Andrea Mueller
Queen's University

Time to Talk: Creating Classroom Contexts Where Students Begin to Talk Science

This study describes and examines how a classroom teacher and a teacher educator create educational contexts where students begin to talk science. Specifically, a grade 6/7 teacher and a teacher educator team planned and team-taught science to 29 students throughout one school year. The study was qualitative in nature, and an ethnographic approach was used in data collection. Through inductive data analysis, distinct opportunities to talk science are identified. Talking science in this study includes small-group unguided talk, large-group guided talk, and open-ended talk with an outside audience. A framework for talking science emerges as a guide for teachers to begin teaching science in ways that allow students time to talk science with their peers and with outside audiences.

Cette recherche décrit et étudie la façon dont un enseignant et un formateur d'enseignants créent des contextes pédagogiques qui incitent les élèves à discuter des sciences. Plus précisément, un enseignant en 6e/7e et un formateur d'enseignants ont collaboré dans la planification et l'enseignement des cours de sciences à 29 élèves pendant toute une année scolaire. L'étude était qualitative et la cueillette de données s'est faite selon une approche ethnographique. Une analyse inductive des données a identifié des occasions distinctes pour discuter des sciences. Dans le cadre de cette étude, par discussions concernant les sciences, on entend des échanges non-guidés en petits groupes, des conversations guidées en grands groupes et des présentations au grand public. Il en émerge un cadre pouvant servir de guide aux enseignants pour un enseignement des sciences qui permet aux élèves de discuter des sciences avec leurs camarades et avec le grand public.

Introduction

Current research identifies several areas of focus for improving junior/intermediate science education. First, science curriculum documents (American Association for the Advancement of Science [AAAS], 1993; Council of Ministers of Education, Canada, 1997; National Research Council, 1996) attempt to refocus science education internationally by emphasizing the importance of inquiry. Second, researchers (Barnett, 1992; Gallas, 1995; Halliday & Martin, 1993; Prain & Hand, 1996; Solomon, 1991) suggest that students require opportunities to articulate, defend, and explain their ideas in the classroom context if they are to be active participants in learning science. Third, if students are to be well educated in science, mathematics, and technology they need to participate in science investigations that more closely approximate sound science (AAAS, 1993). These calls for reform are particularly daunting when elementary teachers with little science background (Abell & Roth, 1992; Appleton, 1995) are required to teach a breadth and depth of science content they are unfamiliar with in ways that allow children to be active participants in learning science

Andrea Mueller is an assistant professor in science education. Her current research program includes a focus on science education, professional development, and teacher education.

(Allen, 1997; Dalton, Morocco, Tivnan, & Mead, 1997; Marlow & Stevens, 1999). Without research attention to how teachers and teacher candidates might begin to create meaningful classroom contexts where students begin to talk science and participate in science investigations, the calls for reform noted above may be difficult to implement.

Studies of classroom interaction (Carlsen, 1992; Lemke, 1990; Moje, 1997) reveal that science is often "presented to students through whole-class conversations, controlled and dominated by teacher talk, and oriented toward the transmission of scientific facts" (Kelly, Brown, & Crawford, 2000). Although these studies focus predominantly on high school science, these practices are not uncommon in elementary schools (grades 4-8). Lemke (1990) responds by proposing ways for creating educational contexts where students can "talk science." More recently, Gallas (1995), reports on how children talk their way into science in elementary classrooms. Wassermann and Ivany (1996) promote talking science when teaching science to children in the early primary grades. Nevertheless, educational researchers (Gallas et al., 1996; Johnson & Lawson, 1998; Solomon, 1998) point to a need for more opportunities for students to engage in exploratory talk and in an exchange of ideas in science classrooms. Students require a context and a purpose for generating and for sustaining scientific discussions. Therefore, it is vital that teachers be able to create meaningful learning environments where students are encouraged to talk science.

Solomon (1998) reports that many science teachers do not provide discussion time in their classrooms because they "do not have time." She speculates that the real reason discussion does not take place is because the value of discussion is not recognized, nor is it easy to orchestrate a thoughtful discussion. Extensive work by Driver (Driver & Bell, 1986; Driver & Easley, 1978) on listening to students' ideas in science illustrates that "students are usually quite able to discuss with each other despite their differences of opinion" (Solomon, 1998, p. 59). Similarly, much earlier Barnes (1976) identified that learning by talking is a critical component of learning for children across the curriculum. Other educational researchers (Gallas, 1994, 1995; Roth, Tobin, & Ritchie, 2001) echo the importance of children talking science and talking to learn science. This article provides an example of how a teacher in collaboration with a teacher educator began to teach science in ways that allowed grade 6/7 students time to talk science with their peers and with outside audiences. Talking science for the purpose of communicating with outside audiences provides a unique dimension in this study.

