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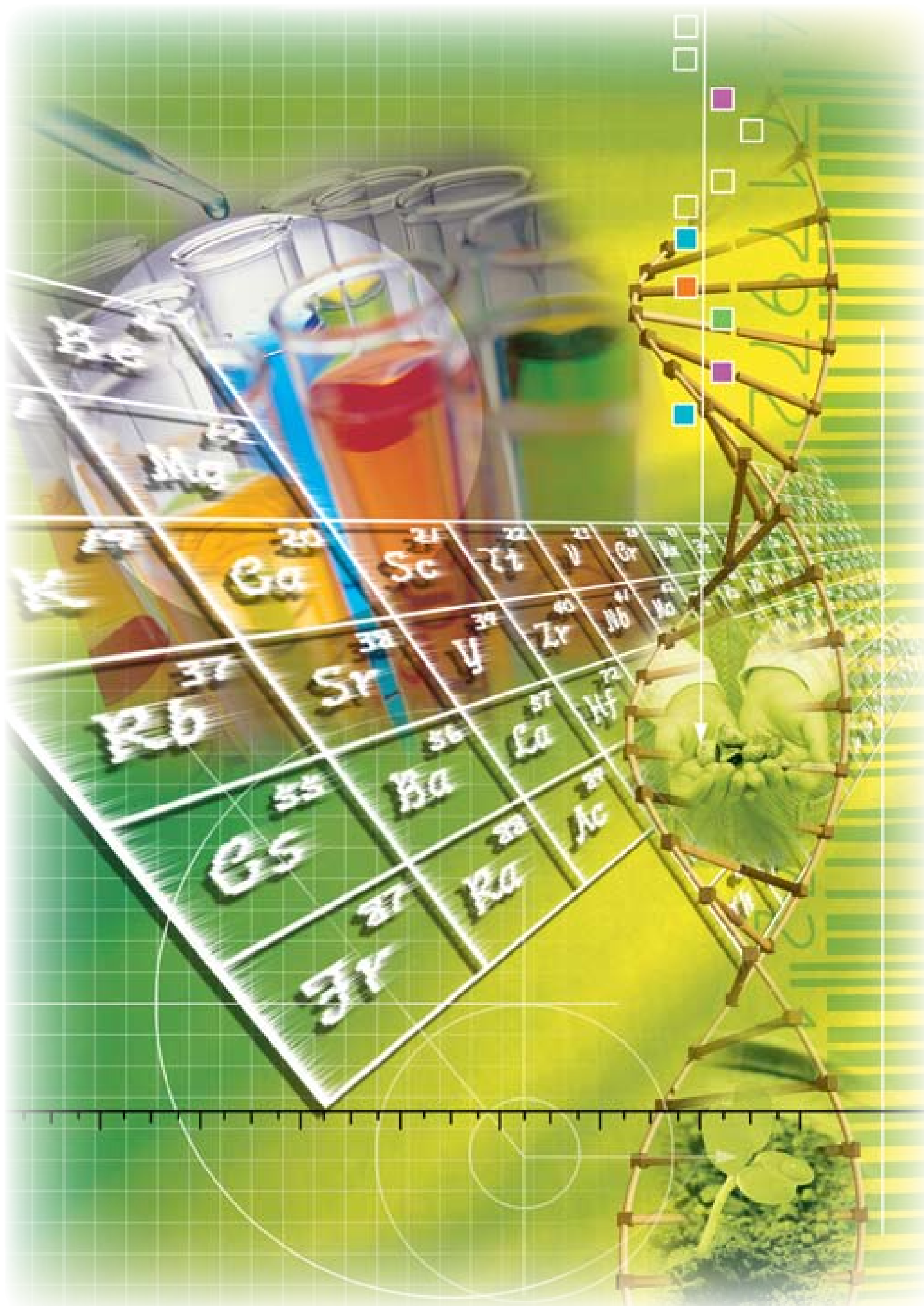

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Contents

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Personal information regarding any person named in this document is for the sole purpose of professional consultation between members of The Alberta Teachers' Association.

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From the Guest Editor

Research and Representations of Inquiry in Science Teaching and Learning

I am very pleased to present this collection of refereed articles written by science educators from across Canada for the *Alberta Science Education Journal.*

This special issue contains clearly written articles that will inform those new to the profession and present information on topics representing the most recent thinking on teaching and learning in science. Each article has a clear message and focus; is strongly founded on research in the field; and provides insight into an important aspect of current thinking about science teaching and learning, or analyzes an aspect of good teaching.

Serendipitously, some common threads run through the articles in this issue. The authors have a collective interest in considering new ways to help teachers and learners build ideas about more effective and personally meaningful engagement in inquiry and science. All the authors are also interested in the ways in which science inquiry is represented to and interpreted by students.

Dawn Sutherland and Sarah Klassen, of the University of Winnipeg, examine the representation of science in children's nonfiction science trade books since the 1960s. Science trade books are extensively used to support and extend science learning in the classroom, particularly in the early grades. The authors found significant differences in the books over the years. They distinguish representations of science as inquiry from representations of science as a process in design technology. Awareness of these two forms of representation in the books children are reading is very useful. It helps teachers consider and select resources to support science learning that contain significant messages for learners about the nature of science and the potential for personal engagement in science as inquiry or design.

Brenda J Gustafson and Marie-Claire Shanahan, of the University of Alberta, write about the role of argument in science inquiry learning. They argue that using teaching strategies that focus on the importance of constructing good arguments to support the conclusions and interpretations of personal inquiries helps portray a more authentic view of science for learners. This view represents science as a socially constructed enterprise rather than as a body of facts to be mastered. The authors show how building arguments about inquiries that are personally meaningful adds further interest and motivates learners to engage in the use of logic and supportive evidence, contributing to a view of science as the systematic process of building models about phenomena. They argue that this reflects the way knowledge is formed in the larger scientific community, and that engaging in the process of forming and supporting arguments helps learners build the intellectual skills they need to become scientifically literate citizens.

Steve Alsop and Sheliza Ibrahim, of York University, build strong foundations for conversations about how to shift thinking about teaching from an emphasis on the traditional triad of school–teacher–curriculum to consideration of a new triad: learner–community–place. Working with teachers in the field, the authors explored the deeper implications of these triads and new ways of engaging in practice. In an effort to enact, test and discuss ideas surrounding the new triad, they encouraged learners to identify science in the community by having them use digital cameras to record images of what they considered to be instances of science in their own environments. As they shared and discussed the products of their work, learners informed fellow students and their teachers about what was personally meaningful and engaging for them, the kinds of topics they considered to be typical of science and the images they held of science. Student photographs became starting points for discussion and more advanced inquiry and research deeply rooted in personal interest, thus creating rich opportunities for deeper study.

John Lawrence Bencze, of the Ontario Institute for Studies in Education (OISE), University of Toronto, contributes an extensively field-tested framework for scaffolding the ongoing development of students' expertise used in conducting science inquiries. Based on constructivist learning theory, the framework suggests ways to draw out students' preinstructional understanding and suggests a philosophical foundation and practical approach to help learners gain the skills they need to conduct more student-led inquiry projects. Bencze makes a number of suggestions for overcoming barriers to helping students learn to engage in what he terms realistic inquiry. As teachers gain experience working with inquiry teaching strategies, and as students build the skills and understanding needed to engage in inquiry, Bencze's approach suggests ways to build bridges to more advanced opportunities that help students conduct inquiry at increasingly higher stages—toward more fully student-directed, open-ended science inquiry projects in the context of units of study.

Each well-written article offers a thoughtful, well-researched perspective on inquiry work in science education. I thank the many reviewers who provided comments on and critiques of all the articles submitted for publication. A warm thank you goes to Wytze Brouwer, for his invitation to serve as guest editor and for his ongoing support. I would also like to thank the editorial staff of the Alberta Teachers' Association for their support and assistance. It has been an honour to work with colleagues in this process, and this special issue has stimulated much ongoing discussion and work.

This set of articles is designed to be read and studied by student teachers who are preparing to teach, and by teachers who are learning to work in informal or public science venues. I hope that teacher educators, researchers and experienced practitioners will also find the articles of great interest, and that the publication will be useful in inservice work, as well.

—Bonnie Shapiro

Bonnie Shapiro is a professor in the Faculty of Education at the University of Calgary.

Distinguishing Inquiry from Design in Children's Nonfiction Science Trade Books

Dawn Sutherland and Sarah Klassen

Abstract

Teachers of early years science education often use children's science trade books as resources for class instruction and science fair projects. These books serve as a historical lens through which to examine the perceptions of science in various decades. The objective of this study was to compare the definition and portrayal of science and technology in children's nonfiction science trade books in various decades, beginning with 1960. The guiding question was, How are science and technology distinguished from one another in general science trade books from 1960 to the present? A total of 93 science trade books containing a definition of science were analyzed for their descriptions of science, technology and the science inquiry process. It is clear from the analysis that references to context, applied science, motivation and interest are prevalent in children's science trade books of the last two decades. The impact of these findings and suggestions for teachers are discussed.

In early years science education, children's science trade books—books published for a general audience—are often the resources of choice for use in classroom instruction and science fair projects. Trade books are more accessible to both teachers and students, through school and public libraries, than are textbooks. In the past 20 years, the production of trade books has increased tenfold. The use of trade books, on their own or to complement textbooks, has been encouraged as a way to explore scientific information in greater detail. With the increased emphasis on scientific inquiry in science education, the demand for trade books has become even greater.

Research on reading has demonstrated that students are more motivated to read trade books than textbooks, because trade books usually cover a topic in more depth. Science trade books can serve as a historical lens through which to examine the perceptions of science in various decades. However, as Ford (2006) notes, rather than following trends in science curricular reform, the trade book industry tends to respond to the demands of the public and buyers from large bookstores.

The objective of this study was to compare the portrayal of science in children's nonfiction science trade books in different decades, beginning with the 1960s. With the rise of constructivist theories of education and reading, as well as the introduction of technology into many science curricula, it was hypothesized that the books' representation of science would change over the decades.

Literature Review

Trade Books and Science Education

The past 40 years has seen a boom in the production of science trade books, and the number of trade books published each year has increased tenfold since 1990 (Kralina 1993). As well, the use of trade books has increased in the early and middle years science classroom. Rice (2002) cites the following reasons for the increased use of trade books in the science classroom: trade books are easily integrated with whole language and thematic curricula (Mayer 1995); trade books provide a context for understanding science concepts (Dole and Johnson 1981); and trade books are more interesting and less confusing for children than are textbooks (Ross 1994). A trade book likely serves as a child's introduction to science (Barlow 1991).

Integration, multimodal representations and whole language are all focuses of many current curricula, and they are the primary reason that science trade books have been introduced into classroom teaching. Several primary and middle schools use science trade books to support the whole-language component of the science program. This approach incorporates reading, writing and verbal activities into science inquiry work.

Science trade books are often used as a basis for thematic units. Several published teacher resource books promote the use of children's literature to teach science (Butzow and Butzow 1994, 2000; Culham 2004; Gertz, Portman and Sarquis 1996). Many theme-based units combine fiction and nonfiction books as a foundation for theme work. Some Canadian examples are the units "Owls in the Family," "Habitats and Communities" and "The Human Body." Some teacher support material links science inquiry activities to specific trade books in the field.

