about matters of representativeness and evidence.

At the EcoAction level of study, students continue to work in multi-aged groups but are also given responsibility for planning, data collection and analysis, and reporting their findings. Each year they work with different scientists to learn what scientists study and are interested in about the critical zone and how they collect data. An online wiki allows students in the middle schools to keep records and make their work accessible to students in the other schools. We wanted to know if ongoing, informal science activities and research projects embedded in students' own communities were available, will they become and stay involved throughout their schooling? At the end of each year, students from all the Whooo Clubs and EcoAction groups get together to meet one another and share what they learned. Whooo Clubs meet at the Whooo Club Jamboree held at one of the schools and EcoAction meets at the local university for the EcoAction summit. Also, at the end of the year, the graduating Whooo Club members are invited to attend a meeting with the EcoAction team.

The Participants

The implementation-research team consists of 26 educators from six elementary and middle schools, one school district, two community-based science organizations, a community college, and the regional university. Some members of the team chose to focus on the development and implementation aspect of the project and others on the research aspect as well. The teacher-advisors who participate in the project are some of the busiest in their schools. Only four have a science background but all joined because they believe students should have more opportunities to study science.

Participants of EcoAction come from three middle schools and Whooo Club from their three feeder elementary schools. The three sets of schools (Elementary-Middle) draw students from different kinds of communities. Two are located in a small city but one draws from a low income area and the other from a moderate income area. The other set of schools draws students from a small town but some students are bused from an even smaller village where a science research station is located.

The Whooo Clubs had to set limits at 25 students after a first year of trying to cope with 35 to 60 plus in one elementary school. EcoAction numbers have been increasing each year with each club averaging 15 students in the final year of the program. One thing we have learned is that in middle school, students in all the schools have a wide range of afterschool programs available.

Data Collection

Data for this paper comes from revisiting earlier interviews we conducted with members of the team from the beginning of the collaboration and from interviews conducted throughout the past winter and spring, asking specifically how these participants compared the Whooo Club or EcoAction experience with learning in their school classroom. We also asked what impact the program had had on their classroom learning. Finally, we asked parents if they had noticed whether participating had had any impact.

The data were analyzed using a constant comparison approach until categories across data sources were identified and threads tracked. Each of the data sets was coded individually and then cross compared to identify categories of similarities and differences. Some categories emerged more strongly and became the basis for claims and in some cases tentative themes. New questions emerged from the data which led to new rounds of interviews and data collection. For example, in asking what impact participating had on learning in their science classes, we learned that students shared what they learned with friends and their families as well. This led us to develop a survey for the parents.

STUDENTS ENGAGED IN SCIENCE LEARNING

As noted above, the problem of student disengagement from school science is emerging as the central, global problem of science education. We wanted to know how programs of informal science education, designed on the assumptions of Science in Action, would affect levels of engagement. We looked at engagement through the comments of participants, parents, and teachers in a number of ways but found that those yielding the most insight were those about Science in Action compared to science class, interest in science, whether there were any changes as a result of participating, and about changes in students' understandings of scientists or doing science.

Whooo Club and EcoAction in Relation to School Science Classes

We asked both elementary school students attending Whooo Club and middle school students attending EcoAction to tell us what it was like to participate through questions like why they joined or rejoined, would they recommend others join, and what they would say if someone from another school asked if the program was a good way to learn science. Embedded in their responses were references to their science classes and frequent statements that they preferred both Whooo Club and EcoAction to their science classes. Intrigued by their comments, we asked directly through a survey and follow-up interviews with both groups whether they liked Whooo Club or EcoAction better than science class and to please explain their response. We also asked whether participating in these programs helped them in science class.

Overwhelmingly, participants in both programs said they preferred Whooo Club or EcoAction better than science class. There were a few in Whooo Club who either liked both the same or preferred science class. In EcoAction none preferred science class to EcoAction though some indicated they preferred EcoAction only a little more. The reasons for those in Whooo Club who preferred science class were two-fold: they liked the teacher or the kinds of activities like projects and field trips they did in the science class. Some who said they were the same said they like studying the different topics in each as one student's comments reflect: "I like to learn what we are studying in both." Some of the middle school students said they do activities and work in groups in their science class but mentioned they have more time to put into the projects and group work in EcoAction.

Students' critical comments about their formal science classrooms mirrored all the problems widely reported in the educational literature. Participants of Whooo Club said the main differences between Whooo Club and science class were, first, in Whooo Club, "we do better stuff"; second, science class is "too much writing without doing"; third, more time to work on things; and last, "we get to work with other people on projects." By "we get to do better stuff," students talked about all the different kinds of things they did in Whooo Club, "not just studying books or writing things down." They said things like, "we get to do more activities," "more projects," and "do a bunch of research." Getting to do better stuff also entailed getting to go more places and interact with other people. For example, students told us they liked "going to different schools and meeting with others" and "meeting people outside in the community or going to bug fair and we have to do our projects." One student said, "In science class we learn the same things over and over." Others mentioned studying different kinds of things than in science class like "bugs and where things live."

When participants talked about "too much writing without doing," they said for the most part "Science class isn't fun. Whooo Club is. We get to do activities." Another participant told us, "In science class they show us things; in Whooo Club we get to do them." However, one student's comment summed up the general feeling when he told us Whooo Club is "more activities, more to learn, just more fun, more challenging—that's what makes it more fun." "In science class you do fun stuff but you know it doesn't matter cause it's not like your grade," a student lamented.

The greatest difference they pointed out was the opportunity to spend more time studying a topic. One child told us they "teach it shorter than what Whooo Club teaches it" and another's comment captured the overall sentiment when she said, "You have more time to research the project, and you don't go quick and put stuff down and move on." The last difference mentioned by these elementary school students was the opportunity to work with others in groups. For some working in groups and with others was an important part of learning as this student's comment attests, "everybody works together in Whooo Club." Being able to work with partners and meeting new people seems an important component of learning for those students who mentioned working with others as a difference. For example, a club member mentioned you "get to work in groups in science class but in Whooo Club you get more time."

Three of the four reasons EcoAction participants told us they like it more than science class were similar to those of the Whooo Club participants—"always doing something fun," "get to do a lot more," and "get to go places." The fourth reason, though mentioned by only one student, was so striking we believe it could reflect the experiences of others. This student told us, "I'm failing in science class and don't really understand it. It's easier to do EcoAction in English than French like in science class." There are a number of students in middle school who participate in the French Immersion program; teachers had mentioned a number of times students told them they liked EcoAction better than science class because they could speak in English.

We conclude that informal science-learning programs like Science in Action are rich in potential to enhance students' enjoyment and engagement. However, we were aware from the larger literature that "always doing something fun" might not mean true learning, if "fun" meant merely "entertainment." However, these students' comments suggest they saw EcoAction as fun in two ways. One way was incidents that happened on the way to learning like coming across a dead deer carcass while out researching on their EARZ or socializing with others as they work on projects—"it's more fun and makes learning easier." The second way science was fun was because it was challenging—"EcoAction is always doing something fun like studying soil, working on presentations, and stuff like that" or "we play games but are still learning."

EcoAction participants told us about how much more they were able to do in this program compared to science class. "Science class in school we sit with a textbook reading the Smartboard," "We have more freedom than a set curriculum like in school," "We don't do experiments in science class." Being able to meet scientists and talk to them was mentioned by a number of students as something they were not able to do in science class. Like the elementary students in Whooo Club, these students liked that they were able to go places, especially outdoors with their EARZ. One student told us they didn't get time outside in science class and another that the field trips was one thing they thought was a good way to learn.

Being more active, that is active involvement in challenging activities, was central to both elementary and middle school students preferring the Science in Action programs. Both noted that programs were more fun but the fun was about doing projects, working with others, going places, and the shared interest. Being engaged in science talk and having more time to work on the activities, especially for the elementary school students, were also key to their liking the Science in Action programs more than science class.

How Interested Are These Students in Science?

Research on informal education programs has been criticized for over-reliance on self-reporting by participants. To meet this criticism in part, we asked parents to tell us about their child's interest in science and the changes in their children due to participation in Science in Action. The parents of Whooo Club participants all described their children as very interested in science. The lowest level of interest chosen was seven on a 10-point scale. These parents described their children's interest in various ways, such as "keen interest," "curious interest—always making potions," and simply, "very interested in science." There were a number of parents who wrote that their child's interest increased as a result of participating. One parent wrote, "Has become more interested. Whooo Club really sparked an interest." Another wrote their child's interest "had been a 4 before but was now an 8." For most of the Whooo Club parents their child's interest in science was linked to an interest in nature or in particular animals. Some parents, however, linked interest in Whooo Club to an interest in learning which was expressed as an interest in exploring, experimenting, reading, and knowing about things.

The range of EcoAction parents' descriptions of their children's interest was much broader with a lower interest level of five and a high of 10. We interpret the wider range of reported interest levels as reflecting the onset of disengagement from science study, a typical phenomenon of the age range. Nevertheless, all but a few middle school students were described as having higher level interest. Most of the EcoAction students were described by their parents as interested in science but a number attributed their interest to "wanting to learn" or to an interest in the program itself. Almost all of the parents wrote about their child's long term interest in science: "always liked science" or "loves science." Some followed with comments such as, "they like some topics better than others" or "in particular engineering and chemistry," but the sense was that most of these students liked science and chose to participate because of an existing interest in science. Some parents also pointed out that their child liked a number of other subjects as well.

For those who linked science interest to the EcoAction program itself, a couple of parents indicated "their child did not like science class so much." Finally, the parents who linked science interest to personal interests wrote things like "she loves learning," "watches a lot of science on TV," and "likes science but likes to learn more." Though one parent did write, "hasn't seen the right topic to interest her yet." These reports mirror those in the larger research literature that middle school students typically like "science" better than formal school science.

Were There Any Changes as a Result of Participating?

Parents, teachers, and students all told us about the kinds of changes they noticed as a result of participating in Science in Action. The reports from the three groups of informants were similar, though a number of the changes students told us about were not noted by the parents or teachers.

Whooo Club as a place of change. We asked Whooo Club members to tell us whether they noticed any changes in themselves as a result of participating. They told us about being less scared, being more interested in science, doing better in science class, and talking to their friends and family about what they were learning. Many children are afraid of bugs and some animals in general as are many adults. Some of these children told us they were "not scared of bugs as much," "careful not to go right ahead and kill spiders," and "not as gross—not as scared." They were willing to "explore more, study more, observe more." This sense of feeling less afraid and willingness to explore more resulted in students being more interested in science and animals. "Science is more interesting now. I never knew so many different kinds of bugs," one student told us. Students also told us that this increased interest led them to share what they were learning with friends and parents. Some of the Whooo Club members said they showed bugs to friends and looked at bugs at home. One person told us his father used to tease him about bugs at home but now he wasn't afraid. These self reports point to new attitudes of curiosity, tolerance, and confidence—all essential to maintaining and expanding students' engagement with science and the natural world it studies.

But the change most students told us about was that they were doing better in science class. They told us about being better listeners in science class, raising their hands to answer questions, and "being smarter." One student told us, "I know more things in science class, before I wasn't that smart." Others said things like, "I changed mentally—thinking more"; "I answer more questions in class"; "I get more questions right and I ask questions I don't know the answers to"; and "I learn more stuff than other classmates." Part of this knowing more was a confidence to raise their hands more often and help other students organize their notes. There is a sense among many of these students that "science is easier" and they are doing better in science class than before. This student's comment captured that sense of increased understanding: "I like science more now; it is more than names and words."

Students, parents, and teacher-facilitators talked about personal changes and changes in students' attitudes towards and understanding of science. Chief among the personal changes were self-confidence, leadership, and learning skills. While most of these elementary students and their parents and teachers noted some increase in understanding of science, their increased interest in wanting to study science and liking science was most evident. Every student we asked said participating in Whooo Club increased their interest in science, with about half saying they had liked science already but liked it more now and another half telling us they did not like science at first but do now. "I almost lost interest in school but now I really like it again." This sense of losing interest or finding science boring was strong among some students. It was even more evident among middle school EcoAction participants.

EcoAction as a Place of Change. Members of EcoAction reported three kinds of changes which were similar to those reported by their Whooo Club counterparts: "liking science more," "doing better in science class," and "sharing what they learned with family and friends." Overtones of disengagement were present in the reports, but they were limited. The one difference between EcoAction and Whooo Club responses was that a few older students reported no change and of those who did report changes a few indicated small rather than big changes. Those who indicated small changes said they liked science before and this experience just increased their interest, though two did say they didn't like science before. Those members who said "no change" told us they liked science already.

One student told us, "I already liked science. I learned more stuff like what a scientist does." This comment is representative of the views expressed by these participants in describing what had changed. Another often-mentioned sentiment was being "less bored and more interested." Students told us they "pay more attention in science class" and that participating had helped with science class—one student also told us it helped with art class as well. Students told us about meeting new people, especially scientists. A couple of students mentioned the leadership skills they had developed by being in the program more than one year. More of the students told us about going home and sharing what they had learned with their parents and friends. For example, one student commented, "We go for walks in the woods with family and I can tell them stuff."

When we asked why the increased liking of science, students told us that being able to explore outside, the program was not as boring, and "didn't know much about it, now I know more." However, as with their elementary school counterparts, the sense of formal science class as mostly boring continues for most of these middle school students.

To compensate for the problem of self-reporting, we asked parents and teachers to tell us if they saw changes in the Whooo Club and EcoAction members as a result of participating. Both parents and teachers pointed to similar kinds of changes, though for parents these changes were more evidenced at home and for teachers evidenced in school. Both teachers and parents talked about the participants as being more committed. For example parents told us their children made sure they came and looked forward to the meetings, for some more than science class. Teachers talked about students just attending all the meetings and wanting to come. Both groups also described participants as having increased curiosity and interest in science. This increased interest took the form of talking about science more and asking more questions both at home and in school, of watching more science shows on TV at home, and tying in science ideas from class with the program at school. This general liking of science was also expressed by teachers as the program having "instilled a love of science" and students "getting more excited about science."

Parents and teachers talked about how much more the participants knew about science, especially their interest in researching and studying science. Parents made comments like, "She is more tentative while working, taking her time on projects," "Willing to research to find answers," "More interested in discovering how things interact," and "more interest in and involvement in science activities." Learning skills was another area in which both groups noted improvement. Parents, especially in Whooo Club, talked about students wanting to research more and working on Whooo Club projects when they did not want to do other things for school. Some EcoAction parents wrote that their children were doing better at science, and getting good marks. One parent noted improved grades in science, though this parent also wrote "not sure EcoAction was the reason." Teachers pointed out improved thinking, asking more questions, improved research skills, and vocabulary development.

While both teachers and parents noted improved awareness and understandings of science, both groups also noted personal changes in the participants beyond learning science. They talked about participants becoming more confident and more social. At home, this confidence was noted by Whooo Club parents as being more aware of things around them, of other afterschool groups, and more willing to join other groups. One parent talked about their daughter as being less shy and more involved. Another talked about their child as being "a good team player" and noted the group activities as responsible. For EcoAction parents, the change was about being more sure of themselves, "more outgoing as a result of having worked with groups and new people," and being more outgoing socially. For teachers, the personal changes were increased confidence to answer questions, participate in science class and a willingness to help others. One teacher noted the number of students who were willing and able to help students who were having more trouble understanding the science ideas in class. Teachers talked about students showing more leadership skills and showing more commitment to science class.

More Whooo Club parents noted changes than EcoAction though there were only a handful in EcoAction who said there were no changes. EcoAction parents noted their children were more interested in being outdoors while Whooo Club parents noted their children were more aware of the environment around them and animals. Both groups of parents noted more self-confidence, more social skills, more interest in knowing about science, more involvement in studying science, and more curiousity and knowledge about science.

Changes in Participants' Understandings of Science and Scientists

The guiding principle of Science in Action, as already discussed, is presenting science as an important if somewhat specialized activity of real persons—scientists—with whom students can be encouraged to identify. The application of this principle, however, differed in the two informal programs. From the outset we did not put as much emphasis on working with scientists or the culture of science with the Whooo Club. Our emphasis in that program was talking about the kinds of things scientists wanted to know and how they talk about things, the language they use, and discussing how it is different from the way we talk about these things every day. It was not surprising then that the kinds of changes we saw in the Whooo Club members' thinking about and understanding of science were not as substantial as those of middle school students in EcoAction, who worked directly with scientists. That said, even these young elementary level learners were sure they had learned something.

We asked the Whooo Club participants on a scale from "never" to "all the time," "Are there things you learned that help you understand science better?" The majority marked “all the time” though some said “sometimes” and a few said “never.” Those who said never told us they “didn’t learn the same things in science class,” “people worked on different stuff I didn’t get to see,” and “not enough help from the teacher, you had to do it by yourself.” Further probing did not reveal more insight but these shortcomings of the program—at least to these students—seemed to make them feel they had learned nothing.

Those who told us “sometimes” still described a number of things they learned, as these comments suggest: “I didn’t learn anything new this year but I did a couple of years ago”; “Always something new to learn but sometimes you already know the stuff”; and “I like to learn stuff but sometimes I don’t in Whooo Club.” One student told us he put the mark in the middle but “I learn something each day.” We took this to mean that something wasn’t always in Whooo Club. It seems these students were aware of when they were and were not learning new things or perhaps they were the students who came already knowing much about animals. We weren’t able to discern this even from further probing.

The majority of Whooo Club members told us they learned “all the time.” These members described a wide range of things they learned, though mostly about animals. They learned about new animals, habitats, life cycles, “their life and how they live,” “how they migrate,” and “animal parts.” While these students have a strong sense they are learning they had difficulty telling us more specifics beyond these general statements.