Background to Study

Working as a team, an experienced grade 6/7 teacher and I, a university-based principal researcher (and former elementary/intermediate school teacher), collaborated to teach science for one school year. The teacher in this study believed that teaching science from a textbook was not only boring, but did not promote student learning. He held vivid memories of reading from a science textbook and answering chapter questions as a student and had taught science in a similar way without enthusiasm. He expressed a desire to make science exciting and active for his students, but he did not know where to begin. Although a science curriculum document existed, it only outlined the topics of study to be taught, not a plan of how to teach these topics. This article reports on how we (teacher and teacher educator) began to create opportunities for students to talk science. This school year would be an attempt to move from using a science textbook to teach science to creating an active learning environment where school science had a purpose for students.

As the teacher educator-researcher in this study, I collaborated with the regular teacher to plan and teach his science classes for one school year. I was present whenever science was taught to his grade 6/7 class (approximately 3 times a week); however, I never assumed full responsibility for the class or for student assessment. In a sense I was the co-director of the science teaching team that school year, seeking to find a fine balance between listening to what the teacher was curious about and willing to attempt at various stages throughout the year and making suggestions for orchestrating the learning environment. This long-term team planning and teaching opportunity allowed me to be accepted as a second teacher in the classroom by the students and to examine teaching and learning continually from an insider's perspective.

Educational Context

The first month of the school year served as a familiarization period for students, teacher, and researcher. Thereafter, the teacher and I collaborated to plan a year-long approach to teaching science that would motivate students to participate in scientific investigations and to articulate regularly what they were learning and where they encountered difficulties. The grade 6/7 class in this study included 29 students: 20 in grade 7 and nine in grade 6. Sixteen girls and 13 boys learned together in this class. The students in this class represented a wide range of multicultural backgrounds including six designated ESL children who were recent immigrants.

Following the successful completion of a small trial "kites project" in the previous year, the classroom teacher and I agreed to plan "a science adventure" in the first term. The term *adventure* was used because the classroom teacher wanted science to sound exciting from the start. From the outset, the classroom teacher emphasized his conviction that students required large blocks of time to research, develop, and communicate their ideas. On the first adventure, Biosphere III (see Appendix), students imagined that they would create an enclosed system that could support life for one year. Moreover, they would select six individuals to live in their biosphere creation. Although a large team of diverse scientists were unable to create a biosphere II successfully in a scientific experiment in Arizona, these 11- and-12-year-old students were excited about the challenge to attempt what they considered a similar task. The classroom teacher and I had been successful in creating an exciting science challenge, but we also needed to guide students to a final outcome that they had only envisaged at the beginning. Nevertheless, giving students time to explore and talk about their ideas, share their questions with the class, and investigate possible solutions remained critical throughout this adventure.

After a motivating first science adventure, two additional science adventures (see Appendix) were planned for the remaining school year. Each adventure occurred for five to six weeks and was designed to invite students to enter a world of science. Students imagined they were real scientists working to understand and improve their world. In the second adventure, Vehicle Visions, students investigated alternative fuel sources currently available, as well as current research underway in the field. They designed a model vehicle and investigated how solar energy, electricity, and hydrogen fuel cells can power a vehicle, for example. In the third adventure, Amusement Park, students investigated how rides move and made a working model using simple machines. The emphasis in this adventure was on applying knowledge gained about how things move.

It was critical for students to work with current scientific knowledge in order to understand the depth of each challenge. Students did not invent new plants or alternative fuels, for example. Requirements included research reports, drawings, and models. However, regular discussion in the classroom science community and communicating their ideas to the outside community (including scientists, teacher educators, teacher candidates, and parents) played a central role in all three adventures. This included locating, reading, understanding, and explaining the importance of an ecosystem or how a hydrogen fuel cell worked to power a car, for example. Both instructors focused on listening to students and prompting them to extend and explain their ideas as they worked through various learning contexts. Typical comments included: "So how would you explain that to someone who knows nothing about it?" and "Tell me more about what you are thinking." Guidance was provided as needed in attempts to honor students' decisions about the direction of their adventure. These students did not simply read about science and search for answers in a book, but rather articulated what they understood and exchanged ideas about its importance in the world. Students had opportunities to talk science in small groups, in the large class, and to outside audiences.