Although these uses of science trade books in the classroom continue, there have been few investigations into the effectiveness of trade books in achieving science learning goals (Royce and Wiley 1996). One of the few empirical studies examining the effectiveness of a specific trade book on the development of science concepts in students was conducted by Mayer in the mid-1990s. Mayer (1995) reviewed the use of a popular children's book about whales called *Dear Mr. Blueberry* (James 1991). After reading the book to 16 young students, she interviewed the students and found that the book had unintentionally confused some of them through its misrepresentations and illustrations. Rice (2002) modified Mayer's study to include a pretest and a posttest on whales, as well as adding some nonfiction books about whales. She found that children changed their prior ideas about whales based on the information in the books and that they were unable to distinguish between inaccurate and accurate science content. Mayer's and Rice's research suggests that we should examine a trade book's content for both its scientific accuracy and its representation of science, and consider how the content may affect the development of children's science concepts.

Philosophy of Science and Technology

Educators and trade book authors are faced with a dilemma when it comes to portraying science in the classroom and in books. In their efforts to motivate and engage students, they risk representing science inaccurately. Some books are overly relativistic in their definition of science, presenting science as being everywhere and everything. Relativistic definitions of science affect how science can be portrayed in the classroom. If science is everywhere and everything, there is no need for a science inquiry process.

To connect science with the technological reality of students' everyday lives, some trade books include technological examples to describe the nature of science and science concepts. Technology and the design process are both important aspects of Canadian science curricula, but they are distinct from science inquiry.

Trade books that describe science in enthusiastic tones can be useful in the classroom; however, teachers should develop an awareness of how science and technology are portrayed in trade books and choose a variety of books to balance out the representations of these disciplines.

The resurgence of inquiry activities in science is attributed to US guidelines for work in science, such as *Science for All Americans* (American Association for the Advancement of Science 1989) and the *National Science Education Standards* (National Research Council 1996). These publications also highlight the need for students' increased awareness of technological design. In many Canadian curricula, science and technology are taught alongside one another as representing two aspects of science: the science inquiry process and design. Rudolph (2005) explores the implications of current classroom practice on public understanding of science using a more expansive definition of inquiry in which inquiry and design activities are taught alongside each other. He raises a concern about the unreflective selection of inquiry activities in the science classroom, when teachers select design- and technology-related activities to cover science learning outcomes. Rudolph suggests that the selection of such activities may misrepresent the nature of science.

It is easy to see why design and applied science inquiry activities have become part of school science programs. Design-related activities are contextual and can more authentically illustrate the methods and applications of science in a real-world context (Rudolph 2005). Design-related tasks can also be more motivating for students. They generate student interest through clearly identified criteria and, in some cases, the competitive nature of the task. Rudolph raises two concerns associated with the rise of applied science inquiry activities. The first concern is that the blending of applied science inquiry activities in a science unit or lesson may result in missed opportunities to explore the unique processes of technology (Cajas 2001). The second concern is the conflict students may encounter with the classroom inquiry activity and the nature of science portrayed in many textbooks.

Emergence of Constructivist Theories in Education

Constructivist theories have had an impact in both reading and science education. Rosenblatt (1991) suggests that a transactional view of reading is dominant in the research on the teaching of literacy. A transactional view of reading and writing sees literacy as a meaning-construction process, and within a given literacy event, both the text and the reader/author are changed. In the field of science education, constructivist thinking is extensive (Solomon 1994). In most forms of constructivist thought, the prior knowledge of the learner is considered and involved in the introduction of scientific ideas. New science content becomes a newly constructed meaning. Both of these guiding frameworks suggest teaching approaches that emphasize the need for students to engage in the meaning-construction process.

These two predominant views of engaging students in their own learning may have also influenced the way books and resource materials for teachers and students are produced. Our study examined how this influence may be apparent in the literature and how general science books for children have changed over the years.

Methods

The following procedure was used to select the books to be included in the study. A search of the Library of Congress database and of the public and education libraries in Winnipeg was conducted. The keywords used in the search were *science* and *juvenile literature.* The search found 333 books, of which 227 were available through the public library system and interlibrary loan. Each book was reviewed. Only general science books were selected for this study; topic-specific science books (for example, a book about light) were excluded. A total of 93 books, approximately 28 per cent of the original 333 books, were included in this study.

Each book then went through three different evaluations. The first evaluation was an examination of the intent or purpose of the book. The book's introduction or preface was read, and the book was then categorized as either a content-intent or a process-intent book. A content-intent book was one that described its purpose as having children do science experiments to learn the content of science. For example, Gutnik's (1980, 1) *How to Do a Science Project and Report* describes science as "the accumulations of verified or proven facts or laws, put together in an orderly system in order to be communicated to other people." Bingham (1991, 2) explains that his book "will help you explore basic science principles of physics, chemistry or biology by trying experiments on your own and with your friends."

A process-intent book typically describes its purpose as exposing the reader to participation in a scientific process or endeavour. For example, Jay Ingram (1992), in his book *Real Live Science,* describes science as a "bunch of questions and nobody has all the answers. When you do the activities in this book you'll feel what it is like to be a scientist looking for those answers." Bill Nye (1993, 2) explains, "In a way, science is how we handle every question in our lives. … Science is the way we *figure out* how to do these things. Scientists, maybe scientists like you, call this way of doing things 'the Scientific Method.' … It's a process, a path, a road to learning that we humans have come up with. Not bad."

The second evaluative task was to determine whether a book contained an explicit or an implicit description of science. Ford (2006) used any of the following three criteria to determine whether a book offered an explicit description of science: use of terms such as *science, scientists and scientific knowledge;* naming a scientist or a specialty; or describing a scientific activity. Similar criteria were used in this study. Passages explicitly describing science were entered into a database. A total of 27 books contained such passages in their introductions.

Each book that contained an explicit description of science was then assessed using the Nature of Science Trade Book Profile questionnaire. This questionnaire is a modified version of the Nature of Science Profile in Turner and DiMarco (1998). The following three statements were used to evaluate the extent of relativism in each book's definition of science:

1. The results that pupils get from their experiments are as valid as anybody else's.
2. The science facts are what scientists agree they are.
3. There are certain physical events in the universe which science can never explain.

As Ford (2006) notes, some books cannot be classified using these criteria: the criteria relate to scientific theories, and few children's science trade books contain scientific theories.

Each book was given a score for each statement, using a range from +5 (strongly agree) to –5 (strongly disagree), and then response scores were added. Books that explicitly agreed with or disagreed with the statement scored +/–5; books that implied agreement or disagreement scored +/–3; and books that provided a balanced view scored 0. A book's score reflected the degree to which it described science in relativistic terms. The books were then categorized by decade, and the percentage of relativistic books was calculated for each decade.

Books that explicitly described science were also evaluated in terms of whether they clearly distinguished science from technology. Some ways in which the books did so were as follows: explicitly stating that science is distinct from technology; using only science inquiry examples, not examples related to design; and not including invention.

Results

Tables 1 and 2 show the results of the study.

As shown in Table 1, almost 70 per cent of all the science trade books clearly stated, or made clear through their layout, that their intent was to have children learn science content through conducting science experiments. However, from the 1990s onward, there was a sharp increase in the number of books emphasizing the processes in science. Books published in our current decade tended to be process-intent.

As shown in Table 2, until the late 1990s, many science trade books covering general science topics did not include an explicit description of science. Of the books containing an explicit description of science, half of the books from 1980 to 1999 distinguished between science and technology, either explicitly or implicitly. None of the books in our current decade distinguished science from technology, and they often used technology examples to demonstrate science inquiry.

Table 1
Analysis of Science Trade Books in Terms of Purpose

Decade	Total number of books	Number of content-intent books	Percentage of content-intent books
2000–Present	8	1	12.5
1990–99	45	31	68.9
1980–89	24	20	83.3
1970–79	7	6	85.7
1960–69	9	7	77.8
Total	**93**	**65**	**69.9**

Discussion

The findings of this study indicate the importance of using science trade books from all decades, to balance out the differing representations of science and technology. Recent books describe the science inquiry process more completely, but they do not distinguish science from technology and they often use technology examples to demonstrate science inquiry. Earlier publications distinguish science from technology but offer science experiences that are highly prescriptive.

General science or science experiment books are an important focus of study because they are often the first books children read when planning a science fair project or developing their interest in science. As well, general science experiment books are often a teacher's first choice because they cover a variety of science disciplines in one volume. Thus, the portrayal of science in this subset of science trade books is of interest.

The publication and purchase of children's science trade books is affected by a multitude of factors, including the importance placed on science, the economy (specifically as it affects library budgets) and the publishing industry as a whole. For example, it was difficult during this study to find books published in the current decade, simply because libraries had not yet purchased them. Thus, more current science books are not as available to young readers. Students and teachers who want to explore current issues in science may have to purchase their own books rather than rely on the local library. This reality may have an impact on access to knowledge in science.

In the fields of reading and science education, concern is increasing about students' engagement with the material with which they are presented in the school system. Children's science trade books have been heralded as an attractive alternative to the standard textbook, which students often consider boring. However, this focus on engaging students may put an accurate portrayal of science at risk.

Teachers, parents and students should consider the following guidelines when selecting science trade books for their own use:

- Read the introduction to the book. Authors often clearly describe their intentions in the introduction. Some books are designed to reinforce science content through science experimentation. These books may be useful as a resource for individual exploration, but in general they contain closed science and design activities.
- Examine the introduction and contents of the book to see if science and technology are distinguished from one another. If not, the next guideline may be useful for identifying specific activities as design-based or inquiry-based activities.

Table 2
Analysis of Science Trade Books in Terms of Description of Science

Decade	Number of books containing an explicit description of science	Number of books containing a relativistic description of science	Percentage of books containing a relativistic description of science	Number of books that distinguish technology from science	Percentage of books that distinguish technology from science
2000–Present	6	2	33.3	0	0.0
1990–99	12	1	8.3	6	50.0
1980–89	4	3	75.0	2	50.0
1970–79	2	2	100.0	0	0.0
1960–69	3	0	0.0	1	33.3
Total	**27**	**8**	**29.6**	**9**	**33.3**

- Consider how the experiments are described and initiated. If an experiment is problem based, is set in context and seeks to solve a human-constructed problem, it is probably a design-related activity. If it is initiated with a question, it most likely represents a science inquiry.

References

American Association for the Advancement of Science (AAAS). 1989. *Science for All Americans: A Project 2061 Report on Literacy Goals in Science, Mathematics, and Technology.* Washington, DC: AAAS.

Barlow, D L. 1991. "Children, Books, and Biology." *BioScience* 41, no 3 (March): 166–68.

Bingham, J. 1991. *The Usborne Book of Science Experiments.* London: Usborne.

Butzow, C M, and J W Butzow. 1994. *Intermediate Science Through Children's Literature: Over Land and Sea.* Englewood, Colo: Teacher Ideas Press.

———. 2000. *Science Through Children's Literature: An Integrated Approach.* 2nd ed. Englewood, Colo: Teacher Ideas Press.

Cajas, F. 2001. "The Science/Technology Interaction: Implications for Science Literacy." *Journal of Research in Science Teaching* 38, no 7 (September): 715–29. Cited in Rudolph 2005.

Culham, R. 2004. *Using Picture Books to Teach Writing with the Traits.* New York: Scholastic.

Dole, J A, and V R Johnson. 1981. "Beyond the Textbook: Science Literature for Young People." *Journal of Reading* 24, no 7 (April): 579–82. Cited in Rice 2002, 553.

Ford, D J. 2006. "Representations of Science Within Children's Trade Books." *Journal of Research in Science Teaching* 43, no 2 (February): 214–35.

Gertz, S E, D J Portman and M Sarquis. 1996. *Teaching Physical Science Through Children's Literature: 20 Complete Lessons for Elementary Grades.* New York: Learning Triangle.