Interestingly, and important for the guiding philosophy of Science in Action, two students told us they understood scientists better. “I understand scientists differently and how they work,” one student told us, and the other said, “scientists put animals in categories to help organize them.” Some students told us they didn’t know much about “science and stuff” before they started Whooo Club, “it is all new to me.”

This conversation about what you learned about science and scientists prompted them to reflect on how they learned this information. For example, they told us “Whooo Club is a better way of teaching people by getting up and doing things.” Others talked about Whooo Club being “an easier way to learn things.” These young learners were not only aware that their understandings had changed, they could tell us what about the program helped them develop these understandings.

We asked EcoAction participants, on a scale from “nothing” to “a lot,” what you learned from the scientists who visited. All but one student, who indicated “nothing,” said they had learned either a little or a lot. Some students, especially those who said a little, seemed to see the question as slighting the teachers or asking for a comparison to what they had learned from teachers. For example, they said things like “teachers do as well as the scientists” or “teachers make it as much fun.”

What the others did tell us when we asked why they put the mark where they did, was that they had learned from the scientists and why they had been able to learn so much. They talked about learning about soil layers, polluted ground water, and water cycle and learning how to dig soil pits and measure water temperature. They talked about learning what was and wasn’t a rock and “what the park had looked like thousands of years ago." As one student put it, "a whole whack of stuff." But not everyone was satisfied. Another student told us they "told us stuff but I already knew" and two others said the scientists did not explain very well.

We also asked students, "What is it you learned about scientists by working with them?" Here the responses were most informative and enthusiastic—"They aren't what you expect." Almost all of the EcoAction members talked about how their impression and understanding of scientists had changed by working on projects with them. Their comments were either about what kinds of things scientists do that they had not realized or what they had learned about them personally. These middle school students told us that scientists taught them things like "how they keep records," "measure to see how dirty the water is," and "how they work out problems."

But mostly they told us how their perceptions of scientists had changed. They don't just wear white coats—"they are regular people," "They work hard," "enjoy what they are doing," and "Some of them are actually cool. Amazing isn't it?" Students told us they do "a lot of different things," "they don't always work in labs, wear white coats and are total nerds." One student told us, "I always thought they were the group that made Frankenstein." Another said, "Scientists are like all over the place. Some study marshes; some will study lichens. Well, it was a big shock."

DISCUSSION AND CONCLUSION

This paper began with global issues: the growing criticism of formal, classroom-based science education; the mounting evidence of student disengagement from school science during the middle years; the sprawling research literature on informal science education; and the promise of informal education to supplement classroom-based studies and so address the problem of disengagement. It then moved to the local: our New Brunswick-based initiative to develop informal science education programs deeply informed by the literature on informal education and by our unique conception of the nature of science. Central to that conception, as we have insisted, is the notion of science as enterprise and culture, a notion in which "learning about science" is brought closer to "learning about scientists," in the sense of learning about scientists' language, techniques, and practices.

The environment we hoped to create within Science in Action resembles in many respects what Shirley Brice Heath has described as a (Re-)generative Learning Environment (Heath, 2007). It shares with Heath's conception the focus on language as socially integrative, on group involvement and group motivation as central to learning, and on learning science as an acculturation or socialization into a distinct culture that may be quite different from one's own. Although we differ from Heath in how we conceive the culture of science, we agree that the concept of learning science as a cross-cultural exercise that must span wide learner diversities is a necessary one. We wanted to know if these programs and that environment could usefully supplement and perhaps anchor classroom science; stimulate interest, achievement, and personal growth among participants; surmount the many challenges to research on informal learning; and in these ways contribute to slowing or reversing the disengagement from science common to the middle school years.

Our research has left us cautiously optimistic that the answer to these questions is "yes." To circumvent the common research problem of results evaluated only by participant self-observation, we went to parents and teachers as well as student-participants to learn what impact participation in the Science in Action program had had. All these sources agreed that the program overall had stimulated students' interest in science, enhanced their confidence and personal growth, developed their capacity for leadership and teamwork, and widened their curiosity about and appreciation of the natural world. Students themselves repeatedly echoed all the standard criticisms of formal science education as it is presented today in schools, and expressed their preference for Science in Action in terms of the opportunity it presented for activities in the field, for in-depth study, and for investigation. Above all, student reports confirmed our belief that direct exposure to scientists and to the activities of scientists would stimulate not only their interest in science but their understanding of what it is to do science as well.

Not all of our results were reassuring. Science in Action was marginally less effective in capturing and holding the interest of older students than of those in the younger age cohort, a sign that well-designed informal programs can slow, but not wholly reverse the disengagement that characterizes the middle school years. It is also a reflection of the myriad of afterschool opportunities available to students, especially sports programs, and with which we were competing. We are all too aware that the "fun" of informal learning programs can easily deteriorate into entertainment that may work to the detriment of real learning. But our results suggest that students themselves perceive this problem and find in our programs value that goes beyond entertainment. We are aware that we have not wholly compensated for selection bias in our research: that students opting to participate in Science in Action may bring levels of interest in science not typical of students across the board.

These reservations stated, our results overall confirm our belief that engaging students in science can be achieved best by introducing them to the culture of science through the inculcation of skills and experiences that allow them to solve problems and think as scientists would first hand, and to interact and communicate with others as scientists might. The potential of informal science learning to promote "interest" in science is, of course, a standard theme of the literature (Dierking et al., 2003). Our concept of "interest" goes further, beyond the notion of the individual's interest or curiosity, to embrace the group and the capacity of group involvement to heighten interest and engagement among all participants. In our view, interest and engagement are most effectively promoted by creating contexts and curriculums that allow students to engage with people who are passionate about and/or have strong interest in science, and then allow them to share their problems and projects with others. While we are sceptical of attempts to duplicate "authentic science" in most learning contexts, we believe that group participation as a spur to interest and engagement communicates something essential about the culture of science today.

Our results indicate that engagement is fuelled by three things, according to these participants, parents, and teachers: interest, success, and active participation in intellectually challenging learning experiences. They suggest that scaffolding is central to engagement—building skills, understandings, and vocabulary/language (Canadian Council on Learning, 2007). Effective informal programs increase the responsibility of participants, widen the scope of activities, and broaden the circle of those involved. They decrease the structure and control of facilitators, and in doing so open up new opportunities for participants to develop thinking and skills.

While demonstrating the potential of informal programs to enhance engagement, especially through activities and personal involvement, our study underlined, in contrast, the continuing problems of formal science schooling as it is presented in elementary and middle school science classrooms. In New Brunswick, less than 90 minutes per week is spent on science instruction in elementary school classrooms. In middle schools less than 20 percent of teachers have a science background, whereas half of the middle school science teachers working with EcoAction and one of the teachers working with Whooo Club had a science background.

Our results confirm our initial belief that many elementary and middle school students are hungry to learn more about science. Informal afterschool science programs can effectively feed that hunger and can work in tandem with classroom science to complement each other's deficiencies with their own strengths, and so build and sustain student interest and achievement in science. Of course, informal programs face many problems of resource and organization. They must compete with other sports and arts-based activities for students' time and interest, and often depend upon dedicated teachers, parents, and scientists who are prepared to donate their time. How best to launch and sustain programs for informal science education presents many questions that require further investigation. But the potential of such programs to enhance science education and grapple effectively with the great disengagement problem, especially programs organized around the notion of a culture of science to which students must be introduced, is clearly demonstrated by Science in Action.

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STUDYING SCIENCE AFTERSCHOOL

Middle School Students' Experiences Working with Field Botanists

Students typically lose interest in science by the time they get to middle school. Research has shown that usually about the time children leave grade five the majority of them perceive science to be a boring subject that requires listening to the teacher lecture about hard-to-understand concepts, using language that has little or no personal relevance (Viebert & Shields, 2003). When these students think about what school science is, they focus on memorization of facts and on taking many notes while passively sitting in a classroom (Braund & Reiss, 2004; Koballa, 1988; Mason et al., 1991; Wieman, 2007). When they think about scientists, they envision the stereotypical middle-aged male, dressed in a white lab coat wearing glasses and conducting experiments in a laboratory (Barman, 1997; Newton & Newton, 1998; Talsma, 1997). It's not difficult, therefore, to draw an association between students being less interested in learning science in school, particularly as they leave elementary grades, and the need for research about alternative approaches to science teaching and learning (Barab & Leuhmann, 2003; Barton & Donnelly, 2005; Hurd, 2002; Tobin, 2002).

Science in Action was developed to be that alternative learning experience for elementary and middle school students. The afterschool program was designed to engage students in investigations of things scientists study, over a long period of time—three years. We wanted students to be able to distinguish between the work of scientists and themselves or others who are not scientists, e.g., use of language and skills such as classifying, naming, record-keeping, sampling, reporting, and making claims. Further, we wanted these students to be able to recognize and explain the contributions of/role of scientists' ideas in solving everyday and/or locally important problems—explain what they, as students, can do because they understand scientists' ideas and methods of working.

It was important for us to avoid confounding the study of scientists and their work with the study of environmental issues of a kind that are often highly socio-economic and sociopolitical in nature. Thus our approach intentionally avoided presenting the study of science through an analysis of environmental issues and specific community-based pollution problems. While scientists' ideas contribute to these discussions/decisions, we wanted to avoid encouraging students to equate science with these issues—that is, to hold the view that studying pollution or climate change is doing science. The objective of this program was to understand the scientists' interest and work in certain areas and the ways their work and ideas

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are used by others. We acknowledge, however, that a focus on community-specific environmental problems has been undertaken in other experimental learning contexts by other researchers (e.g. Lee & Roth, 2001; Roth & Lee, 2004; Pruneau et al., in this volume) who actively promote student involvement in local environmental issues. These different approaches suggest the need for discussion and research on the impact of local involvement on students' understanding of scientists' ideas/work and their contributions to resolving environmental issues.

From the beginning we believed that if children had a chance to study not only what scientists study, but how they study, they would develop a better understanding of and an interest in science. To test this idea, we developed the Whooo Club and EcoAction programs. For both programs we picked a scientific theme to explore in more depth than allowed in the usual curriculum unit, and over a longer period of time the way scientists do. We also wanted to develop skills and vocabulary they will need to be successful in their explorations. Finally, we wanted to introduce them to the culture of science, by which we mean we want them to consider who scientists are, why they ask the questions they do, what it would be like to be a scientist, why and how they study things the way they do, what they do with the information they learn, what kinds of things scientists do in the course of a day, and what use people make of scientists' ideas and findings. While descriptions of scientists' work, especially in the field, has been articulated by researchers like Bowen and Roth (2001, 2007), we did not want to tell students what scientists' work is like. Rather we wanted to see what kinds of understandings they would develop on their own through interacting with scientists.

Having scientists and people who understand and value science as part of the program interacting with students was central to program development from the outset. The ways in which they interacted and for how long were less certain. For Whooo Club, with elementary learners, we involved mostly people who understood science but were not scientists themselves, such as those from science centres and preservice science teachers. In EcoAction, middle school students interacted with scientists and/or technicians with strong science backgrounds working with scientists. In this paper, we report on the impact one encounter with scientists—two botanists—had on the middle school students from the perspectives of the scientists, the teachers, and the students themselves.

THE ECOACTION PROGRAM

EcoAction is designed to build on the skills and understandings developed in the Whooo Club. Students study the critical zone of an approximately one-half square kilometre piece of land (called the EcoAction Research Zone or EARZ) in their community over the course of three years. One year students study the plant life within the critical zone, another year the soils, geology, and hydrology, and finally the atmosphere and surface water. In addition to enhancing the research and investigation skills developed in the Whooo Club, EcoAction members focus on the skill of sampling. We chose sampling as almost every area of science study is too vast or complex or changing to do an actual count. The notion of sampling is at the heart of understanding that science is tentative—we cannot know for certain. Learning how various scientists sample, how they collect data, and what they do with that data is a beginning step in grappling with the more complex issues surrounding data collection, analysis, and reporting found with the science community.

At the EcoAction level of study, students continue to work in multi-age teams but are also given responsibility for planning, data collection and analysis, and reporting their findings. Each year they work with different scientists to learn what they study and are interested in about the critical zone and how they collect data. At the end of each year, students from all three EcoAction groups meet together at the EcoAction Summit where they share what they learned with one another.

Based on the planned experiences during the botany component of EcoAction, we expected that students would learn about a field botanist and his or her work. In other words, we anticipated that the students would acquire a level of understanding about this type of scientist based on what they experienced during their interactions with the field botanists who visited each EcoAction group.

When the field botanists met with EcoAction students, they talked to them about their background training and their typical work activities. The botanists also showed students their field tools and let students use them to complete botanical field tasks. The field botanists also exposed the students to the language of botany and they explained the process and importance of record keeping associated with collecting and preserving plant specimens.

In addition to sharing all of this expertise with the students, the scientists allowed their unique personalities to show through each time they visited one of the EcoAction groups. All of these field botanist/student interactions formed the framework of what EcoAction students were meant to learn about who a field botanist was and what science he or she does. For example, field botanists have the knowledge of what's required to work and sometimes live in the field and they know how to use unique tools and procedures to investigate plants in their natural environment. They are people who enjoy being out of doors where they often have to cope with adverse weather, challenging terrain, and biting insects in order to do their job. Like other types of scientists, field botanists have to be good communicators because they share the results of their work with others either verbally or through technical manuscripts or scientific journal articles. Field botanists are also good at record keeping. They prepare detailed field notes which might include sketches of their observations, location details (i.e. compass bearings or GPS coordinates), comments on species abundance, etc. They also document their findings in photographs/digital images. Field botanists use specific procedures to sample/collect plants and then preserve them. They use these skills for a variety of purposes including creating an inventory of the plants in a study area.

SCIENTISTS' INTERACTIONS WITH STUDENTS IN SCHOOLS

Science education literature from the past decade reveals many reports of scientists being involved in one way or other with students (Bybee & Morrow, 1998; Kim &

Fortner, 2007; Taylor et al., 2008). Indeed, we found that it is commonplace for universities, research institutions, government departments, and not-for-profit foundations to argue that school science can be improved if scientists get involved in the classroom. Typically, such interaction involves a one- or short-time "visiting content specialist" (Laursen et al., 2007). The scientist might give a motivational talk about his education background and why he chose science as a career (e.g. Howitt et al., 2009; Millner-Bolotrin, 2007; Murphy, 1998; Owens, 2000). Or the scientist might visit a classroom to elaborate on a science concept that is central to her work (Howitt et al., 2009; Millner-Bolotrin, 2007; Murphy, 1998; Owens, 2000). Alternatively, a scientist might invite students to do mini-research projects in her lab (Beck et al., 2006), or she might bring specialized scientific equipment to a school and use it to lead students through a hands-on activity (Banner et al., 2008; Donahue et al., 1998; Fougere, 1998; Lawless & Rock, 1998; Weaver & Meuller, 2009). As well, a scientist might mentor students by linking them with his colleagues elsewhere in the world. Or she might provide answers to students' questions by email or in a blog (Williams & Linn, 2003).

No matter which of these forms the involvement of scientists in school would take, our review of the literature about scientists interacting with students indicates there is limited research-based evidence of the benefit to either the student or the scientist. Painter et al. (2006) found that few reports in the science education research literature attempted to establish the actual impact of the collaborations between scientific and education communities. Laursen et al. (2007) held the same opinion, noting that the positive effects of scientists being in the classroom have not been adequately investigated and that little research literature documents the effectiveness of such a liaison. As a result, most writings describing student-scientist interactions tend to provide only anecdotal evidence of the programs' results. Such writings seem more often than not meant to convince practitioners who might be considering implementing them in their own schools with their own students.

When our review of the literature was narrowed to focus specifically on research-based articles about scientists interacting with middle school students in informal settings, it became even more evident how little research has been conducted. However, one study stood out for its similarities with what we were researching through the EcoAction program. Barab and Hay (2001) conducted a participatory science learning experience for 26 eighth graders in which students assisted scientists with their research during a two-week summer camp. Like EcoAction, the program that these authors were researching took place in an informal learning environment and it involved teacher volunteers supervising middle school students during their time with scientists. Also, like EcoAction, the program concentrated on equipping students with skills that scientists use in their work. But there were few other aspects of this summer camp program that were comparable to EcoAction. Where Barab and Hay were attempting to determine what characteristics constitute a rich environment for participatory science learning, the EcoAction research team was interested in the impacts that interacting with scientists have on students. Also, through their summer camp research, Barab and Hay were interested in defining the boundaries of the experiences that participating students had in knowing more about the types of environments that best promote authentic and transferable knowledge. In contrast, EcoAction researchers were interested in whether or not students would develop a better understanding of and an interest in science if they studied not only what scientists study, but how they study it. More specifically, for the botany component of EcoAction, the research team was particularly interested in knowing whether or not EcoAction program experiences impact students' understanding of who field botanists are and what their life and work involves.

Overall, the papers we reviewed suggest that scientists are involved in science education in many ways but seldom in the manner that they are in EcoAction. There is little research-based information available about the impact on students when scientists interact with them through informal education programs.

METHODOLOGY

Science in Action is a research collaboration guided by Reason's (1989) model of co-operative inquiry and, within that framework, qualitative data collection strategies such as surveys, interviews, and observations. Middle and elementary schools volunteered to participate in response to an open invitation. Data for this paper consists of initial surveys and follow-up interviews with students, teachers, and botanists. Analysis was completed by two members of the research group, one a practicing field botanist studying for her doctorate and the other the principal researcher.