Role of Teacher and Teacher-Researcher

From the beginning, the teacher and I established an emergent philosophy regarding student participation in classroom science adventures. That is, we communicated our intentions to students by showing them that there was no fixed blueprint for action, but rather that this was a learning opportunity for all of us. We began with a challenge and encouraged students to work and learn collaboratively as a community of inquiry. After initial visits to each group, we discussed what we had observed and how we might guide students. For example, we told students that it was important for each group member to express his or her ideas and for other group members to consider each contribution. We frequently stopped group work to commend students for their successful collaborative efforts and/or to remind them of how to work more collaboratively.

We planned for students to work in small groups to parallel a scientific team striving to learn together. The teacher and I regularly listened to the various groups while they worked, and we shared insights about students' learning. Early in the first adventure the teacher and I made the pedagogical decision that regular informal presentations to the entire class of work in progress would help students better understand how this project was evolving for each group and provide an opportunity to share information and ask questions. A culminating or final event for students to present their findings to the class and ourselves was planned from the outset. However, the format and details of this presentation evolved during the project in discussion with students. For example, we decided at the end of the first adventure that students should have the opportunity to present their creations to a wider audience outside our classroom community and subsequently connected with the local university.

Data Collection and Analysis

An ethnographic approach (Britzman, 1991; Denzin, 1997; Ellis & Bochner, 1996) was used in this study in order to enlarge the existing state of knowledge on (a) creating classroom contexts where students are encouraged to talk science and (b) various discussion contexts in the elementary classroom. At the end of the school year I had accumulated copious field notes, and audio- and videotape data detailing the collaborative journey of teaching science to a grade 6/7 class to augment my experiences as a participant. In addition, records of students' work (e.g., drawings, research reports, self-evaluations, models, oral presentations, and small-group and class discussions) were kept for all science classes. Multiple interviews with students, individually and in small groups, as well as interviews with the teacher, provided additional insights into learning and teaching elementary science. Specifically, data sources for one school year of elementary science include: 121 pages of field notes; students' drawings and research reports; students' self-evaluations through all three science adventures; audiotape recordings of conversations with children individually, in pairs, and in teams; audiotape of conversations with the teacher; videotape recordings of students' presentations and works in progress; and photographs of students' work.

What emerged as important after inductive analysis, were three distinct opportunities for children to begin talking science (Mueller, 1998a). Triangulation of data sources strongly supports these discussion contexts as providing progressive opportunities for children to talk science. Analysis of all three adventures reveals that students spent most of their project time working and talking in their small groups (e.g., 10 work periods of 75 minutes each for 4 weeks). Moreover, approximately 50% of their total work periods included large-class discussion time of their works-in-progress. Ultimately, the final week always required larger blocks of time for students to finish their work and prepare for their final oral presentations to an outside audience. Preparation for discussion with an outside audience included students' decisions about how to display their completed work and about how to engage audience participants in a conversation about their learning. The total amount of class time dedicated to each science adventure was approximately 20-22 hours for five to six weeks.

Results

This extensive study yielded a plethora of ethnographic data that helped me describe one year of school science in a grade 6/7 class. For the purposes of this article, two central findings are reported from the larger, year-long study (Mueller, 1998b) in order to provide some guidelines for how teachers might begin planning for discussion when teaching science. First, the emergence of three distinct discussion contexts illustrates progressive opportunities for students to exchange ideas orally with one another and others outside the classroom environment. These discussion contexts occurred naturally in the first adventure, and the teacher and I then sought to develop this pattern through the following two adventures. The nature of students' communication in these talking-science contexts are analyzed and tracked through the adventure, providing evidence that students articulate their learning and their questions in various stages when expected to do so. Second, the motivation to learn expressed by students and observed by the teacher and me indicated that this mode of learning science in school was interesting and meaningful for these 11- and 12-year-old students.