Gutnik, M J. 1980. *How to Do a Science Project and Report.* New York: Watts.

Ingram, J. 1992. *Real Live Science.* Illustrated by T Holdcroft. Toronto: Greey de Pencier Books.

James, S. 1991. *Dear Mr. Blueberry.* New York: Macmillan.

Kralina, L. 1993. "Tricks of the Trades: Supplementing Your Science Texts." *The Science Teacher* 60, no 9 (December): 33–37.

Mayer, D A. 1995. "How Can We Best Use Children's Literature in Teaching Science Concepts?" *Science and Children* 32, no 6 (March): 16–19, 43.

National Research Council. 1996. *National Science Education Standards.* Washington, DC: National Academies Press.

Nye, B. 1993. *Bill Nye the Science Guy's Big Blast of Science.* Illustrated by T Marks and T Owen. Reading, Mass: Addison Wesley.

Rice, D C. 2002. "Using Trade Books in Teaching Elementary Science: Facts and Fallacies." *The Reading Teacher* 55, no 6: 552–65.

Rosenblatt, L M. 1991. "Literature—S.O.S.!" *Language Arts* 68: 444–48.

Ross, E P. 1994. *Using Children's Literature Across the Curriculum.* Bloomington, Ind: Phi Delta Kappa Educational Foundation. Cited in Rice 2002, 553.

Royce, C A, and D A Wiley. 1996. "Children's Literature and the Teaching of Science: Possibilities and Cautions." *The Clearing House* 70, no 1 (September): 18–20.

Rudolph, J L. 2005. "Inquiry, Instrumentalism, and the Public Understanding of Science." *Science Education* 89, no 5 (September): 803–21.

Solomon, J. 1994. "The Rise and Fall of Constructivism." *Studies in Science Education* 23: 1–19.

Turner, T, and W DiMarco. 1998. *Learning to Teach Science in the Secondary School: A Companion to School Experience.* London, Routledge.

Supporting Inquiry in the Elementary Classroom: The Role of Scientific Argument

Brenda J Gustafson and Marie-Claire Shanahan

Abstract

One of the challenges of inquiry in the elementary science classroom is how to teach children about the connection between evidence and explanation. This article describes the role of argument in science and how elementary teachers can help children develop argumentation skills. Argumentation skills involve constructing, evaluating and improving on arguments in light of data. Teachers can help children understand the evidence–explanation connection through having them practise these skills and think about how the internal logic of their arguments must fit the evidence. Classroom experiences of that kind hold the promise of helping children understand about science and how to do science.

The importance of teaching science through inquiry was first noted in science education writings in the early 1900s. Dewey (1910) was one of the first to write about the importance of inquiry science, and over the following decades researchers offered ideas about the roles of teachers and children in inquiry-based classrooms (Pine et al 2006).

Currently, scientific inquiry tends to be described as including the diverse ways in which scientists study the natural world, gather evidence and formulate explanations. Students in inquiry-based classrooms are taught to pose problems, gather data, make observations, evaluate findings, test hypotheses and communicate their results to others (Lewis 2006). This description of scientific inquiry is similar to that found in Alberta's elementary science program (Alberta Education 1996), which characterizes scientific inquiry as the pursuit of answers to questions through gathering and interpreting evidence.

An aspect of scientific inquiry that has received much attention in recent years is the connection between evidence and explanation (Hanson and Akerson 2006; Osborne, Erduran and Simon 2004; Sadler 2004). Science relies on empirical evidence, and researchers argue that students should be taught how to evaluate and interpret evidence and then construct and evaluate scientific explanations. In the elementary classroom, an evidence–explanation approach to inquiry would emphasize helping children develop oral and written strategies to assist them in sharing their ideas, clarifying their reasoning and developing logical arguments to support their explanations (Shapiro 1995). An evidence–explanation approach to inquiry would also help educate students about the scientific world view and how to distinguish scientific explanations from everyday notions (Herrenkohl and Guerra 1998; Osborne, Erduran and Simon 2004). Students engaged in classroom experiences that cause them to think critically about science claims and construct arguments to support or challenge those claims would represent the beginning of a more scientifically literate citizenry.

Role of Argument in Science

Argument plays a central role in the professional practice of science (Driver, Newton and Osborne 2000; Druker, Chen and Kelly 1997; Kuhn 1993; Latour and Woolgar 1986; Osborne, Erduran and Simon 2004). Scientists construct and critique arguments as they

- critically examine science claims (weigh evidence, interpret claims, critique study design and so on), and
- attempt to resolve scientific controversies (assess alternatives and so on).

Emphasizing argument helps to portray science as being socially constructed and involving a systematic way of building models about phenomena (Smith, Snir and Grosslight 1992). This view of the nature of science is in contrast to presenting science as a body of facts to be mastered (Smith, Snir and Grosslight 1992). Instead, science is portrayed as a human endeavour in which scientists engage in argumentation as they attempt to interpret observations and construct useful explanations that can be used to predict future outcomes (Munby 1982). From this perspective, the role of argumentation in science classes is to model the way evidence is evaluated within the scientific community.

Role of Argument in Science Education

Recently, researchers have examined the role of talk and argument in helping children develop ideas *about* science and learn how to *do* science (Driver, Newton and Osborne 2000).

Children learn *about* science when their classroom experiences lead to a greater understanding of the character of science. For example, if science teaching is characterized by the presentation of facts, children will view science as the accumulation of facts to describe the natural world. If science teaching involves collecting evidence, offering a variety of explanations and arguing different viewpoints, children will view science as a process of building and revising ideas about the natural world.

Children learn how to *do* science when they work together to gain an understanding of the evaluative criteria used to generate defensible explanations (Driver, Newton and Osborne 2000). Learning how to do science involves understanding the following tasks and skills discussed by Sandoval and Reiser (2004):

- How to generate data (for example, fair tests, acceptable sample size and repeated observations)
- How to interpret data (for example, recognizing trends)
- How to understand uncertainty (for example, recognizing when evidence is unsupportive)
- How to arrive at a legitimate explanation (logically linked to evidence)
- How to justify their claims (providing reasons)

Also, from a societal or STS (science–technology–society) perspective, people have to make many personal and ethical decisions about socioscientific issues, and those decisions are arrived at through weighing scientific claims, applying ethics and morals, and coming to a resolution (Levinson and Turner 2001; Osborne, Erduran and Simon 2004; Ratcliffe and Grace 2003). When faced with media reports about issues such as global warming, stem cell research and mountain pine beetles, people must assess whether the evidence is valid and reliable, distinguish correlations from causes and observations from inferences, and arrive at a decision (Millar and Osborne 1998; Monk and Osborne 1997; Osborne, Erduran and Simon 2004). Faced with such dilemmas and the need for resolution, students need to understand argument in general, and argument in scientific contexts in particular (Osborne, Erduran and Simon 2004).

Perspectives from Argumentation Theory

Recognizing the importance of teaching argument in scientific contexts has led researchers to formulate ideas about criteria that can be used to judge the soundness of arguments.

Pre-eminent among those researchers is Toulmin (1958), who identifies specific components of reasoning that can be used to link data to a conclusion or "knowledge claim." He argues that those components are independent of the specific content and context of the argument.

Osborne, Erduran and Simon (2004) represent Toulmin's components of argument as follows:

- Claim—the explanation ("My belief is …," "What I think is true is …")
- Data—the evidence or data being used
- Warrant—the reason for accepting the claim ("Since …," "Because …")
- Rebuttal—an opposing argument ("An alternative belief is …")

Arguments constructed by students may begin as simple claims and counterclaims (for example, "I think that electrical current is used by the bulb" or "I think that electrical current is not used up by the bulb"). With support, students can progress to creating more sophisticated arguments that include data and warrants and even have a clearly identified rebuttal (Osborne, Erduran and Simon 2004). In the classroom, teachers should work toward having children construct increasingly sophisticated arguments for what they claim to be true and developing their ability to challenge arguments put forth by others.

Strategies for Developing Scientific Argumentation in the Elementary Classroom

It is clear that argumentation should be an important part of the science classroom, but many teachers find argumentation difficult to implement. Kollar and Fischer (2004) recognize that many students have little experience with formal argumentation and find it difficult. In addition, as Geddis (1991) observes, teachers may lack experience in managing discussions that enable children to construct and represent their scientific arguments.

So, what can teachers do? Researchers advise that children need explicit instruction in order to develop argumentation skills, and teachers should also establish a classroom context in which children can comfortably share ideas and support each other.

Explicitly Teaching and Supporting Argumentation Skills

Teachers should help children develop the intellectual tools they need in order to construct and critique arguments (Herrenkohl and Guerra 1998). Children have difficulty interpreting data, composing arguments and presenting arguments for and against a claim (Driver, Newton and Osborne 2000). Teachers, therefore, must use children's intellectual resources to carefully scaffold their understanding of the types of argumentation discourse (Southerland et al 2005).

Teachers should not present to children an issue such as mountain pine beetles and then expect them to marshal evidence and present arguments about their rate of spread throughout Alberta. Neither should teachers provide children with data about the colour preferences of mealworms and then expect them to independently compose arguments to support different interpretations of that data. Instead, teachers should consider how to provide a framework within which children can gradually develop these skills.

Solomon, Duveen and Scott (1992) suggest as a first step providing children with two competing explanations for a phenomenon and a range of statements that may support one theory, both theories or neither theory. Children can then be divided into groups and challenged to state a claim, select what they deem to be supporting evidence, and argue one idea or another. As the children gain confidence in the processes of thinking and discussing, they can begin to think about how to work from their own questions to generate reliable data, interpret the data and construct arguments in light of the data. For example, children participating in an activity that involves adding 25 mL of water to 25 mL of alcohol but coming up with only 48 mL of liquid can be presented with competing explanations, such as the following:

- "The alcohol evaporates very quickly."
- "There was a measurement error."
- "A chemical change occurred."
- "Molecules come in different sizes and can fit together to make a smaller volume than expected."

Children can then be given a range of everyday evidence explanations, such as the following:

- "When you add drink crystals to a glass of water, the water level does not change very much."

- "When you walk into a medical clinic, you can smell rubbing alcohol."
- "When you spill a few drops of water onto the kitchen floor, it could take all day to evaporate."
- "Burning is a chemical change, and you end up with a smaller volume of wood than you started with."

Children can then be divided into groups and asked to select supporting statements and add to them to construct a group argument.

Herrenkohl and Guerra (1998) suggest as a preliminary step discussing the various intellectual roles children can play in constructing a group argument. Children can also be provided with examples of good and poor arguments, and be guided to evaluate, critique and improve those arguments. After this initial practice, children can gradually move toward completing activities that lead to the formulation of different explanations and arguments.

Wray and Lewis (1997) use writing to help children develop a sense of what is involved in building an effective argument. They suggest using sentence stems, such as the following:

- My argument is …
- My reasons are …
- Arguments against my idea might be …
- I would convince somebody who does not believe me by …
- Evidence to support my idea is …

Kollar and Fischer (2004) take a similar approach in advocating that students be supported in developing the language of argumentation. They describe this language form in terms of scripts. Students' internal scripts consist of the words and word forms they have learned to use in everyday argumentation. For some students, these internal scripts are highly structured and closely resemble the norms of scientific argumentation. For other students, they are less structured and may not contain the components described earlier (data, warrants and rebuttals). Kollar and Fischer have found that providing external scripts with sentence stems, such as those used by Wray and Lewis (1997), can help students develop more sophisticated and structured internal argumentation scripts.