Schools and Students

At the outset, elementary and middle schools within a two-hour commuting radius of the university were invited to apply to participate in Science in Action. Since we wanted to collect data across the five years, we asked for sets of schools to apply—middle schools and their feeder elementary schools. Through this process, we ended up with three sets of schools in the project. Two of the sets of schools are located in the lower socio-economic section of a mid-size city in New Brunswick. One of these elementary schools has been designated as a school of special need. The third set of partner schools is set in a town with students bused from surrounding communities up to an hour away.

New Brunswick itself is a rural province with small pockets of population density. As such, schools are often the centre of community activity and the teachers in these schools are often called upon to undertake extracurricular activities and projects. For example, coaching even middle school requires afterschool commitments and up to two and a half hours of travel to games. The middle school teachers who volunteered to participate in the project are some of the busiest in their schools; most ran at least two other afterschool activities. Only two of these teachers have a science background but all say they volunteered to participate because they believed there should be more science experiences for students in their schools.

The two botanists who participated were professional colleagues of one of the authors and practicing field botanists. Both have done outreach programs with the public, although one had more experience working with schools than the other. The botanists were sent information on what we wanted them to present and talked with a member of the research team as well.

Data Collection and Analysis

Data for this study was collected from middle school students and their teacher-facilitators from three schools, as well as two botanists.

Middle s*chool* s*tudents.* To explore these middle school participants' understandings of botanists as a result of working with them, we first used a cartoon template and asked them to draw for us a day in the life of a botanist (see Appendix A). We chose drawings as a data collection strategy due to the number of participants with limited writing and language abilities. We also found individual interviews too time consuming for the schools and used them sparingly, while small group interviews are too often influenced by individual speakers.

When we began to analyze the data, it became apparent that it would not provide us with the kinds of insight we wanted for two reasons. One, the drawings ranged from full comic-book style drawings with balloon captions to stick figures with little details. Secondly, the two researchers brought widely different experiences in field botany and found too much difference in interpretation beyond initial coding. With too little data to support interpretation, we decided we needed to talk to the students directly and use the drawings as prompts.

In small groups of two to four we asked 26 students to tell us about a day in the life of a botanist. While 29 students completed the drawings, only 22 students completed both the drawings and interviews. Having the individual drawings reduced the possibility that individual student responses would influence others in the group. We each interviewed about half of the students. As we conducted the interviews, each of us developed additional questions to further probe their experiences, such as, How do you know the things you know? and What makes a botanist a botanist?

Teacher-facilitators. Two teacher-facilitators in each school ran the weekly EcoAction program. Because of their busy schedules, we used a questionnaire via Survey Monkey to explore their perceptions of students' experiences with the botanists. We wanted to know whether they felt the interaction has had any impact on the students. Based on their responses we had follow-up questions which another member of the research team asked as part of phone interviews she was conducting for another aspect of project research.

Botanists. Each of the botanists responded to a questionnaire we developed and sent via Survey Monkey. In analyzing their responses, new questions arose. We decided we needed to ask them follow-up questions directly, and as a result conducted individual interviews.

Data Analysis

Each of the sets of data from students, teacher-facilitators, and botanists were analyzed individually, across data sets within participant groups, and finally, across participant groups. Every level of analysis was guided by Strauss's (1987) method of constant comparison from initial coding, through searching for patterns and establishing categories and final claims. In all three participant groups, initial data collection and analysis resulted in further data collection and analysis. However, we reanalyzed all the data sets in preparing this paper. Throughout the process we searched for insight about students' experience in interacting with the botanists and any kind of impact these interactions might have had.

The interview data from middle school students was analyzed using two approaches. In one we looked at the 22 students who were interviewed and had completed drawings. We felt that analyzing their responses across data sets would give us insight into the range of student experiences interacting with the botanists. Secondly, we analyzed only the interview data consisting of responses from 26 students looking for the range of experiences students reported and which seemed to have had the most significance or impact. Patterns and categories identified in each analysis approach were compared before comparing with the data from other participant groups.

After the 29 students from the EcoAction clubs at the three middle schools involved in this research program interacted with two different field botanists over a four-month period, they were asked, during one of their club meetings, to create a series of six drawings, on a template provided, to depict a day in the life of a botanist. This way of collecting a record of the student's impressions has been used by many other researchers (Driver et al., 1996; Finson, 2002; Ntarajan et al., 2002; Rennie & Jarvis, 1995; Talsma, 1997).

Subsequently, each of the students was interviewed and asked to describe what they had included in their drawings. These interviews were recorded and later transcribed. The students' responses allowed the researchers to validate meanings, language, and symbols constructed from the students' drawings (Alerby, 2000; Payne, 1998).

Follow-up interviews with students. Eight months after the students' experiences with the field botanists, they were asked, in groups of three or four, to examine a collection of tools and to comment on if and/or how a botanist would make use of each of them. Their responses were recorded and transcribed to allow the researchers to determine the students' ability to recall aspects of a field botanist's endeavors, particularly the equipment and the relevant terminology used in his or her work. The students' answers gave the researchers insight into the depth of understanding that the students had acquired as a result of working with a field botanist.

Botanists' questionnaires and written reflections. After their last outing with the students, the two field botanists were asked to respond in writing to a series of 10 questions which were designed to have them recall their experiences with the EcoAction program. As well, the botanists were each asked to prepare a written reflection of interactions with the program organizers, the students, and the teachers involved.

Teachers' questionnaires. The six teachers who had supervised the three EcoAction clubs were asked to respond in writing to a series of 10 questions about their involvement with the botanists in the program.

FINDINGS: STUDENTS' PERCEPTIONS OF A DAY IN THE LIFE OF A BOTANIST

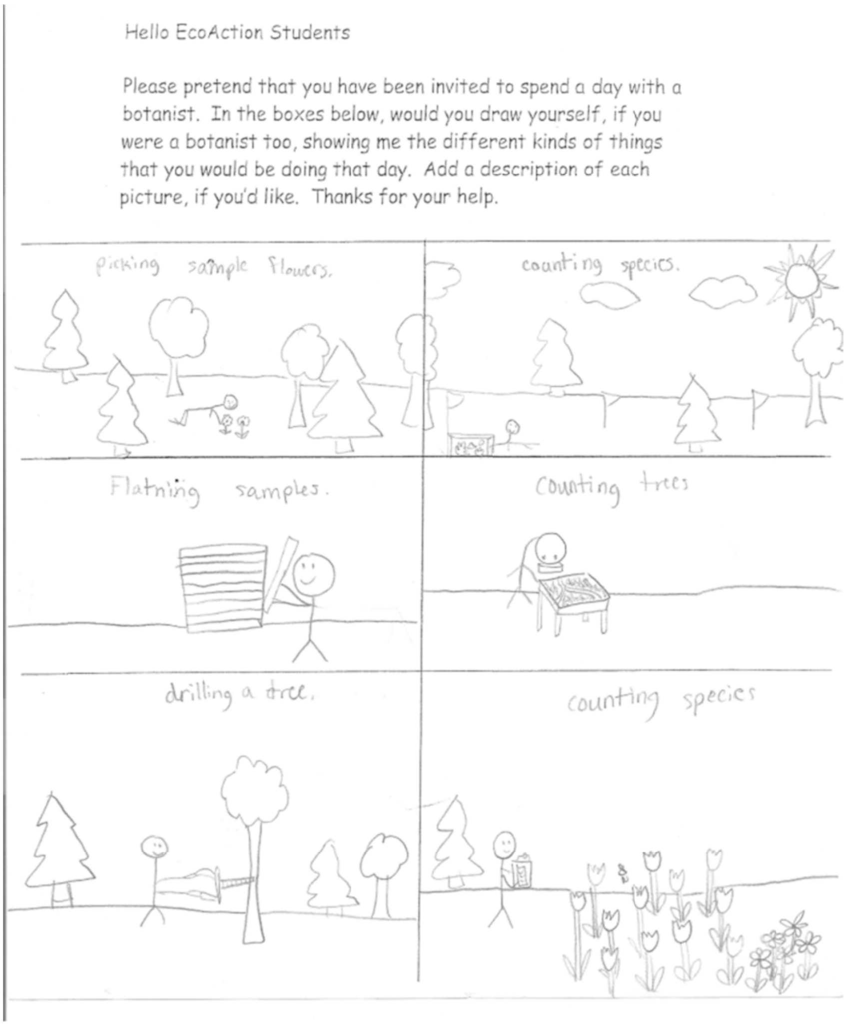
When we asked students to draw us a day in the life of a botanist, we were curious to see what they would remember almost six months later. We were not surprised that some students remembered more than others, but we were surprised at how much every student had been able to tell us about botanists. Though introductory, these middle-school EcoAction students developed a rich and complex understanding of botanists, especially about their work, what makes a botanist a botanist, how they know these things, and why botanists do what they do.

The Range of Students' Understandings of Botanists

Even though our data indicated that every one of the EcoAction students understood a lot about a field botanist after participating in our program, when we juxtaposed their understanding with what we expected them to learn, we could detect various degrees of sophistication in the knowledge they acquired interacting with the field botanists.

To be more specific, at the upper range of understanding, we expected students would show us they could make explicit reference to or give a sound explanation of the majority of the concepts that the field botanists and the research team had presented them with. In addition, we were expecting that the students would be able to actually describe the equipment of a field botanist and the use for it and that they would know about a field botanist's journal and its importance as a record-keeping tool. As well, we thought that they would show us that they could relate to and use a range of vocabulary appropriately. Finally, we expected them to be able to explain the processes that a field botanist would follow while sampling, collecting, and preserving specimens from his or her field work. Students who showed us that they had learned all of this had a very sophisticated level of understanding, in our opinion.

An example of a student with this very sophisticated level of understanding of the life and work of a botanist is illustrated in Figure 1. Here the student shows a person collecting samples of flowers at a field site and then counting species within a quadrant. The student shows marker flags spaced out along a transect line where the quadrant will later be placed. The student also shows the person using a plant press, using a stereoscope to count trees on the stereoscopic images of the study site, and using an increment borer to measure the age of a tree. Finally, the student shows a person writing information on a clip board related to counting the species of plants that are on the ground in front of him. The student adds these labels to the



Hello EcoAction Students

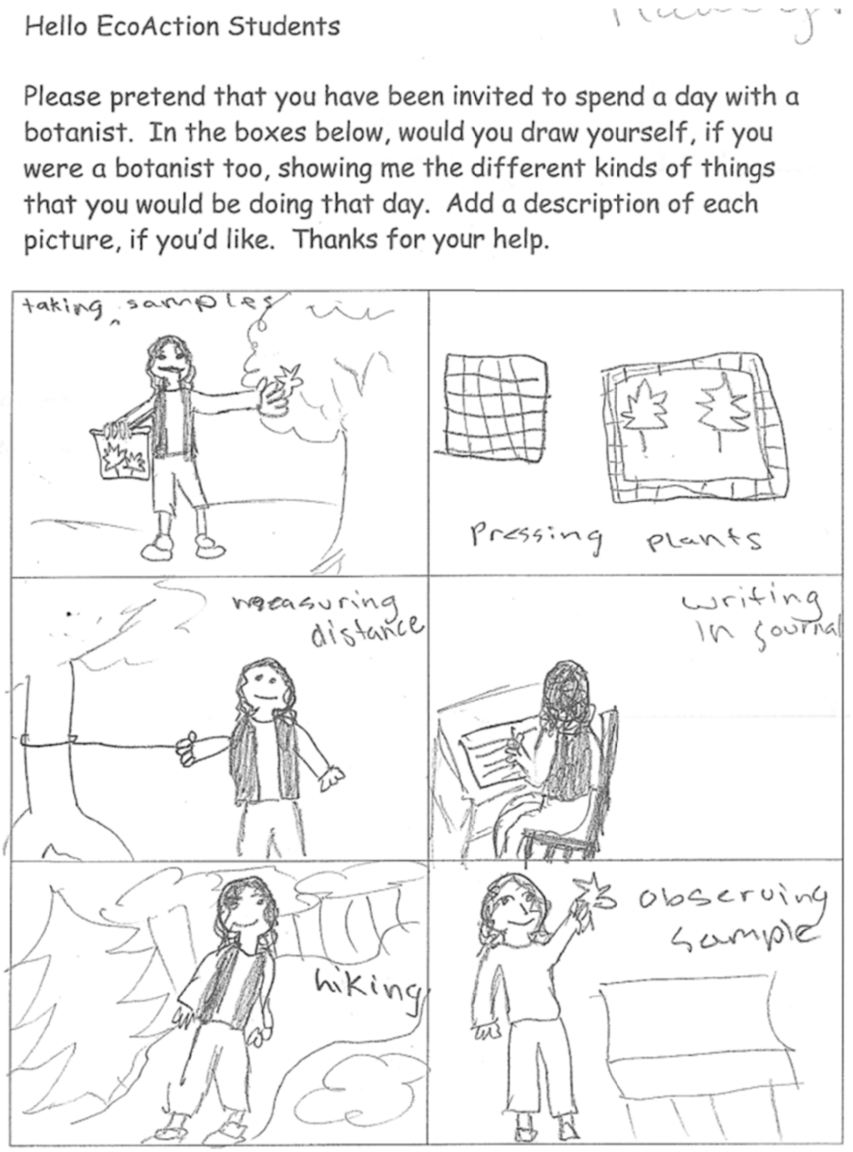
Please pretend that you have been invited to spend a day with a botanist. In the boxes below, would you draw yourself, if you were a botanist too, showing me the different kinds of things that you would be doing that day. Add a description of each picture, if you'd like. Thanks for your help.

Figure 1. Example of student drawing illustrating a very sophisticated level of understanding about the life and work of a field botanist.

drawings: picking sample flowers, flattening samples, drilling a tree, counting species, counting trees. During the follow-up interview, this student explained his drawings by saying that "I was picking sample flowers here and then I was flattening them in a press and I was drilling in a tree and counting different types of species in an area. Then I was counting trees in the property and I was counting different species and flowers." The student added that "you put it [the plant sample] in a little baggy and then you go and press it down and make it flat so that it lasts long." The student explained what he was doing with a quadrant by saying that "[I was] counting species in a little area. The flags were 10 metres apart and then with a little square you count all the species in the area [to see] how many species there are, like what there's most of." The student said that this was done to find out "all the different types of species in our property." The student that drew and explained these images for us recounted the detailed processes that he learned from the field botanists while the two of them were together at the EARZ. He had a strong sense of how and why these processes were part of an investigation about the different types of plants on a piece of land. He also knew about the tools with which field botanists expand their field exploration once they return to the lab. Only two of the 22 students demonstrated this very sophisticated level of understanding to the research team.

An example that illustrates an EcoAction student's slightly less sophisticated understanding of the life and work of a botanist is illustrated in Figure 2. The student has drawn a field setting where a person is taking a sample and measuring a distance from a tree with a piece of rope so as to create a sample location. The person is travelling by foot through the field location and is making a journal entry and examining a plant sample. The student has also drawn a plant press in which a specimen is being placed. There is text associated with the drawings: taking samples, pressing plants, measuring distance, writing in journal, hiking, observing sample. During her interview, the student explained her drawings by saying that she was taking plant samples and trying to "see what was inside" a 10-foot circle around a tree. She talked about "quoting" (i.e. recording) this distance in her journal and about writing about "stuff we did that day" in the journal "back in the classroom." She also explained that she "looked at [the samples] when we brought them back and sometimes when we were pressing them we looked at them to see what they were. We were collecting a whole bunch of different plants to see which ones we could get and then when we got them we could look them up and find out stuff about them like where they usually grow and stuff." She explained that she pressed the plants "so they would stay" instead of getting "kinda crinkly and dry." The student that drew and explained these images for us recounted fewer details about the processes that were presented to EcoAction students by the visiting field botanists. She wasn't focused on how and why these processes were part of an investigation about the different types of plants on a piece of land. She did however know the basics of what field botanists do when they study a piece of land. The majority of the 22 EcoAction participating students demonstrated this level of understanding.