Time for Talking Science

A generative space: Talking science in small groups

In small-group discussions, students work and learn with a group of four to five peers. Here students "generate" ideas individually and as a scientific team, delegating work and coming together to discuss findings (in classroom; in library). Students had opportunities to communicate tentative ideas and time to listen to each other's ideas in this generative space. Barnes (1976) described this time as learning by talking. In response to a challenge, students were invited to engage in science as opposed to studying science. Students indicated in interviews that this was a rare opportunity in their past school science experiences, as they remembered mainly reading and answering questions from a text and working individually.

Students learned to communicate with team members when required to work together in groups of four or five. Each group found different ways to communicate throughout the projects ranging from collaborative discussions to heated arguments about decisions to be made. The teacher and I regularly sat in with the groups during these work sessions, listening and offering guidance when necessary. The following transcript excerpt provides a glance at a group conversation during a component of the third project (Amusement Park).

> *Christa*: Okay, Lance isn't here.
> *Renate*: Well, we should start and get some ideas.
> *Christa*: Like you could be sitting here and the hurricane would come.
> *Renate*: Yeah, it would start like a slow whistle and then it would get louder and louder and then you start to feel the hurricane and you go upside down.
> *Eli*: Maybe we could do … to make it more real …
> *Renate*: I was thinking we could have it spiraling down so that … instead of having to have …
> *Christa*: Renate, you're right, you're right, you're right. So you have it at the top and it goes down like that.
> *Renate*: Cuz then gravity can pull it down instead of having to have something pushing it.

Moreover, students identified the advantages of small-group learning in their self-assessments. One boy explained: "I think learning to work in a group is really good; I don't always like it but it's a good skill to have; like when you get older you'll have to work with groups and it's more fun." Others spoke about the benefits of learning "how to cooperate and work with other people." Several acknowledged that they learned more because of their audiences as "the presentations really forced us to know our stuff." "When you learn stuff without help you are really proud of it," another reported. Still others noted the importance of "doing it ourselves and learning from our mistakes." Such comments when taken as a whole suggest the rich diversity of learning opportunities that children see attached to projects in which they work together.

A rehearsal space: Talking science in class discussions

In class discussions, student groups presented their work-in-progress to the class. Here students shared works in progress, articulated problems, responded to each other's questions, and extended their thinking about the challenge. In this interaction with their peers and teacher, students fielded questions about their drawings, research, and models. They experimented with diverse presentation styles (use of visuals, drama) and practiced responding to and generating questions with peers. Ultimately, it was an initial opportunity for students to pull together their ideas and present them to a peer audience. Students regarded this as an important opportunity to communicate works and ideas in progress—learning along the way.

Students developed strategies for communicating with other groups in their class when required to present their works-in-progress in class discussions. Generally, students were informed by the classroom teacher 15-20 minutes in advance that they would be presenting their current work in progress to the class. Initially, when groups presented works-in-progress to the class, one person did all the talking and read in a monotone. When the instructors pointed out that all group members should participate and to remember that audience members knew little about their work, students began to use more visuals and to share the responsibilities of presenting their work in an informal manner. The questions below were raised by students in the audience who were listening to various group presentations of works in progress (Biosphere III adventure).

1. What will you do with your sewage?
2. What if biosphereans reproduce?
3. Do you think you'll have enough oxygen?
4. Don't you think that will be too expensive?
5. Do you think you'll have time to play basketball?
6. What purpose does the rainforest have in your biosphere 3?
7. What is the beach for?
8. Where does the water come from?
9. How will you treat your sewage?
10. How big are the solar panels?
11. What kind of animals?
12. How big is the base?

In class discussions students focused on presenting and critiquing each other's work. They practiced formulating questions that demanded deeper responses and related to the task at hand. This was an opportunity to think through others' work and at the same time to apply this learning to their own projects.

A performative space: Talking science with outside audiences

In audience discussions, students talked about what they had learned (completed work) in a science adventure to an outside audience. Students perceived themselves to be in the role of scientists exchanging ideas with audience participants (including teacher candidates, teacher educators, scientists, and parents). At the outset, for example, many students did not know the word or understand the concept of a biosphere or of a fuel cell. Yet by the end of each project, they confidently shared their expertise on these topics using their drawings, research, and models as resources when articulating and explaining the importance of what they had learned.