To implement these teaching strategies, there needs to be a shift away from typical classroom interactions (Herrenkohl and Guerra 1998). Interactions dominated by teacher talk should move toward a balance with student–student discourse. Teachers must develop a comfort level that enables them to step back during productive student–student interactions but intervene when students need to be reminded how to challenge each other's claims and arguments.

Establishing an Appropriate Social Context

Researchers maintain that in order to encourage scientific argumentation, teachers must provide children with a comfortable discourse environment (Puntambekar and Kolodner 2005; Van Zee et al 2001). Without such an environment, children may be intimidated and less likely to participate, and they may wonder what is to be gained by engaging in argument.

In their study of Grade 4 children, Herrenkohl and Guerra (1998) found that young children had to be taught how to ask each other difficult questions without creating tension. Children must be helped to understand that challenging another's argument is not a personal attack or an adversarial process. Researchers such as Osborne, Erduran and Simon (2004) recommend that classroom argument be presented as a process of collaborative brainstorming, a kind of "We're all in this together in order to gain a better understanding of scientific practice" approach. Teachers can show children how moving away from saying "You're wrong because …" to asking "How does your data support your theory?" is one way to refocus discussion on the content of the argument and away from the child who is voicing the opinion. Kollar and Fischer (2004) take a similar view and introduce their external scripts to students as "collaboration scripts."

Even with a teacher's best efforts, some children will remain reluctant to voice an opinion or mount an argument. Children who have been socialized at home to not argue, who associate argument with emotional upset or who are uncomfortable speaking up in class will need extra time and encouragement. This is also true for students whose internal argumentation scripts are different from those advocated in the science classroom. A first step could involve integrating those children into groups and assigning them roles important in constructing arguments. Later, they might be willing to report on the group's explanations and arguments and even engage in rebuttal. In the end, teachers play a critical role in the extent to which children engage in scientific argumentation.

Using Assigned Roles to Support Children's Arguments

In their work with Grade 4 children, Herrenkohl and Guerra (1998) found that when children were assigned intellectual roles as presenters and audience members, they were more likely to develop argumentation skills and engage in deep learning. Deep learning results when children gather evidence, interpret data, critically evaluate arguments and restructure their understanding of a phenomenon (Barker 2006).

To generate an explanation and construct a group argument, children can assume the following intellectual roles during practical activities:

- Scribe—record data/evidence on chart paper, compose written explanations, prepare oral report
- Reporter—help with preparing the oral report, deliver the oral report

Audience roles that can be assigned to children include the following:

- Questioner ("What is your prediction?" "What is your theory?" "What did you find out?")
- Clarifier ("What did you mean when you said …?" "How exactly does your data support your conclusions?")
- Commentator ("These results seem to support the findings of another group")

The degree to which children can assume these roles and monitor comprehension, challenge each other's perspectives, and coordinate theories and evidence provides teachers with insight into the development of argumentation skills (Herrenkohl and Guerra 1998).

The following example shows how these strategies can be used to teach argumentation in the elementary classroom. The teacher asks students to consider the question, What kind of food do mealworms prefer? Children work in groups to discuss their initial ideas and then extend those ideas through practical activities with mealworms. Based on the evidence collected, children assigned the role of scribe write out the group's claim using sentence stems such as "What our group thinks is true is …" or "Our argument is …." To support their claims, children outline their evidence (data) and provide a warrant ("Since …" or "Because …"). Children assigned the role of reporter help construct the argument in preparation for reporting to the class.

Throughout the mealworm activity, the teacher works to portray the activity as collaborative brainstorming: "First, we work together in small groups and then we work together as a class to understand better what scientists go through when they share ideas in an attempt to resolve controversy." Like scientists, children in the classroom work together to build and revise ideas about the natural world.

As the reporters present their ideas about the food preferences of mealworms, audience members should be prepared to act as questioners, clarifiers and commentators. Audience questions such as "What was your prediction?" "What did you mean when you said …?" and "What was the evidence to support your argument?" help the children understand the evaluative criteria used to generate defensible explanations.

Conclusion

Argumentation is important to learning how to *do* science and learning *about* science. It is part of scientific inquiry and should also be part of an evidence–explanation approach to classroom inquiry. Using argumentation in the classroom requires that teachers explicitly teach argumentation skills and norms and establish a classroom context that fosters and values argumentation. Deep learning results when children are guided to collect evidence, interpret findings, construct explanations and examine the internal logic of their arguments. Deep learning takes time, and this could well mean that some topics in the elementary science program should be cut to allow for the time needed to teach scientific argumentation. Classroom experiences of this kind hold the promise of helping this generation of children become part of a scientifically literate citizenry able to participate in making well-informed decisions about scientific issues.

References

Alberta Education. 1996. *Science (Elementary)*. Edmonton, Alta: Alberta Education.

Barker, S. 2006. "Interactive Starters and Closures for Deep Learning." *Alberta Science Education Journal* 38, no 1 (November): 3–5.

Dewey, J. 1910. *The Influence of Darwin on Philosophy, and Other Essays in Contemporary Thought*. Bloomington, Ind: Indiana University Press, 1965.

Driver, R, P Newton and J Osborne. 2000. "Establishing the Norms of Scientific Argumentation in Classrooms." *Science Education* 84, no 3 (May): 287–312.

Druker, S L, C Chen and G J Kelly. 1997. "Introducing Content to the Toulmin Model of Argumentation via Error Analysis." Paper presented at the annual meeting of the National Association for Research in Science Teaching, Oak Brook, Ill, March.

Geddis, A N. 1991. "Improving the Quality of Science Classroom Discourse on Controversial Issues." *Science Education* 75, no 2 (April): 169–83.

Hanson, D L, and V L Akerson. 2006. "Will an Improved Understanding of Nature of Science (NOS) Improve Elementary Teachers' Self-Efficacy for Science Teaching? A Call for Research." *Alberta Science Education Journal* 38, no 1 (November): 6–11.

Herrenkohl, L R, and M R Guerra. 1998. "Participant Structures, Scientific Discourse, and Student Engagement in Fourth Grade." *Cognition and Instruction* 16, no 4: 431–73.

Kollar, I, and F Fischer. 2004. "Internal and External Cooperation Scripts in Web-Based Collaborative Inquiry Learning." In *Instructional Design for Effective and Enjoyable Computer-Supported Learning: Proceedings of the First Joint Meeting of the EARLI SIGs Instructional Design and Learning and Instruction with Computers,* ed P Gerjets, P A Kirschner, J Elen and R Joiner, 37–47. Tübingen, Germany: Knowledge Media Research Center. Also available at www.iwm-kmrc.de/workshops/sim2004/pdf_files/Kollar_et_al.pdf (accessed October 11, 2007).

Kuhn, D. 1993. "Science as Argument: Implications for Teaching and Learning Scientific Thinking." *Science Education* 77, no 3 (June): 319–37.

Latour, B, and S Woolgar. 1986. *Laboratory Life: The Construction of Scientific Facts.* Princeton, NJ: Princeton University Press.

Levinson, R, and S Turner. 2001. *Valuable Lessons: Engaging with the Social Context of Science in Schools.* Final report to The Wellcome Trust. London: Institute of Education.

Lewis, T. 2006. "Design and Inquiry: Bases for an Accommodation Between Science and Technology Education in the Curriculum?" *Journal of Research in Science Teaching* 43, no 3 (March): 255–81.

Millar, R, and J F Osborne, eds. 1998. *Beyond 2000: Science Education for the Future.* London: King's College London, School of Education.

Monk, M, and J Osborne. 1997. "Placing the History and Philosophy of Science on the Curriculum: A Model for the Development of Pedagogy." *Science Education* 81, no 4 (July): 405–24.

Munby, H. 1982. *What Is Scientific Thinking?* Toronto: Guidance Centre, University of Toronto.

Osborne, J, S Erduran and S Simon. 2004. "Enhancing the Quality of Argumentation in School Science." *Journal of Research in Science Teaching* 41, no 10 (December): 994–1020.

Pine, J, P Aschbacher, E Roth, M Jones, C McPhee, C Martin, S Phelps, T Kyle and B Foley. 2006. "Fifth Graders' Science Inquiry Abilities: A Comparative Study of Students in Hands-On and Textbook Curricula." *Journal of Research in Science Teaching* 43, no 5 (May): 467–84.

Puntambekar, S, and J L Kolodner. 2005. "Toward Implementing Distributed Scaffolding: Helping Students Learn Science from Design." *Journal of Research in Science Teaching* 42 no 2 (February): 185–217.

Ratcliffe, M, and M Grace. 2003. *Science Education for Citizenship: Teaching Socio-Scientific Issues.* Maidenhead, UK: Open University Press.

Sadler, T D. 2004. "Informal Reasoning Regarding Socioscientific Issues: A Critical Review of Research." *Journal of Research in Science Teaching* 41, no 5 (May): 513–36.

Sandoval, W A, and B J Reiser. 2004. "Explanation-Driven Inquiry: Integrating Conceptual and Epistemic Scaffolds for Scientific Inquiry." *Science Education* 88, no 3 (May): 345–72.

Shapiro, B. 1995. "'Cause All These Are Squares': Patterns of Ritual and Reason Giving in Language Use in a Small-Group Construction Task." *Alberta Science Education Journal* 28, no 2 (July): 20–24.

Smith, C, J Snir and L Grosslight. 1992. "Using Conceptual Models to Facilitate Conceptual Change: The Case of Weight-Density Differentiation." *Cognition and Instruction* 9, no 3: 221–83.

Solomon, J, J Duveen and L Scott. 1992. *Exploring the Nature of Science: Key Stage 4.* Hatfield, UK: Association for Science Education.

Southerland, S, J Kittleson, J Settlage and K Lanier. 2005. "Individual and Group Meaning-Making in an Urban Third Grade Classroom: Red Fog, Cold Cans, and Seeping Vapor." *Journal of Research in Science Teaching* 42, no 9 (November): 1032–61.

Toulmin, S. 1958. *The Uses of Argument.* Cambridge, UK: University Press.

Van Zee, E H, M Iwasyk, A Kurose, D Simpson and J Wild. 2001. "Student and Teacher Questioning During Conversations About Science." *Journal of Research in Science Teaching* 38, no 2 (February): 159–90.

Wray, D, and M Lewis. 1997. *Extending Literacy: Children Reading and Writing Non-Fiction.* London: Routledge.

Searching for a Science Motive: Community, Imagery and Agency

Steve Alsop and Sheliza Ibrahim

Abstract

Through a collaborative action research project, the researchers sought ways to rediscover science through learners, communities and places. Visual documentaries in the form of photographs taken by students, combined with their discussions, served as a point of departure from traditional science learning activities. Conversations surrounding the photographs formed the basis of science projects that students and teachers designed together, researched, explored and shared.

This approach helped the researchers shift educational conversations from the triad of school–teacher–curriculum to learning–community–place. Their evolving argument involves the motive to learn and the ways in which science education might be fruitfully reconnected to more familiar everyday settings and local knowledge. The emergent curriculum and pedagogical design seek to develop a model of teaching with strong orientations toward contextualized or situated learning: learning for one's own interests, one's own community and one's own place, rather than learning for the teacher, the school and the curriculum.

If recent research might be generalized, students' attitudes toward science are declining (Alsop 2005a; Osborne, Simon and Collins 2003; Sjøberg 2002). Contemporary studies conducted in North America, Europe and Australasia establish that as students study science in schools, their motivation and attitudes toward science often wane. Notwithstanding the multifaceted nature of those studies, this conclusion is worthy of some extended reflection. Why is it that the longer students spend with us, the more negative their attitudes toward science and toward learning science become? How can a subject of such importance and beauty—a subject that has occupied our hearts and minds for so long—be unappealing? Is it a simple case of familiarity breeding contempt?