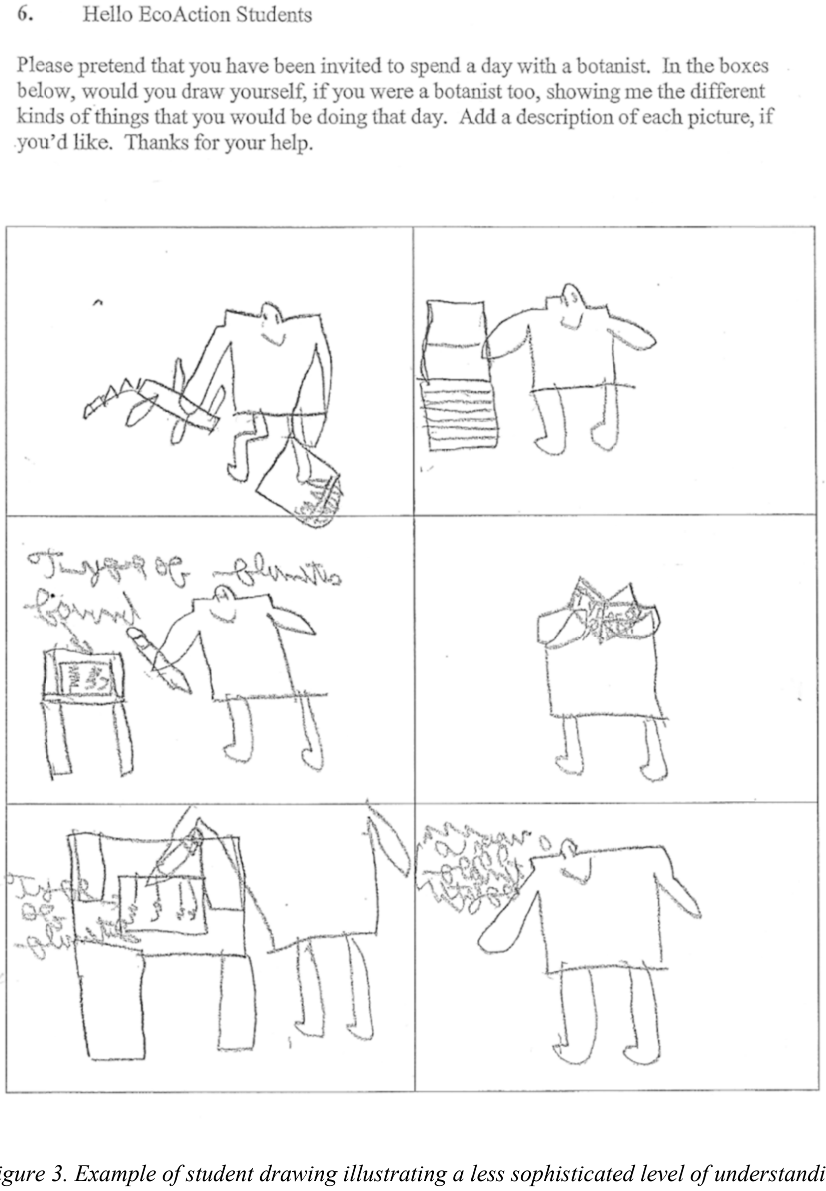
Finally, the drawings of an EcoAction student who had the least (as compared to his peers) sophisticated level of understanding about the life and work of a field botanist are illustrated in Figure 3. The student has drawn a person collecting a plant sample, storing it in a plastic bag, and then writing down the plant type. He has also drawn a person standing beside a plant press, reading a book about types of plants and talking about "a new plant type." There is text on the drawings:



Hello EcoAction Students

Please pretend that you have been invited to spend a day with a botanist. In the boxes below, would you draw yourself, if you were a botanist too, showing me the different kinds of things that you would be doing that day. Add a description of each picture, if you'd like. Thanks for your help.

Figure 2. Example of student drawing illustrating a sophisticated level of understanding about the life and work of a field botanist.



6. Hello EcoAction Students

Please pretend that you have been invited to spend a day with a botanist. In the boxes below, would you draw yourself, if you were a botanist too, showing me the different kinds of things that you would be doing that day. Add a description of each picture, if you'd like. Thanks for your help.

Figure 3. Example of student drawing illustrating a less sophisticated level of understanding about the life and work of a field botanist.

types of plants found, type of plants. During his interview, the student told the researcher that he had drawn himself "processing a plant." He added that processing meant "pick a plant up, hold it, and write the name down and check to see what the type is and write down the names and decide what type it is." He also noted that "I can't really see any other part to it" when he was asked if there was anything else that a botanist would do to process a plant. Even though he drew a plant press he didn't mention it. And even though he drew himself looking in a book titled "Types of plants," he didn't say that he would be using this book to help him decide anything about his sample. He also failed to make it clear in his drawings that some of these activities occur in the field while others occur in the lab.

Field Botanists' Work

Even though some students knew more than others, as a group, their responses tell us they remembered much of what the botanists had shown them. With their drawings as a starting point, students told us about the work of botanists—the kinds of things they study, what they do during a day, where they work, and the kinds of things they record.

What kinds of things botanists study: Foremost, the EcoAction participants told us that botanists study plants, especially trees, flowers, and rare plants. They told us botanists study change—they are "looking for" or "tracking" plants. For example, they are "looking at plants' age and growth," "leaf development," and "bug infestation." A few students told us they "ask questions" about plants.

What kinds of things botanists do: By far, they knew the most about botanists' work, about the kinds of things that scientists do: sampling (including finding and collecting), sketching-writing, pressing plants, identifying-categorizing, looking up-researching, and sharing-presenting. For these students, sampling took two forms. They talked about finding and collecting samples of plants, e.g., "clipping pieces of trees or plants" as well as "taking the whole plant." Botanists took pieces of plants when they could not take the whole plant or if the plant was rare. At one EARZ, the botanist had noticed and pointed out a plant that was rare to that area. This notion of botanists finding and taking special care of rare plants was a strong memory for all the students in the group who found the plant. Students also told us about collecting samples of whole plants, roots and all. They wrapped these in paper and put them in bags to bring back to the school.

Sampling had a second meaning for those students who talked about "sample areas"; one student even used the term "quadrant" to describe the sample areas a botanist showed them how to lay out. Mapping the area was also mentioned in reference to plant locations and finding the places where they took samples later. These students said that botanists "identify what is in the area" and "wanted to know the numbers and kinds of plants" found across their EARZ.

Another part of sampling was counting. Students mentioned learning to "count their paces," "count plants and trees in an area," and "count the different kinds of species." The teacher-advisors taught them to count the number of their steps in 25 metres so they could use that to pace off distances on their EARZ. The research team thought it important students felt comfortable being in the woods, and being able to find their way around was an important safety feature.

Many of the students told us sketching and writing were part of a botanist's day. Botanists could sketch plants instead of taking them, one student told us. Others said they sketched the location where plants were found, drew parts of plants like "thorns or flowers," they drew the shape of plants noticing the "difference between plant roots." Instead of sketching plants or the location, a few students told us botanists would take photographs. One student talked about sketching "a campaign to protect plants." These sketches would be done "on paper," "in books," or "in a journal." Writing was another thing botanists put in their journals. Making notes about where they had been and "what they had done" that visit.

Like sampling, pressing plants was a strong memory for many of the students. Students put the plants they brought back from the field in the square presses we provided. They recalled layering the plants on top of one another in sheets of white, then newspaper, and then cardboard and strapping them tight in the wood frames. The students told us this was done to "take out the moisture" or "to dry them out so we can keep them a long time," A couple of students talked about looking at them under the microscope after they dried them out.

At the same time they were pressing the plants, students told us they would be identifying the plants they collected. They told us about "double checking" and "matching the plants" they found in the field to the names in the reference books we provided for them. Once the plants were identified, students told us they were categorized, or as one student explained, catalogued. They told us they made labels that contained information about the plant's name, where it was found, the time of year it was collected, and whether it was rare. One student mentioned that botanists would use photographs of the plants with labels on the back instead. Debby Peck, one of the authors and a field botanist herself, had shown students how to remove the dried plants from the presses and mount them properly on paper using museum-style labels.

This "looking up" and "researching" more about the plants was two-fold. First, they talked about looking up the names and identifying the plants using what one student described as the "taxonomic" books we provided. They had learned to use the taxonomic system to identify plants. But, second, they also talked about "finding out more about them" and "visiting a plant museum to examine the exhibits." They were interested in where they grew and again, whether they were rare. One student drew and told us that botanists look up "words to sound smart." For this student sounding smart is about using certain kinds of words.

While the fewest students mentioned sharing and presenting, they told us that botanists share what they know with students like themselves. They make presentations to others of the plants they drew as well.

Where botanists work: These EcoAction participants described botanists as working both outdoors and inside. They told us outdoors is where botanists hike through the woods or their piece of land. They also said that they "would be sitting in nature" if they were botanists. Much of the finding, collecting, and sampling took place outside. Even the sketching and most of the writing was done outdoors with one student saying she wrote on her lap outdoors sometimes and back in the classroom other times. Indoors botanists press the plants, identify and categorize them, and do research. Things like pacing and mapping were done outside, while using the microscope and computer were done indoors or as a couple of students noted in a lab.

What botanists record: In talking about sketching, writing, categorizing, and researching we learned that these students have a good idea of the kinds of things botanists record and keep records of. They record plants that they cannot collect or are too large or rare to collect. They record locations of where they collected plants so they can return later, especially if they are interested in the growth or changes in these plants. A number of students talked about the records being used to track changes or being used to look for differences when they returned. They told us that botanists record what they saw each visit, keep records of the samples they collected and locations, and record information like colour, kind, size, and whether flowering or not. One student told us they did that so they "could review their notes the next day."

Students also told us that botanists keep records on computers of the kinds of plants they collected and what they saw each visit. For example, they told us "they upload findings to a computer" and "create a log." These records include uploading pictures they took in the field. They talked about recording their research results on the computer as well.

In probing EcoAction students' descriptions of what a botanist would do during a day, we asked students "how do you know that?" Many of them told us that a botanist and the teachers showed them. Some only mentioned the botanist and a couple only mentioned the teachers. There was one student who said he learned the things from his father before he joined EcoAction. However, almost all agreed they learned these things from being in EcoAction. We were not surprised that six months later they were not able to untangle who had shown or taught them what more specifically.

Who Are Field Botanists?

We were intrigued with the EcoAction students' elaborations on their drawings and asked them "what makes a botanist a botanist?" and "Why do botanists do those things?" In response EcoAction participants told us they "spend their life studying plants, going out and finding them." Part of studying plants was sketching, collecting, keeping, and recording information about them. The second most noted thing that makes a botanist a botanist is that they "care about plants" and "are not bored with plants." Lastly, students said botanists "find out information about plants" and "tell other people so they will care about the plants as well."

EcoAction participants explained that botanists do these things "for their job." One student told us botanists "enjoy studying plants," after all, "he looked for a job in that." In addition, to being their job, students said botanists do what they do so they can track plants, do research, and because they want to know.

According to these EcoAction participants, field botanists track changes in plant growth within an area and through the seasons because they want to know when plants are flowering and whether there are any new plants. They said botanists research an area to “find out more about an area in case there is development.” One student told us that “plants are medicine and they might want to find out another way to use that medicine.” Another student pointed out that “you couldn’t learn everything from a book”; botanists needed to study plants in the field as well. EcoAction students told us that botanists want to know “what plants grow where” and collect samples “from areas that grew that plant.” One student said botanists survey the area to “find out what percentage of plants is in the area.” Students said they also want to know what different kinds of plants are in an area and whether any are poisonous. Another student told us, botanists “get to walk everywhere, meet other people, and make sure plants will be around—don’t go extinct.” In some ways, this question more than others gave us insight into these students’ perceptions of what it is to be a botanist—to be a scientist.

For these participants, doing science requires knowing things, using equipment, and being able to negotiate your way around the out of doors and labs. According to them, botanists need to know skills like writing, sampling, collecting, identifying, and categorizing. They talked about being able to use equipment like compasses, computers, plant presses, and microscopes. To them, botanists are people who enjoy working with plants and want to understand different kinds of plants, how they grow, and how to protect them.

Teachers’ Perceptions of Students’ Experiences

When we talked with the teachers about their perceptions of the EcoAction students’ experience they told us that just meeting the botanists was a positive experience. The teachers felt students were “really listening” to the botanists and were very interested in what they had to say. One teacher noted that students not only listened but felt listened to by the botanists. The teachers reported that students liked collaborating with them and that the experience was more “authentic.” That is, students got to see scientists close up and work with them doing something the botanists do everyday. They said the EcoAction students wanted to work with them longer, wishing they could come again or stay longer.

The teachers also told us EcoAction participants were amazed that the botanists knew so much. One impact of working with the botanists that all teachers reported was that students learned more science and more techniques. They also felt the students would remember what they learned longer. Teachers noted that the students were “wowed” by the botanists and viewed them differently from how they viewed their teachers. They were amazed as one teacher put it, that one person could “know so much.” Finally, teachers told us that they felt working with the botanists had given students a different understanding of who scientists are and the kinds of things they do as “they see them in action.”

Botanists' Perceptions of Students' Experience

The botanists' perceptions of the EcoAction students' experience interacting with them was that students not only connected with them but that interacting made a difference. Neither botanist had worked with students at this age level though one had considerable experience working with high school students. Both botanists told us that the students were open and accepting of them. They also said that in their experience that was not always the case. Both also told us how interested the students were in what they were doing and felt that having a choice to be there contributed to that interest. One botanist felt some students showed more interest initially; those that seemed to know what to do already led their groups in doing the activities. But she told us that when it came to pressing the plants "everyone got excited."

One botanist told us that during one visit, students did not dress properly for going outdoors. Teachers told them that the students had been informed but the botanist noted that being cold distracted them from the activities. The botanists also reported that the students liked knowing the names of plants though they both commented that learning so many names in such a short time was too much to expect.

Both botanists told us that they noticed changes throughout the four visits. One botanist said the students were initially scared of "wandering through the woods" rather than walking on trails; they were afraid they would get lost. By the end, though, she said they were more comfortable being in the woods and doing the activities. She also told us some of these same students formed a bond with her—some of the girls came up to hold her hand. She also said that girls more than boys seemed to bond. Finally, she noted that one impact of her working with the students is that it might be good for students to see women as scientists and doing science. It could give them more ideas of the kinds of things women could have as careers.

The second botanist also told us that interacting made a difference; he gave us two examples. He said two girls who were recent immigrants were very afraid of being in the woods and withdrew when he talked to them. He told us that by the end of the four weeks, though, they were more comfortable and trusted him enough to talk to him. The second example he told us about concerned a student who was described to him as struggling in his science class. He noticed though that this student did really well at pressing plants.

Neither botanist felt the students had a complete grasp of the idea of sampling and cataloguing plants by the time they left. One remarked that she wished she had been able to see how the project turned out. However, she also pointed out being exposed to the kinds of things scientists do in the field and determining whether you liked that or not at an early age was more valuable in the long term. She felt that students would "stick with things they had a chance to try out and liked."

DISCUSSION AND IMPLICATIONS

Interacting with scientists has the potential to do more than change attitudes or increase interest in science. Further, the context in which that interaction takes place may have almost as much impact as the interaction itself.

Programs like EcoAction provide an alternative context in which middle school students experience science in a new light, from a more cultural perspective. In the few studies that have looked at interaction of students and scientists, in particular middle school students, context has been an important factor. Rahm and Downey (2002) argue that the perspective of science students developed from media is that the classroom is grim. They studied oral histories of scientists gained through immigrant middle school students' interviews with scientists in the scientists' workplaces as part of an outreach program. Their study revealed these encounters changed the students' views of who scientists are and what they do, but mostly increased their belief that they could and would want to learn science. Using the notion of apprenticeships, Barab and Hay (2001) also had middle school students interact with scientists in their laboratories. They argued that the apprenticeship model conducted in the scientists' workplace is a more authentic context that allows students more "legitimate" experiences. However, our research suggests that this interaction does not have to take place in the scientists' workplace. When interactions take place in the students' workplace, learning is relevant to the students' field of study and can continue to be utilized and developed beyond the limits of the interaction itself.

Interacting with scientists had an impact on both the students and the field botanists. First, and perhaps most significant, was the connection formed between the students and the field botanists. Secondly, the EcoAction students developed multidimensional understandings of scientists, what they know, and what they do.

The connection between the middle school students and botanists took several forms. The EcoAction participants felt listened to by the botanists and the botanists felt the students became interested in what they had to share and wanted to listen to them. Both the students and the botanists wanted to spend more time together—unfortunately, more time than either the program or botanists' schedules allowed. Connection also took the form of trust and becoming more comfortable with one another. The botanists talked about the ways the students opened up and talked to them more, especially the English as a second language (ESL) students who may have felt less sure of themselves even in the EcoAction group. Trust was also evident in wanting to "hold their hands" and become less afraid of walking off the trails and exploring different parts of their EARZ with the botanists. The botanists connected with the students' enthusiasm. Even if at the beginning only some students were more willing to take leadership roles and do or direct most of the activities, by the fourth visit all the students were getting involved. For one botanist, knowing that a student who did not do well in classroom science was excelling and really interested in learning the skill of preserving plants, was rewarding. The teacher-leaders left us with the impression that they noticed something quite unique about the way that the scientists and the students responded to each other and that this certainly wasn't something that they were used to seeing with these students everyday in school.

Connecting requires opening up and trusting on both sides. Both field botanists had had negative experiences sharing their work with groups of students and adults. The longer term interaction and, as both botanists noted, students choosing to be there, are responsible for the level of connection and positive experiences in this situation. We wonder if "connecting" is an important or even crucial factor in developing the broader, more holistic kinds of understandings of scientists and their work that we wanted. We think so, but it bears further study.

A second impact this experience had on EcoAction participants was the multidimensional understanding of field botanists and, as an extension, the understanding of scientists they developed. All of the students we talked to remembered something about working with the field botanists, though some remembered more than others. What they remembered was more than just information. They remembered skills they had been taught, what kinds of things field botanists do, equipment they use, and the places where they work. Beyond these particular field botanists, students understand that scientists do things because they need a job, they choose science as a career, and scientists like the things they are studying and where they study. They have a sense that scientists do things for the benefit of other people, to protect them or help them. And, in the case of living things, they study plants and other living things to protect them as well.

Though the field botanists felt students did not learn much from them or at least many of the students did not seem to be picking up on the ideas, what we learned from talking with the students later suggests they would be pleased with what the students had learned and been able to build on throughout the project. Both the teachers and the botanists noted how excited the students were to work with the scientists and how some students, who were not reported as doing well in the classroom, excelled at some of the activities they did with the botanists. Interestingly, both botanists reported that even students who started out seeming less enthused at the outset became excited later on, especially with certain of the activities. This positive experience was contrasted by both of them with most of their outreach experiences where only a few of the participants were generally really interested. Importantly, both botanists attributed the students' level of interest to choice, that is, the students chose to be there.