Students articulated their learning to adult audiences (teacher candidates, science professors, education professors, parents) and to other children at their school (grades 1-7 classes) throughout the school year. Such audience discussions provided each student with the opportunity not only to display completed work, but to discuss it with an audience participant. Some of the comments below were transcribed from audible portions of videotapes or were recorded after listening in on a student-audience participant conversation. Because all 29 students participated simultaneously in discussions with participants, it was only possible to hear fragments of conversations.

> I like the way ...
> What a cool idea ...
> How did you think of this?
> What are the waste products?
> Can you recycle this water?
> Can you explain how this works?
> Where does the hydrogen and oxygen come from?
> What safety features does the car have?
> I don't quite understand how this works.
> Does it run on water or gas? No gas at all? How does that work?
> How long will the solar cells last?
> How much do you estimate such a vehicle would cost and how soon will this be a possibility?

The first two audience discussions took place at the local university and the third at the school. It was a rare opportunity for the two instructors to participate in a learning environment without any other responsibility but to listen in on students conversations with audience participants. The clarity and creativity employed by students to communicate what they had learned to others had not been displayed in the other learning contexts of the adventure. For example, students' abilities to adapt their scientific explanations for a 5-year-old child in kindergarten or for a science professor were remarkable: particularly so because they were not taught how to modify their communication of ideas for various audiences. Further research on this specific component of student learning would contribute significantly to the literature on transfer of knowledge.

Expectations of students to talk science varied in small-group, class, and outside-audience discussions. In small groups students were expected to cohere as a team and to determine how they would go about responding to the challenge. Often students worked individually or in pairs for a time before reporting back to their group. Instructors were always available for consultation and assistance. Sometimes we simply provided resources (books and/or materials), and other times we engaged in discussions with the groups to help them sort out a problem or to move forward. It is important to point out that often children researched details of the project (e.g., specific plants in the

Savannah; hydrogen fuel cells) that challenged the instructors to do homework reading in order to keep up with their questions and inquiries. Students also contacted researchers at the university (professors and graduate students) for additional resource assistance. From our perspective, with each adventure students became more efficient in their abilities to work in and with their groups on a common challenge.

During class discussion time each group was responsible for presenting its work-in-progress to the classroom community. We expected that students would share their work, their inquiry processes, raise problems faced, and respond to each group's presentation. Students rehearsed communicating their thinking and findings in these spaces where they faced many more ideas and questions from their classmates. From the teacher's perspective these class discussions were critical for focusing and moving students' thinking along. Finally, presentations to an outside audience provided the important goal for students to communicate their completed work to members outside the classroom community. These opportunities were extremely important for students' learning as they were highly motivated to work toward this goal. Ultimately, students felt their work was genuinely regarded as important to others in their community through this opportunity.

For example, students described their learning of science content after the first project in the following ways.

- Designing an imitation of life on earth is way more complicated than it first seems.
- I didn't realize that things we think of as pests are so important.
- Algae are good oxygen producers; marshes are like a filter; tilapia fish grow very fast.
- You must have a lot of plants in the biosphere.
- A large mirror can't burn things; only small ones.
- I learned how many components are required to support life.
- I learned what a photovoltaic panel is; what a hydroponic greenhouse is.
- You need lots of information about a habitat to make a biosphere.
- I learned about the real biosphere.

Motivation to Learn

Student motivation

The classroom learning environment established by the teacher and me provided a deep source of motivation for students' learning and for teaching science. Interviews with students provide evidence of their expressed motivation to learn science throughout the school year. The following comments are excerpts from an interview with four students at the end of the school year as they reflected back on the year of learning science.

> Jade put it this way, "I really enjoyed working this way. We didn't have like tests at the end, but really it was tougher than a test cuz everyday we had to find out something new and be able to explain it. We really learned a lot." And Celia added, "The whole thing was like a test with no right or wrong answers. We learned along the way. It was really fun this way. Sometimes it was hard because groups didn't work out that well. But we learned how to work." Darren then adds a new twist saying, "I think the projects were really neat. It will be a total shock for the grade 7s because we've heard that in high school all you do is write