One danger of such thinking is that it can lead to deficit conclusions. Learners emerge labelled as a generally uninterested and unmotivated lot (and, in extreme cases, even a hostile lot). "No matter what you do," you can hear the disgruntled teacher saying, "they don't seem to want to learn anymore."

The pedagogical reaction to such circumstances is to search for innovative instruction to make the disgruntled happy once more. Successful teachers are wonderfully creative in this regard. They use a whole series of tricks, prompts and props to juggle the abstract and remote with the real and entertaining. Indeed, in our recent work we have become fascinated by the structure and form of these strategies (Alsop 2005b, 2007). These are foundational aspects of teaching that research, until recently, has largely overlooked.

In this article, however, we focus on something slightly different: we explore motives rather than motivation. This is a story of a search for motives for learning, rather than the more common extended reflection on lack of motivation. This switch, we believe, is particularly germane because it implicitly acknowledges that there might be something missing from education and schooling (*what* we do, as well as *how* and *why* we do it), rather than bemoaning the undesirable opinions of our students. Indeed, we suggest that educators need to listen to and respect learners' attitudes (even if they are negative) and accept that the problem is broader in its origins. With discussion of motives, one's attention is drawn toward a search for deeper-rooted educational questions. This viewpoint, although considerably more complex, is of lasting value.

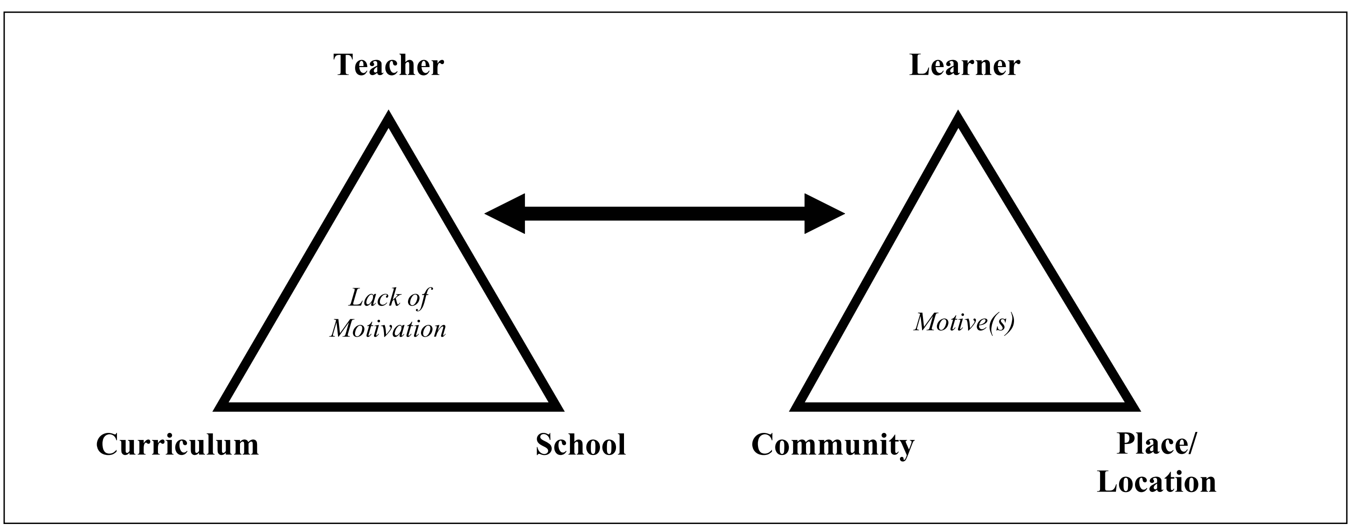
Our supposition is quite simple: too many of our students lack clear *motives* for learning science. It doesn't matter how much effort teachers put into making science fun and engaging; in the end, students fail to see a rationale. As a consequence, for some, school science becomes just another subject (among many), an academic pursuit that one is either good at or bad at. And, in the tradition of performance-oriented learning, if one sees oneself as being bad at science, why invest time and energy in it? Even the self-assured suffer pangs of insecurity and inadequacy when confronted with unlikely success. Studying science, then, becomes akin to climbing Mount Improbable (to borrow from the title of Richard Dawkins's [1996] popular book on evolution).

In Search of a Motive: Beyond the School, Teacher and Curriculum

It is rarely possible, if ever desirable, to separate teaching, schooling and the curriculum. Education is a multidimensional, complex subculture with history, language and traditions so ingrained and familiar that they have become largely invisible on a day-to-day operational basis. Waves of educational reform are really mostly shifts in curriculum reform, with accompanying tides of professional development and performance targets for teachers. Rarely in these circumstances is there an extended opportunity to discuss the institutions of schooling—shifting the subculture—other than perhaps a fleeting reflection on reducing class size. Moreover, in a broader sense, the relationship between schools, learners and their communities is rarely contemplated. Reform, it seems, occurs with curriculum blinkers on.

In our work, we have been taking a broader look, purposefully stepping beyond the curriculum. We have been theorizing education as a dynamic dialectic of two triads (see Figure 1). Such conversations (we hope) will bring together the general (discourses of teaching, schooling, science and the curriculum) and the specific (discourses of learners and their lives, communities,

Figure 1
The Dialectic of Triads: School–Teacher–Curriculum and Learner–Community–Place



families and local places). See Alsop, Ibrahim and White (2007) for an extended discussion.

We have been exploring what would happen if we moved beyond the school–teacher–curriculum triad to seek motives to learn within the context of learners and the places they inhabit (the learner–location–community space). We are intrigued by the very real question, How might we regain a sense of motive in school science by recovering a sense of the lost Dialectic of Triads?

Though the reconnection of science to local places is an emerging pedagogical construct, it may serve as a starting point to elevate student-led processes of science knowledge making. Although teacher involvement remains a crucial component of science lessons, the dynamics of the teacher's role in a study like ours are admittedly nontraditional.

In Search of a Dialogue

We invited teachers from two inner-city middle schools to take part in a participatory action research (PAR) project. This project was part of a larger project, funded by the Social Sciences and Humanities Research Council of Canada, titled Feeling for Science. Skimming through the PAR literature leads to a vast array of research linked with action in some way, whether in education or other disciplines (such as agriculture, social work and health) (McTaggart 1997). Our research group consisted of five science teachers working with three science education researchers. Through collaboration we sought ways to promote conversations about agency, learners, locations and communities and the ways in which they might connect with more familiar everyday discourses of curriculum and teaching.

It is no easy task to begin formulating ideas about how classroom practice might shift to this magnitude. Our group started with reflections on what we thought about science classrooms and what we wanted. Not only were our regular meetings forums for reflecting critically on pedagogy but each also served as a moment in a busy, gruelling teaching week to refocus attention on bigger questions such as, What is science education? and, Why did I become a teacher in the first place? Naturally, the start of each meeting was devoted to shop talk. We humoured ourselves by commenting on teaching, classroom management, assessment, and curriculum triumphs and letdowns. At the end of these productive and critical sessions, we realized that entire teaching weeks were devoted to such talk; in fact, several of the participating teachers commented that they had never had the opportunity to really discuss their craft, what they wanted to do, and what inspired their practice and their students. In short, they were too busy trying to get through the curriculum to consider the bigger picture.

During one of our meetings, we viewed video clips of the teachers teaching and of students during interviews and during class. We were excited by the information the images revealed and recognized how much is missed while teachers are absorbed in typical classroom practice: lectures, chalk and talk, book work, inquiries, management, assessment, group labs and demonstrations.

We wanted to pull back and see our actions and ourselves from the perspectives of learners, communities, and broader questions of justice and purpose. In retrospect, the participating teachers commented on what they might change or do differently in lessons they had performed for many years and had never before thought about changing. Digital video ethnography (Goldman 2004) served as a useful vehicle for teachers to reflect on their practice. They shared their own insight and ideas while on camera. They commented on the work at hand and its relation to their world (in practical and sometimes humorous or satirical ways). The teachers wondered how they could learn more *from* their students and more *about* their students, and how such knowledge might inform their learning. As we discussed how we could reconnect with students, communities and places, the use of visual images became a primary choice, emerging as a way of entering our students' world in an inviting and nonintrusive way.

Pictures of Possibilities

Despite the prevalence of images in science, the use of cameras is not common in science classrooms, and using photography as a basis for science projects is rare. Using these visual tools to produce images that reconnect science education with a sense of local place, self and community is rarer still. In an attempt to closely link agency to science learning and science teaching, our collaborative research group began to think of science education through a sense of place-referenced pedagogy, such that the science classroom might become a venue that recognizes the significance of the community—a place that promotes passionate engagement, agency and personal awareness of what science might mean to students as science citizens, not simply as science students.

Reorienting education within our group was difficult because of the dominant educational world view. Participants were constantly returning their focus to the triad of school–teacher–curriculum, almost as if by habit: "In my school we have to do it this way. I am already behind and have to cover the earth and atmosphere unit before the end of the term." "There are examinations at the end of the year, and we have to cover so much content." "I don't think the parents would like it, and neither would my principal, to be honest." "I don't have time to think during the week. There is so much admin and reporting nowadays."

The meetings were an excellent opportunity to reflect on dominant philosophies and pedagogies, in order to see science in the specific and to challenge ourselves to connect with science outside the subculture of schooling—even if for a fleeting moment.

Devoting time to teaching students about photography and how to take a good shot takes time away from the regular science curriculum and represents the tension between what ought to be done in a science classroom and what might be done differently. In actuality, allowing the discourse of learners, communities and local places to share the space of the science classroom with the teacher is often disconcerting because of teachers' obligations to the school and teaching practice. Our study emphasized the dominance of evaluation, assessment, curriculum, and teaching schemes and materials. Later, through the visualization process of our meetings, we began to struggle with these expectations as we moved toward a dynamic understanding of science teaching, particularly sociocultural contexts, affective concerns, and sense of self and community.

In the end, we decided that we wanted to know more about students' relationships with science, and using photography allowed us to see our students' science lives in a less intrusive way. Research funding was used to purchase disposable cameras for all the students. Students' photographic skills were initially developed using two digital cameras (provided by the teachers and researchers) during a class walk through the neighbourhood (which was a significant activity in its own right). The students then took their disposable cameras home and were asked to bring back pictures of science and their communities, their places and themselves.

The images the students brought back were personal, exciting to them, real and authentic (White, Alsop and Ibrahim 2007). The images offered a natural context of learning—a point of departure for science inquiry. They also served as a moment of teaching revisited. Classroom activities emerged in which participating teachers taught students about the science they witnessed in their lives by sharing their photographs.

While our study refrained from defining what science is, we allowed students to discover, investigate and wonder about their world and the existence of science as they claimed to see it. Because science is a process, it was crucial to have discussions about what the students captured at fixed moments in time, in order for the teacher and the students to understand what science was embedded in each moment. The process of science was evoked even more after the pictures had been taken, through the scientific inquiry that the students engaged in while trying to understand each photograph and reflecting on how they might find answers through investigative processes. The unanswered questions that became problematic in their communities and lives encouraged them to explore the multiple dimensions of each photograph.

The participating classes then prepared to share their photographs with each other. Leading up to the photo gallery, the students were given a series of lessons: a lesson that invited them to look at images taken by science photojournalists and to examine issues in the photographs critically; a lesson that taught them how to use a camera and consider angle, foreground, background, light and story; and a lesson that asked them to look at their world through a creative scientific lens when they had their cameras with them.