We also wondered whether it was the novelty of the experience rather than interacting with the scientists that was responsible for students remembering for so long so much of what they did with the botanists. Was it that they continued using the skills and ideas the botanists shared with them? If they worked with them even longer or worked with other scientists for longer periods of time would the impact increase or would the novelty wear off and the impact peak or become a negative or just another or even a normal experience? Would having scientists share with them a day on their field site helping with their work have evolved their understandings even further? Would scientists be willing to engage students in conversations about the kinds of things that happened with or that others used their research for? Or to talk to them about the way their research influenced their thinking about local environmental issues? Would we be straying from education to indoctrination? Is it an illusion we can have one without the other?

The botanists told us that they felt a sense of connection with the EcoAction students and we certainly got the sense from the students that this feeling of trust and respect was reciprocated. All of this leads us to the conclusion that the multidimensional nature of EcoAction is an important step with respect to its program and to the experiences that the students and the field botanists shared with each other. Indeed, the nature of EcoAction is beyond what has been reported on elsewhere about middle school students learning science from scientists. We feel that by integrating scientists' visits, over an extended period of time, with activities that allowed the participating students to apply what the scientists had taught them, EcoAction provided an alternative context for an optimum science-learning experience for middle school students. Furthermore, we believe that our work shows that scientists can make a contribution to science education that goes beyond simply delivering scientific information to students.

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Part Three

Insights and Introspections

ENSEMBLE

INSIGHTS AND INTROSPECTIONS

Throughout this book, we have tried to introduce you, the reader, to the work of CRYSTAL Atlantique and to the larger argument that researchers are only beginning to understand the potential of informal learning contexts, especially in the areas of science, mathematics, and technology. To date most of the studies recognized as informal science learning research have been directed at museums, science centres, and outreach or environmental programs. The full scope of informal science learning, however, is much broader, more complex. We contend that co-operative research communities like that created by CRYSTAL Atlantique offer an ideal context for studying informal learning, especially for scholars whose interest is a secondary rather than primary area of study. Most importantly, we contend that such research—research like ours—pushes the boundaries of understanding the potential of informal learning. We even suggest that informal learning may provide a more effective learning context than that offered in schools.

In the final part of a book, it is normally the editors who write a culminating chapter reflecting on the words and ideas that preceded it. We elected a different approach. In the commentaries that follow, the major participants in CRYSTAL Atlantique—those who worked and contributed to the research throughout the majority of its six-year mandate—contribute their voices, thoughts, and final ideas about the CRYSTAL experience. Individually, we address some or all of the following questions:

- What did you learn from your research about informal learning?
- What did you learn from the participants who participated in your research studies?
- What did you learn about research?
- What kinds of effects/impacts did participating in CRYSTAL Atlantique have on your work and the direction of your research?
- What implications/impact on the future of informal learning do you believe will result from your participation in the project?
- What advice would you give to others contemplating joining or organizing a research project like CRYSTAL Atlantique?

Every person brings their own experiences, and as such, their own insights and introspections. Together they are a conversation, a discussion of what lingers, what was undertaken, what was felt.

We present our contributions in alphabetical order so as to preserve the importance and equality of everyone's reflections and contributions. Each entry

K. S. Sullenger & S. Turner (Eds.), New Ground, 271–289.

represents our individual voices, our final thoughts, and the concluding ideas we would like to share with our readers.

Michael Edwards
Program Director, Science East
Graduate Student—Master's of Education Degree (Completed)

When I first got involved with CRYSTAL Atlantique, it was simply just another thing I had to do as part of my job. The science centre I work at was one of the community partners in the Science in Action section, and I was designated the person to do the work. I was going to spend a few hours every week helping to develop activities for an afterschool science club, and that was it. That designation did not last for long. Very soon I found myself delving a lot deeper than I ever anticipated, reading more and more background material to help me understand the type of collaborative qualitative research which I had never come across before during my time in a science lab. I was made to feel important and that my contribution was valuable, despite being a novice in those early days, and that helped to build both my confidence and my expertise. It was a warm, nurturing environment where everyone shared the same ultimate goal: to gain a better understanding of informal science education, in all its guises.

With each subsequent meeting, I became more fascinated until the only logical next step was to enroll into the Masters of Education program and formalize this new interest. And that changed everything. Instead of just showing up and going through the motions, I found myself taking the lead in a part of the project. As we worked our way through a variety of research questions, I was able to discover which area appealed to me and make that the focus for my thesis. It was a very natural, organic process where I felt like I was involved in the majority of decisions, and I liked that a lot. Compared to my previous experience working in scientific research, CRYSTAL Atlantique was a revelation.

Looking back, I can't overstate how important CRYSTAL Atlantique was, both personally and professionally—it still influences me on a daily basis. It has helped to guide how I now approach designing exhibits and plan programming at the science centre. It has also made me more aware of how to best collect assessment data and then act upon that information. And most importantly it has made me eager to continue learning more—without my involvement, I would have been happy enough just to continue on as I was. It opened my eyes to a whole new kind of research, immersed me into an environment where people could learn while actively involved in a research project, and broadened my knowledge in the best possible way.

I'd happily do it all again.

Viktor Freiman
Professor of Mathematics and Computer Education
Université de Moncton

The history of mathematics is full of examples when mathematicians challenged each other and a larger public with interesting but difficult problems. We can recall, for instance, a wonderful book of recreational problems entitled *Problèmes plaisants et delectables qui se font par les nombres* published in 1612 by the French mathematician Claude Gaspar Bachet de Méziriac, or more recent problems that guided advancement of mathematics in the 20th century formulated by David Hilbert in his lecture given in 1900 before the International Congress of Mathematicians at Paris (http://aleph0.clarku.edu/~djoyce/hilbert/problems.html).

An educational value of mathematical problems is also well known, as many cultures try to develop in young people passion for posing and solving rich problems, as well as communication and reasoning skills that enhance the ability to solve them successfully. From my early school years in Russia I remember nice problems marked by a * all throughout the textbook or from the special section called "problems for outreach work." Some of those problems took a form of riddles, like "How can we divide 5 apples among 5 people so than one remains in the bag?" My teachers were always ready to give us an extra task, just for fun, like one I got *after* my formal exam was done, just before I was exiting the room: the problem was to prove that "a sum of distances from any point inside of an equilateral triangle is the same"—the conjecture so counterintuitive that it still puzzles me for its beauty.

As a university student, I had a chance to be involved in the activity of a "correspondence math and science school" that offered extracurricular challenging mathematical and science activities for students living far from the urban centres but who could be reached by regular mail. In Canada, where I worked for many years as an elementary school teacher, I discovered a challenging potential of the textbooks from the collection *Défi mathématique*, used in many Québec and New Brunswick schools to nurture interest of many students to solve difficult problems (Méli-Mélo section).

All this experience was helpful when I took over, in 2003, the CAMI website created in 2000 by my colleagues Nancy Vézina, at that time professor of math education at the Université de Moncton, and Maurice Langlais, in charge of mathematics at School District 1 of New Brunswick. In fact, computer technology, available at that time in school, enhanced with the high-speed Internet, allowed for organizing weekly problem-solving online activities by posting problems, collecting solutions, and analyzing them with help of the mentors, pre-service elementary and high school teachers. Many students got involved in these activities, some being asked to do so by their teachers, others just for fun. One of them, nowadays a high school mathematics teacher, when asked by me about what was a reason for him to study in math and math education, said, "Viktor, did you see the names of those who did successfully CAMI problems in 2000-2001 posted on the website? I was one of them. Not challenged enough by regular curriculum, I got motivated by solving your problems and thus interested in studying math further."

Later, when a new website was developed and named as CASMI (including also science and chess problems) and the project became a part of the CRYSTAL Atlantique, we collected students' opinions that participants seemed to enjoy solving interesting problems that "do not look like in textbooks from the 60s" and will be analyzed by someone who is not their classroom teacher. As many authors claim, our design-based research showed how technology could help to "break up the walls of the classroom," thus bringing almost unlimited potential of an anytime, anywhere informal learning for all students.

From my CRYSTAL experience I learned a lot of inspiring success stories my colleagues shared with me during the five years; also I discovered multiple ways of collaboration with researchers from CRYSTAL (which included, among others, organization of the Mathematics and Its Connections with the Arts and Science international Symposium in 2009 in Moncton). Also, the project helped me to establish and conduct many innovative initiatives with local schools (within the Innovative Learning Agenda program), such as RoboMaTIC (robotics-based learning) or Doués enrichissent la communauté (middle school gifted students created multimedia supported problems for the CASMI website). The experience also inspired me to continue with other online informal activities for schoolchildren like the Virtual Mathematical Marathon we launched in 2011.

As heritage from CASMI useful for continuation of our work, I realize the importance of collective efforts to bring more challenging mathematics and science activities to more young learners.

Khashayar Ghandi
Professor of Chemistry
Mount Allison University

CRYSTAL Atlantique offered us the opportunity to make an exciting environment for high school students, faculty and student-researcher supervisors, and directors of the Go Global science program at Mount Allison University. The excitation came as a result of the following: 1) close interaction (every day for close to 10 days) with high school students who were engaged in a research intensive program that also included daily discussions (after each full day of research on a research topic that lasted for close to one week) on different aspects of science perception, ethics, science vs. science fiction, science careers, etc.; 2) both faculty, undergraduate students involved, and high school students felt they learned a great deal from this experience; 3) continuous interaction with other members of CRYSTAL Atlantique in which we shared our experiences and learned from each other.

The theme was common and as can be seen from all different contributions, they all show informal learning/teaching could be more profound and with more lasting experience than the conventional approach. The common result of the research of different teams is that even for a junior level student, at almost any age, a short research experience has a positive impact on learning. In the case of high school, research-intensive but short programs—probably the activities outside research which is in individual labs—worked as a glue of the team of students involved which makes a feeling of a community among students, undergraduate student helpers, and directors of the program.

I think this sense of community of people curious and excited about science is behind the joy that many students, student helpers, and directors of program felt despite the intensive nature and hard work involved. Maybe that is why one of the Go Global science students wrote to us, “this was the best experience I have had in my life!” It was also one of the best experiences in my life.

Another common factor among several groups involved in CRYSTAL Atlantique, including Go Global science, was building a student-mentor relationship between students involved in the program and directors of the programs. I include undergraduate student program leaders in the category of the directors of the program and therefore as mentors. The built student-mentor relationship lasts longer than formal student-teacher relationships. This is despite the fact that such research-intensive programs have been less than 10 days while formal teaching makes teacher-student interaction close to a year or longer.

Robert Hawkes
Professor of Physics
Mount Allison University

Too rarely do scientists work directly with science education researchers in an intensive manner. CRYSTAL Atlantique offered this opportunity, and that may well be the most lasting legacy. Science education research experts provided expertise in quantitative, qualitative, and community of practice research methods, while scientists helped focus the research on authentic aspects of science. The CRYSTAL program has been terminated after the pilot stage by NSERC, but I hope that in some format NSERC will encourage that interaction in the future.

The experience of sharing our campus and research labs for seven to 10 days with the bright, enthusiastic, and idealistic high school participants in the Go Global: Science Research program has left an imprint that will last a lifetime on all of us. While they certainly learned much from the program, so too did we all learn from their fresh eyes and fresh outlooks, in particular their idealistic exuberance.

While CRYSTAL Atlantique in many ways operated as parallel research programs, the regular meetings where we shared approaches and early results was a valuable bridging experience. For example, even though we worked with older students, and in a different environment (extended residential experience vs. class related day experiences), our Go Global: Science Research had much in common with the environmental education research by Diane Pruneau and her group. Also, from the outset we had interests in student perceptions of the nature of science, and we learned much from the expertise of Steven Turner in this area.

One advantage of multi-year programs is the opportunity to refine and evaluate. One change we made part way through was to introduce discussion sessions on questions such as ethical aspects of science research, and the portrayal of scientists in the media. The maturity and energy that the students put into these discussions, and the associated written reflections, made me wonder why we so rarely incorporate similar aspects into university science courses. This is just one area where I think the research reflected here could inform the scholarship of teaching and learning in higher education.

The theme of our contribution to this volume dealt with the impact of authentic science research experiences for true engagement. In many ways CRYSTAL Atlantique was itself an exercise of engagement through authentic science education research.

Tang-Ho Lê
Professor of Computer Science
Université de Moncton

I have learned from the CRYSTAL Atlantique project that informal learning can have different forms. Many of them give effective results to the students' learning. As a teacher, I believe that we must exploit these forms which are appropriate for our students.

I have participated in this project with a software tool (OCOWS: Online Co-operative Working System). It is a tool for both teachers and students and is used with the approach of problem-based learning. On one hand, the experimentation with hundreds of attended students showed that the students like the "dynamic" content, thus they adapt easily and rapidly to any lesson's context. On the other hand, the teachers have the tool to create the "problems" which are attractive and challenging for their students.

I believe that OCOWS is an appropriate educational tool for collaborative learning, because with a group of students, many sources may be found rapidly on the Web and be easily integrated into the content. The content becomes richer and more attractive. Students are well motivated and creative because they build the lesson's content (or formulate the solution) by themselves with the teacher's supervision and help. They would archive their work like an artist looking forward to finish his masterpiece to contemplate it.

Many times in this experimentation, I was surprised at the content created by the teachers and at the solutions developed by the students, too. Certainly, the human creation is great! Finally, in the technological context of our society that progresses rapidly, I hope that experiences gathered in this project will motivate us to create more educational tools, not only as OCOWS on a website, but as a new mobile learning tool.

Essie Lom
Teacher-Administrator (Retired); Organic Orchard Owner
Graduate Student—Philosophy of Education Doctoral Degree (Completed)

For four years during my time as a graduate student, I was fortunate to be part of the Science in Action project. Despite my limited experience as a researcher, I quickly found a place at the table. My interest in teacher professional development began early in my three-decade teacher/administrator career. My own PD experiences were usually disappointing, mostly because they were neither relevant to my teaching nor collaborative. One-shot presentations or one-day workshops were sometimes thought-provoking, but rarely impacted my practice. So when I joined the Science in Action project, I wondered how the teacher-facilitators would perceive the experience. Would they consider their efforts to be a form of professional development? And if they did, what was the nature of this learning? Would this new knowledge impact their own practice? This is a unique research perspective in the literature on informal learning, which usually focuses on the student participants. What I learned confirmed my own perceptions that the adult learning was significant and relevant.

The opportunity to confer with colleagues and content experts, trial-run the activities, and then use student data to evaluate and fine-tune content delivery provided valuable professional development. For these teachers, who mostly were not science specialists and lacked confidence in their delivery of the prescribed science curriculum in their classrooms, the impact on their own practice was significant. In addition to this discovery, I learned that involving participants in the analysis of the interview data can provide a second, richer source of data.

The discussions during this analysis revealed even more about what these teacher-facilitators learned and felt about participating in the project. What a novel idea! Trusting these teachers to be research analysts was consistent with their role as collaborators throughout the project. Overall, what I have discovered is that informal learning must be flexible but organized, collaborative but consistently directed. The richness of my experiences in the CRYSTAL project will continue to enrich my thinking.

Lisa Lunney Borden
Assistant Professor of Aboriginal Education and Mathematics Education
Saint Francis Xavier University
Graduate Student—Doctoral Degree Completed

I began my doctoral studies at UNB in 2005, working with Dr. David Wagner. CRYSTAL arrived at UNB around the same time and, in many ways, it seems we were destined to meet one another. After 10 years of teaching and leadership in a Mi'kmaw school, I suddenly had space to read, think, and reflect on my experiences. As a teacher, I had taken every opportunity I had to talk with elders in the community and learn about words and ideas, but I was anxious to make talking with community elders about mathematics a big part of my new role as doctoral student and, as luck, or perhaps destiny, would have it, Dave had funds through CRYSTAL to do just that.

As a teacher I had always told my Mi'kmaw students that community mathematical knowledge existed even if it didn't make it into the textbooks. Our conversations with elders reinforced this idea. The chapter Dave and I have written for this book begins with a story from our very first interview with elders and this initial conversation has influenced much of the work I have done since. As we describe in this chapter, Show Me Your Math (SMYM) emerged as a result of this conversation with the elders, particularly inspired by the words of Diane Toney, the quill box maker, and was made possible through our initial CRYSTAL Funds. SMYM invites children to engage with elders and other community members to examine the mathematical reasoning that is used daily within the community. Since 2007, thousands of Mi'kmaw students have participated in the SMYM program and each year approximately 200-250 students present their work at the annual math fair.

As I completed doctoral studies and became a professor of math education at StFX, Dave and I continued to work together on SMYM. However the CRYSTAL funding was coming to an end and we worried about how SMYM might be sustained. We had no reason to worry however, as Mi'kmaw Kina'matnewey (MK), the education collective of Mi'kmaw communities in Nova Scotia, agreed to sustain the program, ensuring funding would be in place for the annual math fair each year, and schools agreed to fund their own transportation to the event.

In recent years, SMYM has been enhanced and expanded through funding made available through the Tripartite Forum Fund in Nova Scotia, a collective of Provincial, Federal, and MK authorities. SMYM has received funds to provide professional learning opportunities for Mi'kmaw and public school teachers, to develop the website (showmeyourmath.ca), and to encourage wider participation. Funding has also come from other sources including the Aboriginal Health and Human Resources Initiative (AAHRI), the Department of Education and Early Childhood Development in Nova Scotia (EECD), and the Canadian Mathematics Society (CMS). Each organization has seen the value in enhancing mathematical learning experiences for Aboriginal youth.