> tests and memorize textbooks. We won't get to do anything anymore that is fun." Sina agrees and asserts, "We're really lucky. People always say to me you're really lucky cuz you get to do things in your class. In high school we don't get to do anything. People say your class is so lucky even people in elementary say that from other schools." Then Diva declares, "I think this is the best class in science I've ever had. We actually got to do things ourselves. We have to figure out how then." And Ria affirms, "You have more fun when you learn this way. This way you learn every time you do a little part." Sina then expresses a final comment before I stop writing feverishly. "When I'm actually into doing something I really want to understand it. When I'm reading a textbook it's really boring and I don't want to understand it." (Mueller, 1998b, p. 95)

Some students were convinced that their learning was really important because others would see their work. For example, in a pair interview at the end of the year Renate points out,

> It was neat because it makes you feel like the project that you're doing is worthwhile—like some of the projects you make you do it and then it's done and over. But to present it and stuff makes it feel like you're really doing something and people want to see it. (p. 157)

Teacher motivation

Conversational interview data with the teacher and myself provide additional evidence that we too were highly motivated to direct and guide these adventures. After the first adventure, we talked about student learning. The following is an excerpt from those reflections.

> "I think ... it relates to enthusiasm doesn't it? I mean, we (teacher and I) were excited about it and that enthusiasm is catching. If you're excited about teaching and you're excited about what you're doing that enthusiasm is contagious. And I think that's really important too that you really have to be into it." Thereupon, he adds, "We're both, I think we're both enthusiastic about science. And we both like kids. That makes a big difference." Yet Ross admits, "There's no doubt it takes a hell of a lot more time than your regular out of the book science class, but, I think the payoff is tenfold." (Mueller, 1998b, pp. 38-39)

The following is an excerpt from our reflections after the second adventure (all names are pseudonyms).

> Ross began in this way, "They (students) knew that this was a real performance. It was real life again to them. This was a whole different audience and these people (prospective teachers, professors and parents) are going to take what I say seriously and have an understanding for what we're talking about." In response I add, "Yeah, what overwhelmed me just walking, I mean listening and looking around was how engaged every one of them was ... each person had someone talking to them, at least, and they had two or three people waiting ... so it was this constant overdrive of keep going and ..." Ross continues, "Some of them, some students were begging people to come to their tables—they wanted to tell them all about it.... they wanted to let their knowledge out ... they wanted people there engaged listening to them." (Mueller, 1998b, pp. 66-67)

Discussion

Framing science as an adventure by providing a challenge for students to work on over five weeks was identified by the classroom teacher as a successful approach to teaching and to learning science. Overall, students were highly motivated, seeing a genuine purpose for learning science in contrast to their former textbook learning experiences in school (as expressed in student interviews). Moreover, students delighted in the opportunity to communicate what and how they learned through each adventure. Specifically, students identified the first two challenges (Biosphere III; Vehicle Visions) as critically important because "scientists had not yet figured out the Biosphere project" and "the air is getting more and more polluted so alternative fuel sources are needed." Interestingly, students identified the final project as being "less science" because an "Amusement Park wasn't really that important to the world." Overall, the motivation expressed by students about science this year was overwhelmingly positive and insightful, and learning science seemed meaningful to them.

Kelly et al. (2000) point out that it is important to consider what counts as science in a classroom and to provide opportunities for students to engage in science and in the practices of scientists. When classroom members act as a community of scientists, they create a set of practices that includes a classroom discourse to develop an understanding of science. Mortimer and Scott (2000) add that "the teacher and student talk 'around' these activities is at least as important in establishing scientific knowledge in the classroom as the activities themselves" (p. 126). Through three science adventures in this study, students learned about the complexity of scientific work. Specifically, they learned details about the systems in our biosphere, about alternative fuel sources, about simple machines and movement, and about scientific research. However, their progressive ability to develop and communicate their ideas provided evidence about the depth of their learning. Students learned to be responsible for contributing to their group's work, as well as to contribute to other group's work. Collaborative efforts as a class created a community of learners (Rogoff, 1993, 1994) working together toward the same goal. Unique about this learning experience was students' abilities to explain their scientific understandings in their own words and their expressed excitement about the relevance of the science they were learning in school. Something that was missing in these learning contexts, or that might have been applied in retrospect, was actual hands-on investigations that related to these contexts (e.g., water purification tests, soil studies, air quality tests). Moreover, the adventures might be rewritten to reflect better a science emphasis for students.