When the students shared their images at the photo gallery (held in the participating classrooms), many critical and engaging questions emerged. Students had taken pictures of animals (dogs, squirrels, hamsters, rabbits, birds), the natural environment (trees, soil, snow, icicles, clouds, sun), equipment in laboratories at which their parents worked (test tubes), the experience of sick family members (breathing tubes), technology (iPod, CDs), and items at restaurants (food, icemaker, stove). Their images are symbolic of what is happening in our time. They are images that are current and represent not only what occurs in students' personal lives but what is pervasive in popular culture and the media that surrounds them. Historically, this tells us of the types of scientific phenomena that are of a heightened awareness in public circles. Aikenhead (1990) suggests that the public awareness of such scientific issues tends to rise and fall with major social and historical events. A popular example is the launch of *Sputnik* in 1957, which fascinated the world (and stressed the importance of scientific literacy) (Gregory and Miller 1998). Other examples include interest in pandemic diseases (prompted by the avian flu pandemic), interest in natural disasters (prompted by the devastation of the December 2004 tsunami) and interest in harmful atmospheric emissions (prompted by the innovation of the hybrid car). We became exposed to the types of scientific issues that exist temporally and historically in the local environments of the students who participated in our project. We learned what they questioned and sought to know. The students had taken pictures of what was interesting to them, and their accompanying stories were layered with not only their science understanding in school but also what they gathered from the local environment and popular culture around them.

With this in mind, the students wandered through the classrooms, looking at the photographs, and wrote their comments and questions on Post-it notes, which they then stuck close to the images. Each classroom became a gallery of photographs splashed with fluorescent pieces of sticky paper bursting with enthusiasm and insight. Students were eager to look at the photographs their peers had taken, and they all had questions and comments, wanted to know what others were thinking about their images, and were engaged, motivated and enthusiastic.

We recorded the following student questions:

- "What are the needles for?"
- "Who is that kid and how did they get sick?"
- "Do the tubes help the girl to breathe?"
- "How do you know it's a dead tree? Maybe it's fall, and the leaves are gonna grow back."
- "Why does the rabbit have red eyes?"
- "Why did you take a picture of a building or house? Do you live there?"
- "I really wonder what this fish has to do with science? It smells!"
- "Why did you show a fire truck? Is it because it has water from the hose?"
- "How does the smokestack work?"
- "I like this pic because the hood looks nice and clean for once."
- "I wonder how many volts that light can hold."
- "I see the science in this picture. The science is garbage. It's like what we did yesterday about garbage and how come? They disintegrate."

Because of ethical and privacy issues, we shared the students' photographs only with the project's participating members.

By situating the learners in a place that connected socially and ecologically with them, we hoped to stimulate greater interest and self-actualization when learning. In our place-based, visually documented classroom project, the images the students captured represented science in their local communities, and the images were accompanied by a written photo diary about the students' experiences. Visual perspectives of science, in contexts that are personal to the students, allow science to cross the boundaries of the classroom or laboratory, to enter places of science experience and learning that are uncommon. Polarized notions of "school and me" begin to waver, and students are the ones who change those notions as they become the educators, teaching us about their science world.

Conversations about the photographs then formed the basis of student-led science projects. For example, a picture of fish led to a project in which groups of students worked with a fishmonger in a local market, researching questions about the fish sold there. This type of research is far more community situated than checking remote textbooks, the library or Internet sources. The students visited the fishmonger and were invited to conduct interviews and to videotape and photograph various aspects of the fish. In their research, they explored scientific topics that they questioned, such as diversity, biology, food production, fishing, animal structure and sense of smell. Their collaborative work with the community expert (the fishmonger) created an awareness of the local market as an important part of their community, and allowed the fishmonger to take on an active role in the education of children in his community. Thus, local science knowledge becomes just as important as curriculum science knowledge; the triads are balanced.

A single photograph of a student's sister recovering from an illness at a local children's hospital generated a host of questions. Many curious students inquired about her illness, which led to interesting discussions on breathing, respiration, recovery, hospitals, medicine, family and child care. Directly connecting the experiences of children with science creates a sense of tangible reality, promoting intense conceptual and emotional engagement.

Conclusion

Like all action research projects, our study is a work in progress. There are many unanswered questions and some data has yet to be analyzed. Drawing on empirical evidence, we have reflected on the strengths and weaknesses of our use of images as a means of generating motives. This approach has formed the focus of extended discussion in our PAR group. As a group of teachers and researchers, we see considerable merit in the approach, while recognizing the difficulties involved in its implementation. At times the practicalities become challenging. For example, the project required that an official permission slip be signed by all parents before the neighbourhood walk could take place. While that requirement is understandable, it is just one of the many institutional barriers that separate schools from communities.

At times, the foray into the local was difficult to reattach to the general, and the science, in a curriculum sense, was lost. However, when a child shares a very personal picture of a sibling in a hospital bed, recovering from illness, it is important to respond rather than dismiss the subject as not being in the curriculum. In this very real learning moment, the personal and the academic worlds collide. The students' interest in the child's experience was palpable once the conversations and questioning commenced.

There are many ways to frame our pedagogy. Critical pedagogy highlights the notion that learners need opportunities to reflect on their own "situationality" (Freire 1970) to the extent that they are challenged to act on it. It is important to also explore all spatial aspects of situationality in terms of built and natural environments, because those things directly affect who humans are and how humans exist (Gruenewald 2003). How can we harness our innately inquisitive characteristics to learn together? This question we pose as an important one for future educational reform.

We suggest that students who decode "images of their own concrete, situated experiences with the world" (Gruenewald 2003) will find a greater motive to learn science. Our science teacher colleagues have described this study as an opportunity to learn more about their students and the students' everyday science interests. The teacher also becomes a learner. The science classroom is often deprived of this type of bidirectional educational relationship.

Our emergent curriculum and pedagogical design seek to develop a model of teacher education and teaching that has a strong orientation toward contextualized or situated learning: place-referenced pedagogy. We envision that the use of science imagery will promote discussions about pedagogical approaches that open up real motives for learning science for students and teachers. The evolving methodology for a study of this nature offers many conversations about science, images and action—conversations that narrow the gap, we hope, between the triads shown in Figure 1.

Our study is ongoing, and so far teachers and students alike have engaged with the cameras in ways that have opened up themselves and exposed their local places of community and culture and self. It all becomes personalized. They have been uninhibited and relaxed, and we believe that they feel more comfortable with sharing their personal science experiences (and perhaps even proud to do so). More important, the vision of science opens up a critical eye to science learning and understanding. We hope that projects like this one will raise critical consciousness about science outside the realm of schooling, a science consciousness that is informed, real and personal. We hope that, through the exploration of science education and through the visual dimensions associated with ownership and accountability, science can become engaging and transformative. Through our actions, we hope to refashion a motive to learn.

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Bibliography

Aikenhead, G S. 1990. "Scientific/Technological Literacy, Critical Reasoning, and Classroom Practice." In *Foundations of Literacy Policy in Canada,* ed S P Norris and L M Phillips, 127–45. Calgary, Alta: Detselig.

Alsop, S, ed. 2005a. *Beyond Cartesian Dualism: Encountering Affect in the Teaching and Learning of Science*. Dordrecht, Netherlands: Springer.

———. 2005b. "Motivational Beliefs and Classroom Contextual Factors: Exploring Affect in Accounts of Exemplary Practice." In *Analysing Exemplary Science Teaching: Theoretical Lenses and a Spectrum of Possibilities for Practice,* ed S Alsop, L Bencze and E Pedretti, 146–59. Maidenhead, UK: Open University Press.

———. 2007. "The Emotional Lives of Fledgling Geniuses." In *Science Education for Gifted Learners,* ed K S Taber, 45–59. London: Routledge.

Alsop, S, and S Ibrahim. 2006. "Anodyne Creations and Emergent Emotionality: A Digital Ethnographic Exploration of Emotional Contours in Grade 7 and Grade 8 Laboratories and Grade 6 Integrated Classrooms." Paper presented at the annual conference of the National Association for Research in Science Teaching, San Francisco, California, April 1–3.

Alsop, S, S Ibrahim and F White. 2007. "Learning, Feeling and Doing: Recovering a Sense of Community and Place in Science Teacher Education." Paper presented at the 35th annual conference of the Canadian Society for the Study of Education, University of Saskatchewan, Saskatoon, Saskatchewan, May 26–29.

Dawkins, R. 1996. *Climbing Mount Improbable.* New York: Norton.

Freire, P. 1970. *Pedagogy of the Oppressed.* New York: Herder and Herder.

Freire, P, and D P Macedo. 1987. *Literacy: Reading the Word and the World.* South Hadley, Mass: Bergin & Garvey.

Goldman, R. 2004. "Video Perspectivity Meets Wild and Crazy Teens: A Design Ethnography." *Cambridge Journal of Education* 34, no 2: 157–78.

Gregory, J, and S Miller. 1998. *Science in Public: Communication, Culture and Credibility*. New York: Plenum.

Gruenewald, D A. 2003. "The Best of Both Worlds: A Critical Pedagogy of Place." *Educational Researcher* 32, no 4: 3–12. Also available at www.aera.net/uploadedFiles/Journals_and_Publications/Journals/Educational_Researcher/3204/3204_Gruenewald.pdf (accessed October 18, 2007).

Hodson, D. 2003. "Time for Action: Science Education for an Alternative Future." *International Journal of Science Education* 25, no 6 (June): 645–70.

Kincheloe, J L. 2004. *Critical Pedagogy Primer.* New York: Lang.

Lee, S, and W-M Roth. 2003. "Science and the 'Good Citizen': Community-Based Scientific Literacy." *Science, Technology and Human Values* 28, no 3 (July): 403–24.

McTaggart, R, ed. 1997. *Participatory Action Research: International Contexts and Consequences.* Albany, NY: State University of New York Press.

Oja, S N, and L Smulyan. 1989. *Collaborative Action Research: A Developmental Approach.* New York: Falmer.

Osborne, J, S Simon and S Collins. 2003. "Attitudes Towards Science: A Review of the Literature and Its Implications." *International Journal of Science Education* 25, no 9: 1049–79.

Sjøberg, S. 2002. *Science for the Children?* Report from the SAS (science and scientists)–project. Revised, enlarged and updated version. Oslo, Norway: University of Oslo, Department of Teacher Education and School Development. Also available at http://folk.uio.no/sveinsj/sas_report_new%20.pdf (accessed October 18, 2007).

White, F, S Alsop and S Ibrahim. 2007. "Viewing Science: Student Perspectives and Attitudes Towards Science as Presented Through Visual Documentation of Science in Their Community." Paper presented at the 35th annual conference of the Canadian Society for the Study of Education, University of Saskatchewan, Saskatoon, Saskatchewan, May 26–29.

Scaffolding Students Toward Self-Directed Science Inquiry Projects

John Lawrence Bencze

Abstract

Educational systems often orient students' science education toward learning about the many products (such as laws, theories and inventions) of professional science and technology. Such an orientation can compromise students' opportunities to develop more comprehensive literacy related to science and technology—including the skills, attitudes and preinstructional expertise students possess for conducting independent (although collaborative) science inquiry projects on topics of interest to them. This article discusses a field-tested framework for scaffolding students' development of expertise they could use in conducting their own inquiries, in the context of specific examples and freely available resources. Based on constructivist learning theory, the framework involves students in expressing their preinstructional expertise relating to science inquiry before being tutored in various concepts of evidence frequently used by scientists to develop knowledge. The benefits of student-led inquiry projects that could follow apprenticeship lessons and activities are many and varied. Nevertheless, continued efforts are needed in order to overcome various barriers to widespread student-led science inquiry. Readers of this article may take various innovative approaches to achieving this goal.