Tripartite funding has also supported the development of inquiry units drawing from the ideas generated in SMYM student projects. By connecting curriculum concepts to the topics students have explored, teachers are supported to make more explicit connections to curriculum concepts while still beginning in community practice—beginning with common sense and necessity. The funding has allowed us to bring more elders and community members into classrooms so that children and teachers can learn together, with elders and community members as guides. Units have been developed that examine the mathematics of birch bark biting, paddle making, maple syrup making, drum making, bead work, and more. In fact, next year, almost all of the MK schools will be taking on an inquiry project. We call this program *Mawkinumasultinej! Let's Learn Together!* and it is shaping the way we think about pulling in mathematics. All of this has been possible because of the initial funding from CRYSTAL.

As a final note, Diane passed away from a heart attack the day before Dave and I had planned to go and have a follow-up conversation with her. It was a heartbreaking loss, but her spirit has lived on in SMYM as students explore her quillwork to learn the mathematics that Diane knew as common sense.

Leo MacDonald
Professor of Science Education
Saint Francis Xavier University

The CRYSTAL Atlantique project allowed several complex and interacting projects to be coordinated or carried out at St. Francis Xavier University (StFX). This research project was led by Ann Sherman and myself and involved science educators, scientists, students, and teachers from Nova Scotia. It has shown that informal learning plays an important role in the development of young people and teachers in Atlantic Canada. For young learners, informal learning provides a way for them to gain confidence and envision themselves in science roles that are meaningful to them. Informal learning also affords young people with the opportunity to take control of their own learning in ways that are not always possible in typical school science contexts. For science teachers (particularly at the elementary and middle school levels), the informal learning opportunities that our science kits provided allowed them to enhance their own knowledge of science topics and to interact with their students in ways that were more easily achieved with the support of the science learning resources provided in our curriculum-focused science kits. For the young teens whose science research ideas were supported by StFX scientists, this project offered them opportunities to do much of the work that scientists do and learn about science as a potential career. Many of the students involved in this project have subsequently gone on to pursue science more formally as a career. I continue to be amazed by the generosity of the scientists at StFX who participated in this project. Virtually all of them had personal stories to tell us about how informal learning experiences in their youth helped them to pursue science as a career. If nothing else, informal science learning seems to engender a spirit of collegiality and collaboration, two important qualities for any learner to have.

While the CRYSTAL Atlantique project supported several different research projects at StFX, two projects in particular have emerged as ones with the staying power to continue after the CRYSTAL project has ended. One is a science camp project for young students led by Truis Smith Palmer, and the other a science teacher support project involving science kit development led by myself and Ann Sherman. Both of these projects have characteristics in common: they are easily scalable to include more people and they are fiscally self-sustaining. These characteristics are important because we all know that in the field of education anything that is worthwhile will attract more people, and the money one has to begin a project is always very limited and tends to disappear far too quickly.

We enjoyed the opportunity to share our research at a variety of levels, with science education researchers at many national and international research conferences, including national CRYSTAL conferences, and with teachers at several province-wide science teacher meetings. All of these interactions allowed us to develop new professional connections and friends. In particular, our research involving teacher professional support offered us opportunities to share our ideas with curriculum developers in New Brunswick, Alberta, and with other international researchers interested in science kits. Ann Sherman and I are proud of the fact that the number of science teachers from school boards across New Brunswick and Nova Scotia who are actively using our science kits continues to grow over time. In fact, Ann and I have continued to collaborate in this research area.

The CRYSTAL Atlantique project has taught me that a professional collaboration does not require researchers to live in the same region. I very much enjoyed the opportunity this project provided to work with other science education researchers across our Atlantic region and across Canada. But the StFX portion of this project would not have succeeded without the participation of one colleague in particular. Ann Sherman's academic career took her to two new universities during the CRYSTAL project. Despite this, she remained intensely involved in the research throughout. I am thankful for Ann's resiliency and remain indebted to her for seeing this project through to the end. I think that resiliency is not impeded by geography if one has dedication, collaboration, and a sense of humour—and friendship.

Chadia Moghrabi
Professor of Computer Science
Université de Moncton

I came to the CRYSTAL Atlantique project with a formal science and math undergraduate education and a doctoral computing education. My initial involvement was naturally to create e-learning content where teachers and students would collaborate on teaching and learning. Moreover, my research has always concentrated on artificial intelligence and its application to real world problems. So the CRYSTAL Atlantique project started with creating mathematical content for teaching polynomials where students could learn theory and practice on problems. They had a forum to discuss problems, and instructors could monitor and intervene in case there were any misconceptions. LogiAuteur was an in-house software tool that allowed teachers to upload any existing content material in any format. We did not want to increase their work load.

The people we meet always influence us. I met Mrs. Francine Helmy, a now retired teacher and advisor in the Moncton French District who introduced me to "low tech" instructional design, and how teachers in a classroom can adapt their teaching and exercises to the learning style of students. What an encounter was this. I could at last use artificial intelligence R&D in the design of e-learning material and content.

The work was fine up till then but other questions started coming to mind. Who says that the chosen instructional design was the best? Users are imposed a certain software structure. Why? Do certain positions for the buttons and icons make life easier and hence learning in an e-learning environment easier? Thus, in the next research projects, we tested the various colour combinations and dispositions of buttons and icons on the screens and asked students of varying ages about their learning experiences. I truly believe that the presence of a software tool in any environment changes the habits of its users and its creators, if they keep an open mind.

My experience in CRYSTAL Atlantique changed the direction of my research projects. I started delving more and into learning styles and preferences. To recognize student preferences, they are usually asked to fill out long questionnaires. For example, the Myers-Briggs Type Indicator (MBTI) has more than 90 questions. Thanks to Prof. Robert Baudouin, a Université de Moncton expert on MBTI, who supplied us with 2000 filled-out forms, we could use artificial intelligence and machine learning techniques to reduce the size of the form by at least 33 percent and dynamically (as they are being filled out) by up to a median of 80 percent.

My experience in the CRYSTAL Atlantique changed, also, my own teaching. I always made it a point to give ample examples during my classes. But now, I make sure my examples cover a variety of learning styles and preferences. So thanks to this project, I feel that I started out as a software developer allowing at-your-pace-e-learning and ended up as a better teacher, researcher, and learner all informally and unintentionally!

Diane Pruneau
Professor of Environmental Education
Université de Moncton

The CRYSTAL project made us aware that although the objective of teaching students to solve environmental problems is a difficult task, it is achievable. These complex, open, and multidisciplinary problems are made up of many qualitative and quantitative dimensions: indicators, actors, causes, impacts, obstacles to the solution. Informal learning and in particular field trips are really useful for students when solving environmental problems. In fact, students need to observe on site the various elements of a problem in order to construct at once, a specific, large, and vivid representation of it.

This is why field trips accompanied by scientists to guide the observations can nourish the systemic and connective thinking of students by refining their representation of the studied problems and by helping them create connections between the different elements of a problem. Learning on a field trip also acts as an important source of motivation in environmental education because students can interact with their peers, develop an attachment to the natural environment and have, through the experience of solving real problems, an impression of being able to make a difference in the quality of life of their community.

The exchanges with CRYSTAL colleagues allowed us to criticize and to refine our pedagogical interventions and our research methods with students in problem solving. Among other things, we got acquainted with new data collection tools such as prompts and participative videos. The CRYSTAL project also served as a training tool for our science teaching. We learned the strong pedagogical value of some informal approaches in teaching science: summer camps, afterschool programs, and student visits in scientific laboratories. Just like field trips in environmental education, these informal approaches (being outside and/or working in collaboration with peers and with scientists on real problems) seem to represent a source of intrinsic motivation within students in science.

Ellen Rose
Professor of Educational Technology and Instructional Design
University of New Brunswick

I feel very fortunate to have had the opportunity to be part of CRYSTAL Atlantique. However, to be honest, when Karen first invited me to participate in the project, I was rather reluctant. I thought about research—or at least, my research—as a solitary undertaking that would only be slowed or sidelined by the need to connect with others who were doing very different kinds of research in very different areas. Further, I couldn't perceive a place for my own research on instructional design and technology beneath the CRYSTAL's informal learning umbrella.

From the first of the group's colloquia, however, it became clear that there were interesting synergies between our diverse research areas and interests. For example, Viktor Freiman and Tang-Ho Lê were clearly doing work that overlapped in interesting ways with my focus on designing effective, engaging online learning, while Steven Turner and Karen Sullenger's investigations into the shaping of public and student beliefs about technology and science had strong linkages with my research on teachers' attitudes to instructional design. Over time, I came to understand that much of my research had to do with understanding how concepts develop outside of formal structures for learning; I found a place for myself beneath the informal learning umbrella. And, seeing how well team-based projects worked for others in the CRYSTAL, I conducted my first collaborative research studies with graduate student assistants.

Ultimately, being part of CRYSTAL prompted me to begin thinking differently about what research is and can be, largely as a result of the opportunity to work with others: to collaborate with student-researchers, to share my research with other members of the CRYSTAL, and to begin to see how our very different areas of study intersected in interesting and potentially fruitful ways. As I said in *On*

Reflection (2013), a book written while I was a member of CRYSTAL, "the essence of reflection is synthesis: the creation of new ideas, perspectives, and possibilities." I have no doubt that this observation was influenced by my CRYSTAL experience and the kinds of syntheses it made possible.

Ann Sherman
Dean, Faculty of Education
Professor of Science Education
University of New Brunswick

I have enjoyed my participation in CRYSTAL Atlantique and gained many valuable insights through the partnerships and collaborations that have developed. Leo MacDonald and I worked together at St. Francis Xavier University (StFX) when Karen Sullenger approached us to help submit a proposal to CRYSTAL. We diligently prepared our portion of the proposal that would bring together a group of scientists and science educators from StFX and other Nova Scotia higher education institutions.

Once the grant was awarded, Leo and I worked on several projects related to Informal Science Education. We worked with Truis Smith-Palmer to prepare engaging science activities for her Chemistry Camps, held annually on the StFX campus. We interviewed young children who were camp participants and designed an active inquiry interview process that engaged children in activities from the camp to help them describe their learnings from the camp. We used this process with children as young as six year of age.

Leo and I also interviewed the camp instructors both at StFX and also at a University of Calgary science camp that ended in a presentation/paper at AERA. This gave us interesting findings that we could apply to our work in teacher education.

We also completed a project with an afterschool science program that existed in Antigonish and this led to interviews with local scientists about their interests in supporting young developing scientists in high school.

In another project, we developed science kits for classrooms at the elementary level to provide support for alternative ways to teach science. While not strictly informal science, these kits moved teachers away from traditional approaches to teaching science. We were fortunate to be invited into a large number of classrooms where we could interview students. By this time, I had moved to the University of Calgary and also interviewed a number of teachers using kits developed by the Alberta Science Foundation. This allowed Leo and me to do some interesting comparisons of professionally developed kits (graphic artists, machine-made activities) with our "homemade" kits.

Leo and I have certainly gained from our research through CRYSTAL with new contacts, collaborators, insights from our research, and it has allowed us to expand and extend our research into new and different areas. Researchers contemplating a large collaborative project such as CRYSTAL Atlantique should be aware of the necessity to have clear policies and practices in place as they begin the project and of the importance to clearly understand how the research group will collaborate and share results and funding. With these in place, our CRYSTAL project was able to enjoy success.

Truis Smith-Palmer
Professor of Chemistry
Saint Francis Xavier University

As a professor, I have always been both a scientist and an educator. In the CRYSTAL collaboration, however, I focused on a younger age group and began to seriously engage in reflection on the scientist-youth interaction. These youth are growing up in a world that is based on science and it is important that they grow up in a culture of science. I am currently even more involved in facilitating school workshops on science and camps on our campus, in First Nation communities, and in a variety of rural communities. Our program last year reached 6000 youth.

The discussions and interactions with my CRYSTAL collaborators inspired me to expand our program, but more particularly they have influenced how we present our material and interact with the students. I continue to ask questions of the teachers, parents, and students we work with to ensure that we are meeting the goals we have set. Discussions with CRYSTAL collaborators at our meetings have left lasting impressions and play in my head as I plan new workshop and camp activities. Not only does this program expose the targeted youth to a culture of science, but also their siblings, friends, and parents, and last, but not least, my camp leaders. These undergraduates, fresh from learning complicated scientific principles, are exposed to a broad smorgasbord of science and gain great joy from realizing what they know and passing on their love and excitement in science as a whole.

It is this passion for understanding science, for discovery of the world around us, that drives scientists and is at the heart of the culture of science, and it is the joy of science that we hope to awaken in the hearts of youth. My time with CRYSTAL Atlantique has enabled me to share this passion in many different ways, and especially to focus on hands-on, discovery-based learning with materials that are relevant to the lives of the children involved.

Karen S. Sullenger
Professor of Science Education
University of New Brunswick

CRYSTAL Atlantique opened so many opportunities for me. The project allowed me to pursue my research and personal interests. My vocation is science education, more specifically, exploring the nature(s) of science, the role of writing in teaching and learning science, and more effective learning contexts. I want to know at what age children can grapple with understanding scientists' ideas, what it is scientists do, and what it would be like to be one. What I learned through the years, especially through my collaborations with Steven Turner, is that we need to shift what counts as knowing science from an accumulation of knowledge to understanding science as an enterprise, a research culture, an occupation—it is what a group of people who call themselves scientists do and think.

The CRYSTAL project allowed me to create and study a context in which young learners could focus on studying scientists, interacting with scientists, gaining insight into what it is to be a scientist. I was fortunate to also create a small research community of colleagues, teachers, educators from community-based science organizations, as well as graduate and undergraduate students. Though membership changed throughout the years due to things like retirement, pull to other undertakings, and graduation, a core of us remained.

As a small community of researchers, we learned a lot about how young learners are able to grapple with and develop more complex understandings of scientists and their work. We learned as well some of the challenges of studying informal contexts and developing strategies to address them. I learned even more about directing large and small groups of researchers. When I began, I believed in shared decision making, in choosing the role you want in a research project, allowing roles to change, and especially, I believed that research is integral to our lives, not something that our lives interfere with or disrupt. Members of the Science in Action research team taught me that I didn't have to come up with all the questions, research ideas, or curriculum. Whether I assigned them, suggested to them, and/or allowed them to choose areas of responsibilities, they ran with them. Not that we didn't clash at times; the vision I had for a learning community was foreign to most of them—I wasn't sure what was possible myself when we began. Over time each of us grew; teachers talked about being responsible for the program not just being passive participants, graduate students took responsibility for certain questions—they not only shared their progress and concerns as they learned to become researchers, over time they developed a critical eye for research and effective research practices. They were giving feedback, gaining a voice.

I learned even more from my colleagues who were also creating small research teams and pursuing their own aspects of our research threads. Each one shared their work, their insights, and their questions and strategies. I applied much of what I learned to my own work. In some cases, we collaborated on projects and conferences, in others we shared new insights and/or problem solved. As a leader, I learned that trusting in the work and decisions of each lead researcher was more effective, a richer experience, than holding us as a group to some fixed plan we initially put forward even at the expense of drawing criticism.

My avocation is the environment and as such it causes me much consternation. I am pulled between extremists on all sides who want control to implement some good they deem important. From my experience, rarely are these groups willing to educate people and allow them to make their own choice—an informed decision about any issue. Instead, they create biased messages—more interested in indoctrinating than educating. As one person said to me when I asked how they had come to their decision, “I first read and talked to people but there is not enough time now for the public to do the same.” For me, the Science in Action research project we implemented and studied was a step in creating a space where children, as young people, could interact with others, learn for themselves, and find their own way.

R. Steven Turner
Professor of History of Science
University of New Brunswick

My academic and research background lay exclusively in the history of science and in contemporary science studies. Stimulating conversations with Karen Sullenger, however, piqued my interest in science education. Once into the research literature I was appalled to find the field relatively little-influenced by recent findings from the discipline of science studies concerning philosophy of science, scientific method, and science-and-society relationships. But conversely, science-studies theorists largely ignored science education. Yet another research field with which I was professionally familiar was the Public Understanding of Science (PUoS). There, too, I was frustrated to discover that the research community largely ignored how public understanding is shaped by K-12 science education or youth experience in general, and conversely that the findings of the PUoS seemed unknown to most researchers in the field of science education.

Today, thanks to bold border-crossing by many key scholars, this unhappy disciplinary fragmentation is no longer as acute as formerly. But that earlier, sorry state of affairs, and the clear need to overcome it, awakened my enthusiasm about CRYSTAL Atlantique. I welcomed CRYSTAL’s focus on science as culture; its dogged interdisciplinary commitment; and its idealistic determination to bring together scientists, science-educators, K-12 teachers, museum personnel, science-outreach experts—and me!—to ferret out and address our common problems and passions. CRYSTAL Atlantique was sprawling, it was sometimes anarchical, and it was wildly different from what our national NSERC patrons had envisioned. But by the end, an unlikely community had been built, collaborations forged, insights broadened, and valuable research sponsored and developed.

The most important thing I learned about informal science education from the CRYSTAL collaboration is this: that the study of informal science education is closely linked to the PUoS, and that both are central to what may be the most important issue in K-12 science education today: the engagement problem. A large body of research literature suggests that while younger children exhibit enthusiasm for and interest in science in early grades, that intense engagement disappears for a substantial majority during the junior high school years, to an extent not observed in other school subjects. Whether one is concerned about adequate recruitment into the STEM disciplines, or about science as a prerequisite for enlightened citizenship, or science as an invaluable culture legacy, disengagement today is a central problem. It cannot be addressed adequately by the study of formal science education, because so much of the problem lies outside the formal curriculum: in peer attitudes, media presentations, cultural imagery, and day-to-day encounters with science-and-technology-related issues and problems. Recognizing that fact brings, or ought to bring, the study of informal science education to the centre of the research agenda. CRYSTAL Atlantique has strived to promote that movement to the centre.