Although there are many exceptions, educational systems (involving governments, textbook publishers, business partners, administrators, teacher educators, teachers and parents) often orient science education toward teaching and celebrating the products (such as laws and theories) of science and technology—at the expense of other potentially important learning outcomes (Hodson 1998). Such an emphasis can lead students to incorrectly assume that science and technology are always successful and unproblematic. Allchin (2004, 939) contends that school science often portrays professional science as "pure and isolated from culture." At the same time, it is apparent that a focus on the products of science and technology can limit the extent to which students develop the expertise needed to self-determine explanations about nature and inventions that address problems about phenomena, which in turn can create a degree of dependency. Collins et al (2001, 4) state that an "overemphasis on 'what we know' at the expense of 'how we know' results in a science education which too often leaves students only able to justify their beliefs by reference to the teacher [and eventually others] as an authority."

Although it is essential for students to have access to the laws and theories of science and technology, in the world they will inherit

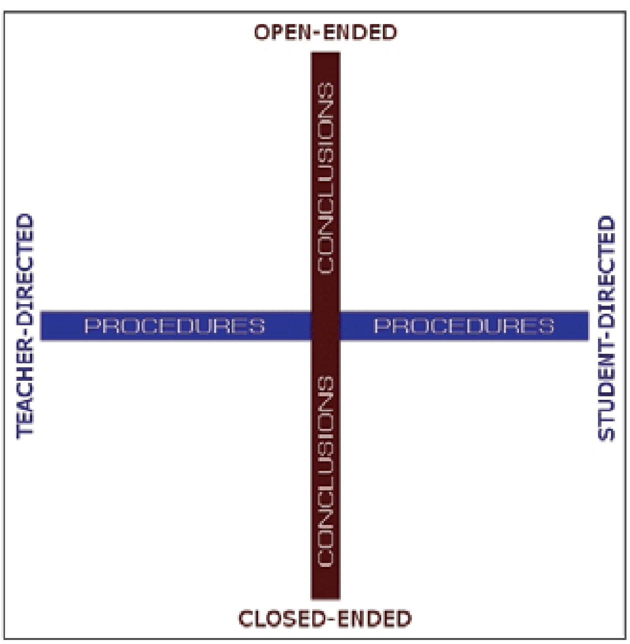
> Nothing could be of greater value than the ability to make your own life up as you go along: to find for yourself what is satisfying; to know your own values and your own mind; to meet uncertainty with courage and resourcefulness; and to appraise what others tell you with an intelligent and healthy skepticism. (Claxton 1991, 130)

Beane and Apple (1995, 15–16) contend that any curriculum in a democracy should include

> Not only what adults think is important, but also the questions and concerns that young people have about themselves and their world. A democratic curriculum invites young people to shed the passive role of knowledge consumers and assume the active role of "meaning makers." It recognizes that people acquire knowledge by both studying external sources and engaging in complex activities that require them to construct their own knowledge.

In the context of science education, an important way students can construct their own knowledge is by conducting student-directed, open-ended science projects (Gott and Duggan 2003; Roth 1995). As illustrated in Figure 1, learning procedures that students follow can range from being fully teacher directed to being fully student directed, while their conclusions can range from being fully closed ended (that is, predetermined) to being fully open ended (not predetermined but, rather, student determined, based on available data and theory). In a student-directed, open-ended project, students could, for example, attempt to gather data to support ideas about the effects on plant growth of variations in electromagnetic radiation from high-energy electrical sources (such as transmission towers). Or they might attempt to develop an innovative bicycle, with improved features such as increased lightness, sturdiness and speed. In such activities, students are the final arbiters of questions, purposes, methods, approaches to data analysis, conclusions and reporting. Teachers, meanwhile, provide support but minimal guidance— except in matters of safety and logistics. Through such science inquiry project work, students can construct their own more personalized conceptions about phenomena, develop skills for future inquiry projects, develop more realistic conceptions about the nature of science and technology, and address problems associated with relationships between the fields of science and technology and societies and environments (Hodson 1998). These goals are expressed in *The Common Framework of Science Learning Outcomes, K to 12,* a foundational position statement of the Council of Ministers of Education, Canada (CMEC 1997).

Figure 1



Prudent Scaffolding of Students Toward Self-Directedness

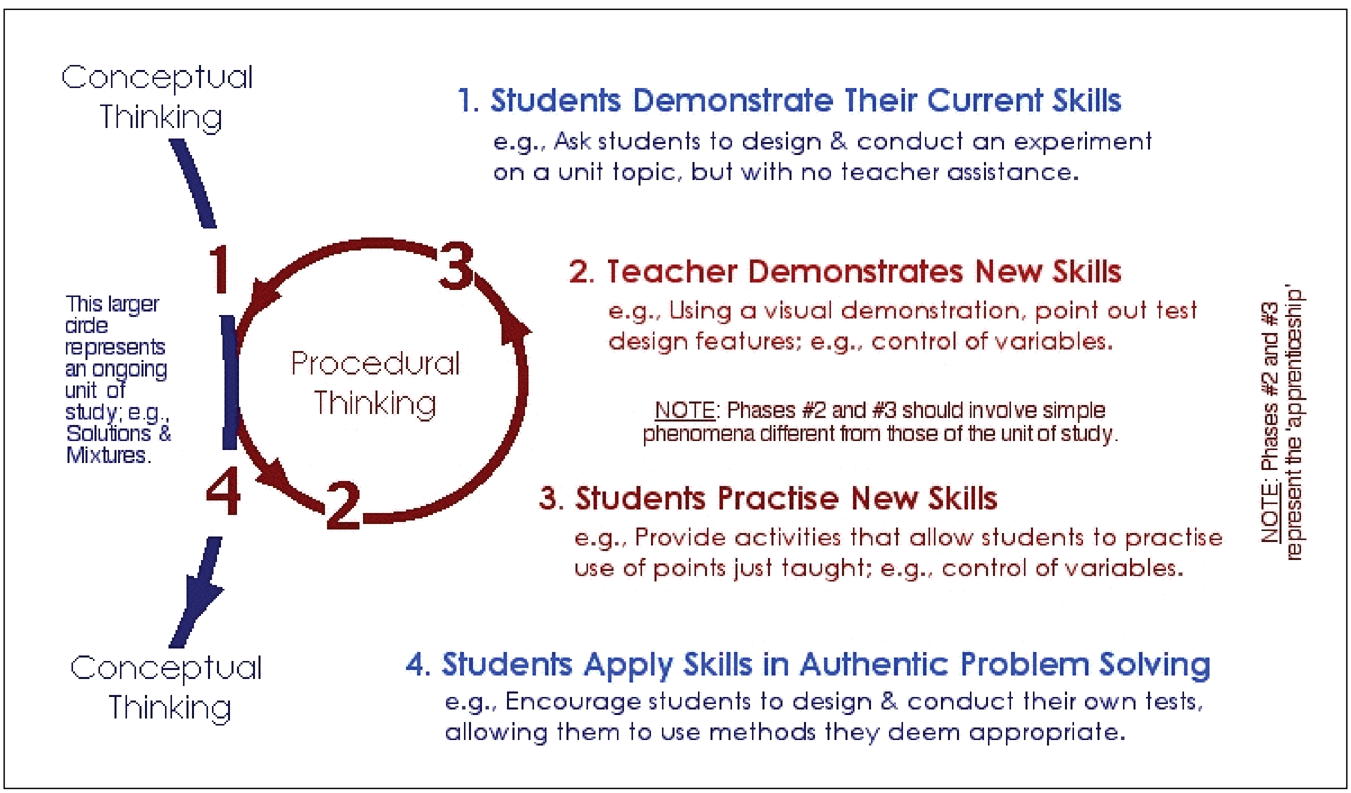
Encouraging and enabling students to conduct student-directed, open-ended science inquiry projects can be a highly complex matter. Teachers might ask the following questions: To what extent should I guide students through projects, as opposed to leaving them to their own resources? To what extent should skills be taught in, rather than out of, the context of learning content (such as laws and theories)? To what extent should students be encouraged to solve problems individually, as opposed to working in collaborative teams? There are, arguably, various ways to answer these questions. In this section, these and related questions are addressed in terms of the overall framework illustrated in Figure 2. This model was initially developed in collaboration with secondary school science teachers (Bencze 1995) but subsequently refined based on later experiences and theoretical perspectives.

One issue addressed in the framework in Figure 2 pertains to the relationship between learning skills for science inquiry and learning content. In many jurisdictions, science inquiry activities are generally used as vehicles for teaching or reinforcing content. In the United States *National Science Education Standards* (National Research Council 1996, 23), for example, *science inquiry* "refers to the activities of students in which they develop knowledge and understanding of *scientific ideas*, as well as an understanding of how scientists study the natural world" (emphasis added). On the basis of these standards, prominent educators assert that "within a classroom, scientific inquiry involves student-centered projects, with students actively engaged in inquiry processes and meaning construction, *with teacher guidance,* to achieve meaningful understanding of scientifically accepted ideas targeted by the curriculum" (Schwartz, Lederman and Crawford 2004, 612). Using science inquiry activities to teach or reinforce content is considered by some, such as Hodson (1996), to be highly problematic. Such guided inquiries tend to misrepresent the nature of science. In a major review of school lab work, for instance, Chinn and Malhotra (2002, 175) concluded that the "epistemology of many school inquiry tasks is *antithetical* to the epistemology of authentic science" (emphasis added).

To overcome problems associated with teaching content through inquiry, the framework in Figure 2 largely separates the two learning processes. The Conceptual Thinking arc to the left represents a teacher's normal lessons and activities (such as lectures, demonstrations and lab activities) aimed at helping students learn content. Running in association with learning content are cycles for Procedural Thinking (as indicated by the loop with four numbers). This outer loop represents opportunities for students to develop attitudes, skills and techniques for science inquiry, as well as realistic conceptions about the nature of science. Although conceptual and procedural learning should largely be separated, students' learning in these two domains should proceed roughly in parallel—since it is clear that in order to use their developing procedural expertise, students must also have reasonable understanding of the contexts in which inquiries are being conducted (for example, living cells versus electrical circuits) (Gott and Duggan 2003).

At various points during units of study, teachers can engage students in apprenticeship activities aimed at scaffolding their development of expertise for eventually conducting student-directed, open-ended science inquiry projects. In the first of four phases of this process,[1] teachers can—in the context of a particular

Figure 2



unit (such as the unit on solutions)—encourage students to express (through speech, writing or drawing) their preinstructional ideas and skills for conducting inquiry projects. Such activities should mainly be student directed and open ended (with the teacher only asking students to express their ideas through certain materials, for example), so that students feel free to express their ideas and skills. For example, the teacher could ask students to demonstrate how they would develop and conduct a simple experiment relating to the topic being studied, and get them to design and carry out experiments relating to questions they pose about a common phenomenon (such as how varying the shape of the container affects heat loss from a hot beverage).[2] Including such "expressing skills" activities in instruction addresses another common educational issue: that students are unlikely to be devoid of ideas and skills for conducting inquiries. Indeed, students likely already possess skills often used in inquiry—such as questioning, hypothesizing and empirically testing ideas—since these skills are used in general problem solving (Aikenhead 2005). Expressing such preinstructional ideas and skills can help students become more conscious of them, which in turn might lead students to reconsider them when confronted with alternative ideas and skills (Osborne and Wittrock 1985).

After expressing their current level of expertise in science inquiry, many students benefit from access to new or alternative attitudes, skills and knowledge relating to inquiry. Although students may acquire such skills from peers, it is frequently necessary for the teacher to proactively help students develop such expertise. According to Gott and Duggan (1995), students should be taught particular concepts of evidence—that is, ideas regarding certain strategies, techniques and so on commonly used for gathering and using evidence for claims.[3] Typical concepts of evidence include those given in Figure 3, such as "Steadily increase the possible cause variable," "Repeat the test" and "Keep all other known possible cause variables unchanged." A much more comprehensive treatment of these is provided, however, in Gott and Duggan (1995, 2003).

At various points during a unit, when the teacher feels that students could benefit from a special focus on inquiry skills, the teacher can take time away from teaching the content of the unit to lead students through apprenticeship lessons and activities (Phases 2 and 3 in Figure 2) aimed at helping them develop various concepts of evidence.[4] As indicated in Figure 2, such an apprenticeship may involve teacher modelling and student practice. Modelling activities should be teacher directed, while practice activities should allow more student control over procedures. For modelling, the teacher could use a questioning process relating to an experiment with balloon diameter (which could be performed as a class demonstration) to help students understand the design factors for experiments given in Figure 3.[5] Shortly afterward (in Phase 3 of Figure 2), students (preferably in groups) could then be challenged to develop and implement experiments relating to their observations about objects and events (for example, bouncing balls) provided by the teacher. In such practice activities, students would make most decisions about questions, hypotheses, methods, data representation and conclusions—although the teacher would be available to challenge and support them along the way. Although it is not clear from Figure 2, students are likely to benefit from repeated cycles of Phases 2 and 3 apprenticeship activities, for various aspects of science inquiry.

Although apprenticeship modelling and practice activities can and should vary in relative levels of teacher and student directedness of procedures, it may be best to leave the activities open ended. On the one hand, it could be argued that conclusions in the sciences are not always open ended. For instance, intellectual property agreements between scientists and private businesses can sometimes lead scientists to develop conclusions that match the interests of companies, rather than conclusions that match data and theory (Ziman 2000). Simulating such outside influences on science by forcing predetermined conclusions in school science inquiry would, arguably, provide students with a more realistic science experience.

On the other hand, minimizing such influences might enable students to develop attitudes and skills for critical and creative thinking—outcomes essential to a democratic life (Carr 1998). Moreover, leaving students' apprenticeship inquiries open ended might match the nature of most professional science: "Unlike the model currently propagated in many science classrooms, in the real world of science, no one final authority exists who can judge whether a scientific finding, model, or theory is correct" (Cunningham and Helms 1998, 488). Indeed, problem solving in the sciences is highly idiosyncratic (that is, personal, including

Figure 3

MODEL EXPERIMENT A scientist made this prediction and hypothesis: "As the size of balloons increase, they should drop faster, because they will be heavier and gravity will pull them down faster." To test these, s/he did the following for each design factor on the left:	
Design Factors	**Sample Experiment**
Steadily <u>increase</u> the possible cause variable (use several amounts).	Circumferences (cm) 10, 15, 20, 25, 30, 35, 40
<u>Repeat</u> the test; e.g., have five copies of each amount of the possible cause variable.	There will be five similar balloons inflated to each of 10, 15, 20, 25, 30, 35, 40 cm.
<u>Measure</u> the possible cause and result variables.	Sizes measured with metric tape; Time to land with stop-watch and a person saying, "Start!" and "Stop!"
<u>Double check</u> each measurement, and report the average.	Two people will make each measurement; then, calculate the average measurement.
Keep all other known possible cause variables unchanged.	Use the same kind of balloon; drop them from the same height; make sure there is never any breeze; make sure the temperature is the same.
Make *descriptions* of possible cause and result variables.	Describe the colour and shape of the balloons of different sizes; look for any 'wobbling' as the balloons fall.

much tacit knowledge) and situated (dependent on myriad contextual variables, including the nature of colleagues' discussions or debates regarding a scientist's work) (Hodson 1998). Thus, truth may be something determined by particular groups of problem solvers (such as students) in particular problem-solving contexts. Explicit discussions about the nature of science and technology,[6] including variations of the question of who controls decisions, should be carefully integrated into the skills-focused apprenticeship lessons and activities (Clough and Olson 2004).

Having been helped to enhance their expertise regarding the nature of *realistic* science inquiry, students should then be ready for the challenge of conducting student-directed, open-ended science inquiry projects in the context of a unit of study (as indicated by Phase 4 of the framework in Figure 2). In other words, after participating in relatively simple mentored activities like those experienced by newcomers to professional science (such as graduate students), students may be ready to become fully responsible for core practices of the field. That is, they may be ready to self-determine (although perhaps best in collaborative groups) more complex and personally meaningful questions, data-gathering methods, approaches to data processing, conclusions and methods of dissemination of findings. Students could, for instance, conduct experiments on the effects of magnetism on solubility (in a solutions unit). In addition to the benefits outlined above, students may develop deep expertise relating to their projects. For deep learning, according to Wenger's (1998) knowledge duality theory, learners need to generate their own representations of phenomena they experience. Through self-directed project work, students (rather than textbook authors, government officials or teachers) generate questions, hypotheses, methods of inquiry, data tables, graphs, descriptions of project characteristics and other representations of science inquiry, and students are therefore more likely to deeply understand them.

Discussion and Conclusions

The many benefits that could accrue to students through student-directed, open-ended science inquiry projects may, in practice, be difficult to realize. The many barriers to apprenticeship and student-led science inquiry projects of the kind described here must be addressed. Briefly, it appears to be essential that governments reduce or consolidate expectations for student learning of the many products (laws, theories, inventions) of science and technology—thus leaving time and motivation for the more creative and realistic activities associated with student-led project work. At the same time, given that teachers often have not had significant experience conducting their own student-directed, open-ended science inquiry projects (Shapiro 1996), they too may benefit from apprenticeship activities (followed by realistic inquiries) like those described here. Indeed, such lessons and experiences in science teacher education contexts have enjoyed some success (Windschitl 2003). However, it seems that much work remains to be done, on many fronts, before student-directed, open-ended inquiry becomes the norm, rather than the exception, in school science. Readers of this article may take various innovative approaches to achieving this goal.

Notes

1. Like all theoretical frameworks, the one in Figure 2 is relatively stylized; that is, it represents a general pattern that could be followed, but it is likely to be much more dynamic in practice, because of the complex and often unpredictable nature of any teaching and learning situation. For example, the arrows in Figure 2 suggest a unidirectional process that in reality may be bidirectional. The time spent on each phase also may vary, depending on numerous situational variables.

2. Use of common phenomena increases the likelihood that students will have preinstructional ideas and skills to express.

3. For an extensive list of concepts of evidence, refer to www.dur.ac.uk/richard.gott/Evidence/cofev.htm.

4. Associated with the framework in Figure 2, many relevant classroom-ready apprenticeship instructional materials have been developed. They are freely available at www.lbencze.ca/InquiryDesignEd.html.

5. During Phases 2 and 3 of the apprenticeship, it seems best to have students work with simple materials (such as balloons) unrelated to the topic of the unit under study (for example, plant growth and metabolism). Avoiding topics addressed in the current content unit will allow apprenticeship activities to be open ended. Using relatively simple materials and concepts, particularly in the early stages of students' procedural learning, may be best so that emphasis can be placed on the development of skills, strategies, methods and so on (Gott and Duggan 2003).

6. Readers can find useful teaching and learning perspectives and practices relating to the nature of science and technology at www.lbencze.ca/NoSTEd.html.

References

Aikenhead, G S. 2005. "Science-Based Occupations and the Science Curriculum: Concepts of Evidence." *Science Education* 89, no 2 (March): 242–75.

Allchin, D. 2004. "Should the Sociology of Science Be Rated X?" *Science Education* 88, no 6 (November): 934–46.

Beane, J A, and M W Apple. 1995. "The Case for Democratic Schools." In *Democratic Schools,* ed M W Apple and J A Beane, 1–25. Alexandria, Va: Association for Supervision and Curriculum Development.

Bencze, J L. 1995. "Towards a More Authentic and Feasible Science Curriculum for Secondary Schools." PhD dissertation, Ontario Institute for Studies in Education, University of Toronto.

Carr, W. 1998. "The Curriculum In and For a Democratic Society." *Pedagogy, Culture and Society* 6, no 3: 323–40.

Chinn, C A, and B A Malhotra. 2002. "Epistemologically Authentic Inquiry in Schools: A Theoretical Framework for Evaluating Inquiry Tasks." *Science Education* 86, no 2 (March): 175–218.

Claxton, G. 1991. *Educating the Inquiring Mind: The Challenge for School Science.* London: Harvester Wheatsheaf.

Clough, M P, and J K Olson. 2004. "The Nature of Science: Always Part of the Science Story." *The Science Teacher* 71, no 9 (November): 28–31.

Collins, S, J Osborne, M Ratcliffe, R Millar and R Duschl. 2001. "What 'Ideas-About-Science' Should Be Taught in School Science? A Delphi Study of the Expert Community." Paper presented at the annual meeting of the American Educational Research Association, Seattle, Washington, April 10–14.

Council of Ministers of Education, Canada (CMEC). 1997. *The Common Framework of Science Learning Outcomes, K to 12.* Ottawa: CMEC. Available at www.cmec.ca/science/framework/ (accessed September 25, 2007).

Cunningham, C M, and J V Helms. 1998. "Sociology of Science as a Means to a More Authentic, Inclusive Science Education." *Journal of Research in Science Teaching* 35, no 5 (May): 483–99.

Gott, R, and S Duggan. 1995. *Investigative Work in the Science Curriculum.* Buckingham, UK: Open University Press.

———. 2003. *Understanding and Using Scientific Evidence: How to Critically Evaluate Data.* London: Sage.

Hodson, D. 1996. "Laboratory Work as Scientific Method: Three Decades of Confusion and Distortion." *Journal of Curriculum Studies* 28, no 2: 115–35.

———. 1998. *Teaching and Learning Science: Towards a Personalized Approach.* Buckingham, UK: Open University Press.

National Research Council. 1996. *National Science Education Standards.* Washington, DC: National Academy Press.

Osborne, R, and M Wittrock. 1985. "The Generative Learning Model and Its Implications for Science Education." *Studies in Science Education* 12: 59–87.

Roth, W-M. 1995. *Authentic School Science: Knowing and Learning in Open-Inquiry Science Laboratories.* London: Kluwer.

Schwartz, R S, N G Lederman and B A Crawford. 2004. "Developing Views of Nature of Science in an Authentic Context: An Explicit Approach to Bridging the Gap Between Nature of Science and Scientific Inquiry." *Science Education* 88, no 4 (July): 610–45.

Shapiro, B L. 1996. "A Case Study of Change in Elementary Student Teacher Thinking During an Independent Investigation in Science: Learning About the 'Face of Science That Does Not Yet Know.'" *Science Education* 80, no 5 (September): 535–60.

Wenger, E. 1998. *Communities of Practice: Learning, Meaning, and Identity.* New York: Cambridge University Press.

Windschitl, M. 2003. "Inquiry Projects in Science Teacher Education: What Can Investigative Experiences Reveal About Teacher Thinking and Eventual Classroom Practice?" *Science Education* 87, no 1 (January): 112–43.

Ziman, J. 2000. *Real Science: What It Is, and What It Means.* Cambridge: Cambridge University Press.

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