David Wagner
Professor of Mathematics Education
University of New Brunswick

The five-year CRYSTAL Atlantique was a formative time in my research career. I joined the Faculty of Education at the University of New Brunswick when Karen Sullenger was leading the writing of the proposal. She invited me to be a part of the group. The collaborations within the project were significant in these first six years (proposal writing plus five years within the grant) after completing my PhD. There are a number of important benefits I experienced from participation. The project fostered cross-disciplinary connections with other scholars within the region. This collaboration began with my first experience writing a research grant proposal. The funding, for which I am very thankful, supported me in important research, which allowed me to develop some good relationships within Aboriginal communities in the region, to better understand the development of mathematical understanding in these communities, and to share this understanding through publication. The funding also supported conference presentations and thus supported even further development of relationships, in this case with people in my field of mathematics education research. These conference presentations and subsequent elaborated publications have made an impact among researchers who study the socio-cultural context of mathematics education, and also among professionals who are modelling programs on the Show Me Your Math program that came out of my research in CRYSTAL Atlantique.

My understanding of informal education also developed through the project, which is the most relevant impact in relation to this book. As I wrote in the introduction to Section Two of Part Two of this book, the discussion amongst CRYSTAL Atlantique's researchers helped me to realize that research in informal contexts compels attention to the values of participants, and thus to their cultures and formative experiences. I think we as a research group learned together that research in school contexts seems to be privileged in education scholarship. Such research is important, but the relative lack of attention to informal learning is regrettable. I would suggest that there would be good reason to compare learning in formal and informal contexts and thus garner insight into both kinds of contexts. Bringing alongside two paradigms is generative for understanding and for drawing attention to phenomena that are otherwise taken for granted. Perhaps the best example of this principle was the research collective of CRYSTAL Atlantique itself. The conversations amongst natural scientists, education researchers, and community partners afforded us all insight into each other's activity, and this insight opened new ways of seeing our own fields.

WHERE TO FROM HERE?
SOME FINAL THOUGHTS ON THE FUTURE OF INFORMAL LEARNING RESEARCH

Our attempt to share the experiences and results of CRYSTAL Atlantique concludes with this ensemble of voices, these personal statements. The range of voices, and of speakers, is as diverse as was CRYSTAL itself: It has included educators, teachers, students, chemists, physicists, computer scientists, historians, and science centre personnel. No two speakers have expressed exactly the same views, nor claimed to have taken the same insights from the CRYSTAL experience, but all have echoed the significance of the enterprise.

But we intend that this conclusion also be a beginning: an invitation to a larger conversation about broadening the current boundaries of research and deliberation about informal learning. In our view, current research has focused too exclusively on museums and science centres as sites of informal learning in science and technology; has restricted the scope of inquiry by evaluating the potential of informal learning primarily as an extension of the school curriculum; and has sought the worth of informal learning too narrowly in its potential to improve students' attitudes and interest-levels in school science. All these are worthy areas of study and discussion, but the experience of CRYSTAL Atlantique suggests there is more, much more.

Broadening the boundaries of research in informal learning means recognizing the diversity of contexts in which informal learning occurs. Students are drawn to these contexts because the projects engage them in multiple ways: they challenge students intellectually, elicit voluntary participation, and promote attachments that are not only cognitive in nature, but also emotional, personal, cultural, social; they can promote reverence for place and respect for context and environment. And broadening the boundaries of research into informal learning also means recognizing the potential of many researchers whose principal area of interest may lie outside the field to contribute to informal learning research. The studies presented in this volume demonstrate that diversity of context and that diversity of voices. They have, for example, included investigations with online problem-solving communities in mathematics and computer science, environmental problem solving, opportunities for first-hand encounters with science and scientists, and an array of camps, clubs, and programs that shape young people's understanding of science beyond the formal classroom.

In 2000, Falk and Dierking dubbed informal learning "free choice learning," and challenged researchers to explore the implications of freedom and choice in the educational process. Today we echo and extend their challenge by stressing the need to interrogate informal science learning in new and broader ways, by asking the kinds of questions which have emerged in this volume. We have asked about the new understandings of science, mathematics, and technology made possible through informal learning, explored the interface of these understandings with culture, age, and context, and analyzed the nature of these concepts themselves when studied in an informal learning context. These questions, and their answers, can be subversive. Understandings of science, technology, and mathematics gained through informal learning can be very different from those gained through school science, and school science alone is considered to mirror "official" understandings. For example, the CRYSTAL Atlantique project on ethnomathematics among Canada's Aboriginal peoples demonstrates how different such cross-cultural understandings can be. Who, then, gets to decide which understanding will count as "correct," which will be rewarded in school and career, and which will inform official curriculums? CRYSTAL Atlantique projects have shown very young children capable of grappling with the complexities of science, mathematics, and technology, problem solving, the role and work of the scientists, and the concept of "being" a scientist. How, then, are we as educators and researchers to evaluate these understandings as correct or incorrect, informed or uninformed? Who will decide?

If the research agenda of the past has been to recognize informal learning as about free choice, then today that agenda must be expanded to ask about the implications of free choice. Educators need to ask substantive questions about the contribution of informal learning to understanding science, mathematics, and technology; about its role in forming lifelong learners; and about the informal learning's impact on culture and community. We need to explore the ways in which informal learning is a learning context in its own right, and ask who is drawn to learning in this way, and why, and whether what they learn informally is unique or merely different.

Whether our individual concern is with effective public understanding of science, positive attitudes, recruitment into STEM careers, sustained citizen engagement and participation, critical cultural appreciation, heightened environmental consciousness, or scientific literacy, the road to deeper understanding leads inevitably over a new commitment of educational research everywhere to address informal science learning in all is complexity and diversity. Nothing else will satisfy the requirements of a twenty-first century global culture in which science and scientific outlooks will be central to human aspirations, and in which science itself may find itself under threat. We hope that CRYSTAL Atlantique has confirmed that agenda and helped point us all in the direction of those deeper understandings.

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CRYSTAL Atlantique researchers were prolific, with over 200 publications and presentations. However, of this number, *not one* of the papers ended up in informal learning publications. Very few of the presentations were given at informal learning gatherings. Without the frame of this book, it is likely that this body of work would be lost to the informal learning community.

Interdisciplinary research communities like CRYSTAL have the potential to broaden and enrich the informal learning field. The interdisciplinary context creates opportunities to connect, share, network, and promote. It connects people with diverse research areas, who might not do informal learning research on their own, or might not otherwise think of their work as informal learning research. Within such a community, they can share their individual and academic expertise. Networking across academic disciplines exposes members to new perspectives and emerging theories. The interdisciplinary context promotes border crossing; the result is new voices, new questions, and new strategies.

The challenge is to make such work visible to the more traditional informal learning community, rather than allowing it to become fragmented along disciplinary lines. We hope this book contributes to that goal.

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Freiman, V. (2005). *Internet challenge CAMI: taste of mathematics through problem solving, communication, & technology*. A presentation at the NAGC Annual Congress, Louisville, KN.

Freiman, V., & Lirette-Pitre, N. (2005). *Innovative approach of building connections between science and math didactics in pre-service teacher education using wiki-technology.* Presentation at The First International Symposium of Mathematics and its Connections to the Arts and Sciences (MACAS 1), The University of Education, Schwäbisch Gmünd, Germany.

Freiman, V., Lirette-Pitre, N., & Manuel, D. (2007). *Building a virtual community of problem solvers: The CASMI project***.** Communication at the International Conference on Mathematics Education in a Global Community, Charlotte, NC.

Freiman, V., Manuel, D., & Lirette-Pitre, N. (2007). *CASMI: Communauté d'apprentissages scientifiques et mathématiques interactifs*. Presentation at CRYSTAL Atlantique Colloquium, Mount Allison University, Sackville, NB.

Freiman, V., Lirette-Pitre, N., & Manuel, D. (2007). *Building virtual learning community of problem solvers: Example of CASMI Community*. Communication at the Second International Symposium on Mathematics and its Connections to the Arts and Sciences, Odense, Denmark.

Freiman, V., Manuel, D., Lirette-Pitre, N., Blain, S., Essiembre, C., & Beauchamp, J. (2007). *Mathematical connections in the New Brunswick notebook computer project: Solving real-world problems by grade 7-8 francophone schoolchildren.* Actes de colloque the ninth, The International History, Philosophy and Science Teaching Group, Calgary, Alberta.

Freiman, V., Deguire, P., Vichnevetski, E., Kerry, J., Therrien, J., & Pruneau, D. (2010). *Comment se manifestent les compétences mathématiques chez les employés de la ville lors de la résolution de*

problème d'adaptation aux changements climatiques? Presentation at Colloque du Groupe des didacticiens des mathématiques du Québec, Moncton.

Hawkes, R. L., Poirier, A., Archibald, L., & Karis Allen, L. (2005). *Unusual forms of learning*. Invited presentation as part of Bright Ideas session in Mount Allison Teaching Day.

Hawkes, R. L., Archibald, L., Karis Allen, L., & Poirier, A. (2005). *Journal writing in a science course: Faculty and student perspectives*. Presentation at Society for Teaching and Learning in Higher Education Conference, Charlottetown.

Hawkes, R. L, Ehrman, J., Jarvis, E., & Bowen, X. (2012). *Seeing physics fast, near, and far: Photographic techniques for the physics lab*. Presentation at Canadian Association of Physicists Division of Physics Education, Calgary, AB.

Hawkes, R. L. (2012). *Making physics learning authentic*. As part of a panel of 3M STLHE Award Winners at the Canadian Association of Physicists Division of Physics Education, Calgary, AB.

Hawkes, R. L. (2012). *10 questions about astronomy*. Presentation at Sackville Starry Nights, Mount Allison University, Sackville, NB. Also televised by Eastlink TV on Podium TV.

Hawkes, R. L. (2012). *Looking back in time*. Presentation at Campbell Carriage Factory, Sackville, NB.

Hawkes, R. L. (2013). *Making physics classes active, engaging, interesting, and relevant: Where have we been and where are we going?* Presentation at Canadian Association of Physicists Annual Congress (invited plenary), Montreal, QC.

Hawkes, R. L. (2013). *The asteroid impact hazard*. TEDx Moncton Talk.

Kerry, J., Pruneau, D., & Langis, J. (2010). *Scientific and environmental competencies*. Presentation at ACASE, Charlottetown.

Kerry, J., & Pruneau, D. (2010). *Competencies demonstrated by municipal employees involved in a climate change adaptation proces*s. Presentation at Forum jeunesse Youth on the Coast, Charlottetown.

Kerry, J., Pruneau, D. & Therrien, J. (2011). Skills demonstrated by municipal employees and farmers during their adaptation to climate change. Presentation at *Conference of the Environmental Studies Association of Canada,* Fredericton.

Langis, J., Gauvin, J., Pruneau, D., Freiman, V., Ouellet, E., Cormier, M., & Lirette-Pitre, N. (2006). *Aider les jeunes à résoudre des problèmes environnementaux*. Presentation at Conférence EECOM Le Sel de la Terre. White Point Beach Resort, Nova Scotia.

Langis, M., & Pruneau, D. (2008). *Students' abilities in posing an urban environmental problem*. Presentation at Research Symposium of the North American Association for Environmental Education 2008.

Langis, J., Barbier, P-Y., Kerry, J., Pruneau, D., & Iancu, P. (2009). *Research on competences for sustainability*. Presentation at World Environmental Education Congress, Montréal.

Langis, J., Kerry, J., Pruneau, D., & Cousineau, M. (2011). *Développer des compétences environnementales et scientifiques chez les élèves*. Workshop at Congrès annuel de l'Association des enseignantes et des enseignants du district 11 au Nouveau-Brunswick, Shediac.

Léger, M.T., Pruneau, D., Langis, J., & Kerry, J. (2014). *De nouvelles compétences à développer à l'école: Perceptions et praxis en enseignement*. Presentation at Congrès 2014 de l'APTICA, Moncton, NB.

Lirette-Pitre, N., & Freiman, V. (2007). *Building the virtual collaborative community CASMI: Communauté d'apprentissage virtuelle scientifiques et mathématiques interactifs*. Presentation at CRYSTAL Atlantique Colloquium, Mount Allison University, Sackville, NB.

Lirette-Pitre, N., & Freiman, V. (2008). *CASMI: Une communauté virtuelle d'apprentissages scientifiques et mathématiques interactifs*. Presentation at Colloque La numératie … la tangente à prendre, Ottawa.

Lom, E., & Sullenger, K. (2009). *Professional development lurking in informal spaces*. Presentation at American Educational Researcher Association annual meeting, San Diego.

Lom, E., & Sullenger, K. S. (2010). *Informal spaces within collaborations: Pushing the boundaries of professional development*. Presentation at American Educational Researcher Association annual meeting, Denver.

Lom, E., & Sullenger, K. S. (2011). *Teachers' experiences developing an innovative science program: A look at professional growth*. Presentation at American Educational Researcher Association annual meeting, New Orleans.

Lunney, L. (2007). *The art of making mathematics meaningful*. Presentation at Dreamcatching Conference, Regina.

Lunney, L., & Wagner, D. (2007). *After this research: Questioning authority when non-Aboriginal people do research in Aboriginal communities*. Presentation at 24th Annual Qualitative Analysis Conference.

MacDonald, A. L., & Sherman, A. (2005). *Pre-service educators' perspectives on a science education module*. Presented at the American Educational Research Association Annual Meeting, Montreal.

MacDonald, A. L., & Sherman, A. (2005). *Pre-service educators work with a science education module*. Presented at the Canadian Society for the Study of Education Annual Meeting, London, Ontario.

MacDonald, A. L., & Sherman, A. (2006). *Grade five students working with science models*. Presentation at American Educational Research Association annual meeting, San Francisco, CA.

MacDonald, A. L., & Sherman, A. (2007). *Summer chemistry camps for young children*. Presented at the National Association for Research in Science Teaching Annual Meeting, New Orleans, LA.

MacDonald, A. L., & Sherman, A. (2007). *Interviewing young children*. Presented at the American Educational Research Association Annual Meeting, Chicago, IL.

MacDonald, A. L., & Sherman, A. (2008). *Elementary science teachers' use of kits*. Presented at the American Educational Research Association Annual Meeting, New York, NY.

MacDonald, A. L., & West, C. (2010). *Measuring kinematics data for high speed rocket cars*. A full day in-service for teachers at the St. F.X. Physics Teachers Workshop, St.Francis Xavier University Physics Department.

MacDonald, L., Sherman, A., & Li, Qing (2011). P*edagogic understandings of student leaders in Canadian science summer camps*. Presentation at Canadian Society for the Study of Education annual meeting, Fredericton, NB.

MacDonald, L., Sherman, A., & Li, Qing (2011). *Pedagogic understandings of science summer camp leaders*. Presentation at National Association for Research in Science Teaching Annual Meeting, Orlando, Florida.

Manuel, D. (2007). *Résolution de problèmes en mathématiques: une étude des perceptions des élèves et des enseignants participant au projet CASMI*. Presentation at Concours de jeunes chercheurs ACFAS-Acadie. Université de Moncton, Moncton, NB.

Manuel, D., Freiman, V., & Lirette-Pitre, N. (2006). *CASMI: Une nouvelle communauté virtuelle d'apprentissages scientifiques et mathématiques interactifs*. Presentation at Congrès APTICA, Université de Moncton, Moncton, NB.

Manuel, D., Roy, G., Freiman, V., & Lirette-Pitre, N. (2007). *CASMI: Tout un site à explorer*. Presentation at Congrès APTICA, Université de Moncton, Moncton, NB.

Marmen, D., & Sullenger, K. (2009). *Who comes to after school science programs: A study of diversity and informal learning*. Presentation at SMArts (Science, Mathematics, and the Arts) Conference, University of Moncton, Moncton, NB.

Milley, E., & Hawkes, R. L. (2005). *Promoting understanding of abstract concepts through personal use of digital video resources*. Presentation and display at Mount Allison Teaching Day.

Moghrabi, C., Chiasson, J., & Mazerolle, R. (2006). *Teacher directed opportunities: Designing effective software tools*. Presentation at CRYSTAL Atlantique Colloqium.

Morrison, P., Peck, D., Marmen, D., & Sullenger, K. S. (2007). *Middle school students' views of themselves doing science*. Presentation at Informal education: Engaging elementary and middle students in conversations about doing science (Symposium). Science Teaching and Learning SIG of the American Educational Research Association, Chicago, IL.

Nicol, C., Andrew-Ihrke, D., Archibald, J., Brown, L., Burton, D., Cajete, G., Commodore, J., Dawson, A., Kelleher, H., Lipka, J., Lunney Borden, L., Nielsen, W., Owuor, J., Rigney, L., Wagner, D., & Yanez, E. (2008). *Creating sustainable change: Alternative perspectives on culturally responsive* *approaches to mathematics teaching and learning with/in Indigenous communities*. Panel discussion, Annual Meeting of the American Educational Research Association, New York, NY.

Peck, D., Morrison, P. Marman, D., & Sullenger, K. (2007). *Is what we are doing science? Middle school students' perspectives of scientists and themselves doing science*. Presentation at Elementary and Middle school students' engaged in science: The potential of informal education (Symposium). National Association for Research in Science Teaching, New Orleans, LA.

Peck, D., & Sullenger, K. (2008). *Enhancing science understanding for middle school students through interactions with a field botanist*. A poster session presented at the National Association of Research in Science Teaching annual conference, Baltimore.

Peck, D., & Sullenger, K. S. (2009). *Exploring place and learning science - Connecting students and the community of science*. Presentation at World Environmental Education Congress, Montreal, PQ.

Peck, D., Poirier, B., & Sullenger, K. (2009). *Writing for communicating and understanding ecology field experiences in middle school.* Presentation at National Science Teachers' Association, New Orleans, LA.

Peck, D., & Sullenger, K. (2009). *Collaborations between teachers and scientists—The impact of EcoAction*. Presentation at Association of Science Teacher Educators, Hartford, CT.

Pruneau, D. (2006). *Aider les jeunes à résoudre des problèmes environnementaux*. Presentation at Colloque Avancées et propositions en matière d'éducation pour le développement durable, Paris.

Pruneau, D. (2010). *Construire chez les élèves des compétences liées à la durabilité dans le cadre d'un travail sur les controverses environnementales*. Presentation at École d'été pour pédagogues leaders en éducation au développement durable, Université Laval, Montréal.

Pruneau, D. (2006). *Creativity techniques that help youth pose and solve environmental problems*. Presentation at The 52nd Annual International Creative Problem Solving Institute, Chicago, IL.

Pruneau, D. (2006). *Des outils pédagogiques pour aider les jeunes citoyens à poser un problème environnemental*. Presentation at Journées scientifiques de l'Agence universitaire de la francophonie, Mostaganem, Algeria.

Pruneau, D. (2006). *The powers of environmental education*. Presentation at l'Université de Sao Paulo, Faculté d'économie.

Pruneau, D. (2010). *Perceptions des enfants au sujet de leur environnement et des nuisances à leur santé*. Presentation at Café scientifique: La santé des enfants et l'environnement, Moncton, NB.

Pruneau, D. (2008). *Quand le territoire devient lieu: l'éducation comme outil d'appropriation et de reconstruction de son territoire*. Presentation at Colloque Patrimoine et la gouvernance des territoires: à la recherche de l'esprit du lieu. 21e Entretiens du Centre Jacques Cartier, Québec.

Pruneau, D. (2010). *Renforcer des compétences scientifiques durant l'accompagnement de citoyens dans un projet d'écodéveloppement*. Cours Approche écosystémique en santé, UQAM, Montréal, PQ.

Pruneau, D., Barbier, P. Y, Freiman, V., Utzschneider, A., Therrien, J., & Langis, M. (2009). *The development of young citizens' sustainability related skills*. Presentation at World Environmental Education Congress, Montréal, PQ.

Pruneau, D., & Baribeau, T. (2006). *Les pouvoirs de l'éducation relative à l'environnement*. Presentation at II Seminario Aquifere Guarani, Urubici, Brazil.

Pruneau, D., Baribeau, T., Duckworth, E., Fullerton, J., et al. (2006) *Creating research partnership*. Presentation at Conférence 2006 de l'Association des musées canadiens, St. John, NB.

Pruneau, D., Chouinard O., Therrien, J., Demers, M., & Cherry, L. (2008). *Climate change and solutions*. Symposium at the 8th National Conference on Science, Policy and the Environment. Washington, DC.

Pruneau, D., Freiman, V., Lirette-Pitre, N., & Cormier, M. (2006). *Creativity techniques that help students pose and solve environmental problems*. Presentation at North American Association for Environmental Education: Pre-Conference Research Symposium.

Pruneau, D., Freiman, V., Lirette-Pitre, N., Gélinas, V., & Langis, J. (2005). *How students state environmental problems*. Presentation at North American Association for Environmental Education Pre-Conference Research Symposium, Albuquerque, NM.

Pruneau, D., Freiman, V., Paun, E., Barbier, P.-Y. et al. (2008). *Des outils pédagogiques pour aider les jeunes citoyens à poser un problème environnemental*. Presentation at Conférence de l'Agence universitaire de la francophonie, Québec.

Pruneau, D., Kerry, J., & Langis, J. (2014). *Competences that can guide and facilitate citizen's involvement in the construction of ecologically viable communities*. Presentation at International Conference on New Development in Science and Technology Education, Corfu, Greece.

Pruneau, D., Kerry, J., & Langis, J. (2014). *Les compétences pouvant guider et faciliter l'engagement des citoyens dans la construction de communautés écologiquement viables*. Presentation at Congrès de l'ACFAS, Montréal, PQ.

Pruneau, D., Kerry, J., Langis, J., & Laroche, A. M. (2012). *Les compétences particulières d'adaptation aux changements climatiques observées chez des agriculteurs.* Presentation at Congrès de l'ACFAS, Montréal, PQ.

Pruneau, D., Kerry, J., Langis, J., & Léger, M. L. (2014). *De nouvelles compétences à développer chez les élèves du primaire en sciences et technologies. Pratiques et possibilités*. Atelier du CRSH: Synthèse des connaissances sur le développement de compétences pour répondre aux besoins futurs du marché du travail canadien, Ottawa, ON**.**

Pruneau, D., Kerry, J., Mallet, M-A., & Freiman, V. (2011). *Champions de l'adaptation: Des agriculteurs démontrent des compétences exceptionnelles d'ajustement de leurs pratiques aux changements climatiques*. Presentation at Conférence des éducateurs de l'Atlantique, Moncton, NB.

Pruneau, D., Kerry, J., Mallet, M., Freiman, V., Langis, J., Laroche, A., Vichnevetski, E., Deguire, P., Therrien, J., Lang, M., & Barbier, P.-Y. (2012). *Skills demonstrated by municipal employees and farmers while adapting to climate change*. Presentation at Congrès Climat 2100: Préparons-nous! Information, outils et stratégies pour les collectivités du N.-B., Fredericton, NB.

Pruneau, D., Langis, J., & Kerry, J. (2013). *Développer de nouvelles compétences environnementales chez les élèves*. Presentation at Symposium francophone 2013. Faculté des sciences de l'éducation, Université de Moncton, Moncton, NB.

Pruneau, D., Langis, J., Kerry, J., Freiman, V. Lang, M., Blain, S., Léger, M., Deguire, P., & Fortin, G. (2014). *Des compétences pour la construction d'un Canada durable et résilient*. Presentation at Conférence du CRSH: Imaginer l'avenir du Canada, Moncton, NB.

Pruneau, D., Langis, J., Kerry, J., Lang, M., & Fortin, G. (2013). *Développer des compétences d'action et de réflexion chez les jeunes*. Presentation at 7th World Environmental Education Congress, Marrakech.

Pruneau, D., Langis, M., & Therrien, J. (2008). *Research for designing climate change education and communication strategies*. Presentation at Research Symposium of the North American Association for Environmental Education 2008.

Pruneau, D., Langis, M., & Therrien, J. (2008). *Building vulnerable communities' capacities to implement climate change adaptations*. Presentation at Conference of the North American Association for Environmental Education 2008**,** Wichita, KS.

Pruneau, D., & Utzschneider, A. (2011). *Bringing up baby in the city — Making kid friendly cities a reality. Young people's decision making process during a conservation design project*. Presentation at Ecocity World Summit, Montréal.

Pruneau, D., & Utzschneider, A. (2008). *The decision-making process of students involved in a sustainable residential development project*. Presentation at International Sustainability Conference, Basel, Switzerland.

Pruneau, D., & Utzschneider, A. (2007). *How do we internationalize sustainability education? Challenges and opportunities*. Presentation at the North American Association for Environmental Education Conference.

Pruneau, D., & Utzschneider, A. (2010). *Involving citizens in sustainable urban development*. Atelier Lorman: Subdivision Development in New Brunswick. Moncton, NB.

Pruneau, D., & Utzschneider, A. (2007). *Students and their decisions in a sustainable neighbourhood*. Poster at the North American Association for Environmental Education Conference.

Pruneau, D., & Utzschneider, A. (2007). *Students' decision making process while involved in sustainable development projects*. Poster at the Research Symposium de la North American Association for Environmental Education Conference.

Pruneau, D., & Utzschneider, A. (2008). *Students' decision making process while involved in SD projects*. Presentation at International Education for Sustainable Development Conference, Winnipeg, MN.

Pruneau, D., & Utzschneider, A. (2010). *Involving citizens in sustainable urban development.* Atelier Lorman: Subdivision Development in New Brunswick, Moncton, NB.

Pruneau, D., & Utzschneider, A. (2011). *Bringing up baby in the city — Making kid friendly cities a reality. Young people's decision making process during a conservation design project*. Presentation at Ecocity World Summit, Montréal, PQ.

Sherman, A., & MacDonald, A. L. (2007). *Chemistry camp experiences for six and seven year olds*. Presented at the Canadian Society for the Study of Education, Saskatoon, SK.

Sherman, A., & MacDonald, A. L. (2007). *Entering the world of the child through interviews*. Presentation at the 19th Annual conference of the Ethnographic and Qualitative Research in Education Conference, Cedarville, OH.

Sherman, A., & MacDonald, A. L. (2007). *Instructional leadership in elementary school science*. Presentation at the International Conference of History and Philosophy of Science Teaching, Calgary, AB.

Sherman, A., MacDonald, L., & Scheaffer, H. (2010). *Crates in the classroom—enabling inquiry based science*. Presentation at American Educational Research Association Annual Meeting, Denver, CO.

Sullenger, K. (2009). *The impact of an informal learning program on students' perceptions of writing as integral to scientists' work.* Presentation at SMArts (Science, Mathematics, and the Arts) Conference, Universite de Moncton, Moncton, NB.

Sullenger, K. (2009). *Who is interested in pursuing science studies outside the classroom - an argument to end school science studies?* Presentation at SMArts (Science, Mathematics, and the Arts) Conference, Universite de Moncton, Moncton, NB.

Sullenger, K. (2009). *Writing and or in science: The shift from writing as an assignment to writing as essential to scientist's practice*. Presentation at SMArts (Science, Mathematics, and the Arts) Conference, Universite de Moncton, Moncton, NB.

Sullenger, K. S., & Cashion, M. (2007). *Science in Action: Can we get it right?* Presentation at Informal education: Engaging elementary and middle students in conversations about doing science (Symposium). Science Teaching and Learning SIG of the American Educational Research Association, Chicago, IL.

Sullenger, K. S., & Cashion, M. (2007). *Joining an extra school science program: Is there any effect on classroom science experiences?* In Elementary and Middle school students' engaged in science: The potential of informal education (Symposium). National Association for Research in Science Teaching, New Orleans, LA.

Sullenger, K. S., & Cashion, M. (2007). *Science In Action: Implementing a new approach to informal education*. Presentation at Elementary and middle school students' engaged in science: The potential of informal education (Symposium). National Association for Research in Science Teaching, New Orleans, LA.

Sullenger, K. S., Edwards, M., Lom, E., Peck, D., & Marmen, D. (2006). *Science in Action: What it means to participate in a collaboration*. A symposium presented at the Conference of Atlantic Educators, Charlottetown, PEI.

Sullenger, K. S., Edwards, M., Morrison, P., Peck, D., & Cashion, M. (2006). *Science in Action: An after school program to engage students in science*. A symposium presented at the Conference of Atlantic Educators, Fredericton, NB.

Sullenger, K., & Freiman, V. (2008). *Choosing to study mathematics and science beyond the classroom: Who participates and why?* Presentation at AERA 2008 Annual Meeting, New York, NY.

Sullenger, K., Freiman, V., Pruneau, D., & Lom, E. (2011). *CRYSTAL Atlantique: Informal learning across science, mathematics and technology*. Presentation at Conférence des éducateurs de l'Atlantique, Moncton, NB.

Sullenger, K. S., Heatherington, J., Gowen S., Pacey J., & Brown, J. (2007). *Science in Action: Informal learning to enhance science understandings and attitudes*. Presented at the National Science Teachers Association annual meeting, St. Louis, MO.

Sullenger, K., & Marmen, D. (2009). *Students who choose to study science: Diversity and informal learning*. Presentation at National Science Teachers' Association annual meeting, New Orleans, LA.

Sullenger, K., & Peck, D. (2009). *Emerging ecological identity: The impact of EcoAction*. Presentation at World Environmental Education Congress, Montreal, PQ.

Sullenger, K., & Peck, D. (2010). *Writing for communicating and understanding ecology field experiences in middle school.* Presentation at National Science Teachers' Association annual meeting, Philadelphia, PA.

Therrien, J., Pruneau, D., & Freiman, V. (2008). *Romanian students using problem-solving strategies while solving an environmental problem*. Presentation at Research Symposium of the North American Association for Environmental Education 2008**,** Wichita, Kansas, October 2008.

Therrien, J., & Pruneau, D. (2009) *L'éducation relative à l'environnement. Définition, objectifs et projets canadiens*. Presentation at l'Université de Nador, Nador, Morocco.

Utzschneider, A., & Pruneau, D. (2008). *Le processus décisionnel d'élèves impliqués dans un projet de développement résidentiel durable.* Rencontre des CREAS canadiens, Sherbrooke, PQ.

Utzschneider, A., & Pruneau, D. (2008). *Description du processus décisionnel de jeunes impliqués dans un projet de développement durable*. Presentation at ACFAS*,* Québec.

Varner, J., & Hawkes, R. L. (2005). *Creating an educational DVD – Promoting learning in asynchronous modes*. Presentation and display at Mount Allison Teaching Day, Sackville, NB.

Wagner, D. (2006). *Critical language awareness in the mathematics classroom*. Presentation at Doyle Nelson Lecture Series, Edmonton, AB.

Wagner, D. (2008). *Positioning and authority in ethnomathematics research*. Symposium on the Occasion of the 100th Anniversary of International Commission on Mathematical Instruction, Rome, Italy.

Wagner, D. (2008). *Positioning theory and intercultural conversations about mathematics*. Presentation at Symposium on the Occasion of the 100th Anniversary of International Commission on Mathematical Instruction, Rome, Italy.

Wagner, D. (2009). *Intercultural positioning in mathematics*. Plenary address at The Third International Symposium of Mathematics and its Connections to the Arts and Sciences, Moncton, NB.

Wagner, D., Johnson, N., & Lunney Borden, L. (2009). *Show me your math: Inviting community knowledge of mathematics*. Presentation at Dreamcatching conference, Winnipeg, MB.

Wagner, D., & Lunney, L. (2006). *Common sense, necessity, and intention in ethnomathematics*. Presentation at PMENA-28.

Wagner, D., & Lunney, L. (2007). *"Show me your math": Inviting children to do ethnomathematics*. Presentation at PMENA-29.

CONFERENCE PUBLICATIONS

Barbier, P. Y., Pruneau, D., & Freiman, V. (2007). Reframing a research project design on how six graders pose an environmental problem within a romantic understanding imaginative framework: An hypothesis. *Proceedings of the Second Annual Research Symposium on Imaginative Education*, Vancouver, BC. Available online: http://www.ierg.net/confs/viewabstract.php?id=360&cf=4

Barhoumi, A., & Moghrabi, C. (2009). Learner directed opportunities through adaptive hypermedia systems. In *Interdisciplinarity for the twenty-first century: Proceedings of the Third International Symposium on Mathematics and Its Connections to Arts and Sciences, Moncton* (Vol. 2011, pp. 155-165).

Freiman, V. (2008). Richer mathematical learning and teaching opportunities using Web-based problem solving environments. In R. Leikin (Ed.), R*esearch and promotion of creativity and giftedness in mathematics: What is done and what should be done? Proceedings of the 5th International Conference on Creativity in Mathematics and Education of Gifted Students* (pp. 107-116), Haifa, Israel: CET.

Freiman, V. (2008). Distance learning and development of creativity through various solutions. In *Multiple solution connecting tasks*. Proceedings of the International Research Workshop of the Israeli Science Foundation (pp. 31-36). Tel Aviv: CET.

Freiman, V., & Gandaho, I. (2005). New curriculum reform in action: New Brunswick's pre-service teachers communicate with schoolchildren on mathematical problems via Internet site CAMI. In *Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications 2005* (pp. 2816-2820). Norfolk, VA: AACE.

Freiman, V., Lirette-Pitre, N., & Manuel, D. (2007). Building a virtual community of problem solvers: The CASMI project. *Proceedings of the International Conference on Mathematics Education in a Global Community*. Charlotte, NC.

Freiman, V., Lirette-Pitre, N., & Manuel, D. (2008). Building a virtual learning community of problem solvers: example of CASMI Community. In B. Sriraman, C. Michelson, A. Beckmann, & V. Freiman (Eds.), *Proceedings of the Second International Symposium on Mathematics and its Connections to the Arts and Sciences* (pp. 209-222). Odense, Denmark.

Freiman, V., & Manuel, D. (2007). Apprentissage des mathématiques. In S. Blain, et al. (Eds.), *Les effets de l'utilisation de l'ordinateur portatif individuel sur l'apprentissage et l'enseignement*. Rapport final. Présenté au MENB par le CRDE et l'équipe de recherche ADOP, Université de Moncton.

Freiman, V., Pruneau, D., Barbier, P.Y., Ouellet, E., Langis, J., Liboiron, L., & Baribeau, T. (2008). How students pose an environmental problem: Case of Grade 3 students trying to reduce sedimentation in a river. *Conférence annuelle de l'American Education Research Association*, New York.

Ho T., Vinh, B.D., Nguyen, T., Lê, T-H., & Long, D. (2006). Collaborative e-learning and in context method. *3rd National Symposium on Research, Development and Application of Information and Communication*, ICT.rda06. Hanoi, Vietnam.

Langis, M., & Pruneau, D. (2008). Students' abilities in posing an urban environmental problem. *Proceedings of the 2008 North American Association for Environmental Education Research Symposium,* Wichita, KA. Online: Naaee.org.

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