Undoubtedly it seems important to provide guidance about how other teachers might embark on similar science adventures. Through our collaboration, two instructors cultivated a way of framing science for students that invited them to imagine their work in school really counted. This was perhaps the most critical component of their learning. Cunningham and Helms (1998) call for "teachers to relinquish power and their role as science authority" (p. 495). The role of the teacher was to facilitate and guide students in their inquiries, rather than to tell them specifically how to proceed. Students directed their own learning by generating ideas in their groups, conducting library searches and consulting with other groups, for example. It is interesting to note that instructors developed this framework as they responded to and supported student learning. At the same time, the structure of the learning environment provided a unique system for both formative and summative assessment. The teacher indicated that the communication and social skills developed throughout these adventures visibly transferred to other subject areas. Moreover, audiotaped conversations between the two instructors about strengths and weaknesses of student learning after each adventure allowed adaptations to their expectations for the next adventure. Ultimately, this collaborative effort to teach science for one school year resulted in the development of a particular model for teaching science in ways that encourage students to begin talking science. The value of team-teaching and the opportunity for teachers to discuss pedagogical issues on site remain unexamined in this study.

Without detailed analyses of these projects, the teacher might have simply stated that students participated in three extensive science projects and that they gave some wonderful presentations. Often project work in school implies that students work individually and present individually on separate topics at the end of a specific time. Generally, students receive a final mark for the final presentation with no prior assessment. However, by requiring a class to work on the same challenge in groups, to report to one another about their work in progress, and to communicate their work to an outside audience at the end, we provided the students with many more opportunities to expand and develop their thinking. After framing the science adventures, instructors supported and guided when necessary, but also observed that students became committed to the challenge and to their learning. The teacher expressed it this way in an audiotaped conversation after the first adventure.

> It always comes back to Celia's comment after the presentations that it had relevance—it had meaning. She gave the example of burning sugar on the bunsen burner. It had no relevance to her at all. And this (Biosphere 3 project) was real to her and that makes a huge difference. What was really important in this project was that all of a sudden science left the classroom. Science went home. And science involved parents and it involved their friends. And there were discussions between classes about the biospheres. And they (students) were quite proud about bringing kids in at lunch time to show what they were doing. (Mueller, 1998b, p. 38)

Creating a learning environment that incorporates the discussion contexts identified in this research study provides a way for teachers to begin. It is a beginning framework for creating science talk time. Gallas et al. (1996) argue for orchestrated and unorchestrated forms of classroom talk. They insist that teachers need to provide "more opportunities for children to use discussion to identify their own understandings and answer their own questions" (p. 613). Depending on the challenge and on the nature of students' findings, it would be possible to incorporate hands-on investigations in small groups and class discussion about findings in progress, for example. Nevertheless, this approach requires a great deal of time and flexibility in planning. It also requires that the teacher establish contacts in the community with scientists (including graduate students) who work in the area. Moreover, the teacher needs to teach students how to work collaboratively, as a large amount of teamwork is required. Finally, it would be ideal if two teachers in a school collaborated to structure a science adventure, as the collaborative teaching component played an important role in the project's success. Simply put, when two teachers collaborate, not only do the results often benefit student learning, but teachers also learn. After a collaborative year of teaching, the teacher in the study remarked "I can do this on my own now because I have a system to plan my teaching of science." An overall structure for a science learning environment that invites children to participate motivates teachers and children. Future research on team teaching efforts where teachers begin to teach science in active ways and invite students to talk science would be informative.

References

Abell, S.K., & Roth, M. (1992). Constraints to teaching elementary science: A case study of a science enthusiast student. *Science Education, 76*, 581-595.

Allen, S. (1997). Using scientific inquiry activities in exhibit explanations. *Science Education, 81*, 715-734.

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy.* Washington, DC: Author.

Appleton, K. (1995). Student teachers' confidence to teach science: Is more science knowledge necessary to improve self-confidence? *International Journal of Science Education, 19*, 357-369.

Barnes, D. (1976). *From communication to curriculum.* Harmondsworth, UK: Penguin.

Barnett, J. (1992). Language in the science classroom: Some issues for teachers. *Australian Science Teachers Journal, 38*(4), 8-13.

Britzman, D. (1991). *Practice makes practice: A critical study of learning to teach.* New York: SUNY Press.

Carlsen, W.S. (1992). Closing down the conversation: Discouraging student talk on unfamiliar science content. *Journal of Classroom Interaction, 27*, 15-21.

Cunningham, C.M., & Helms, J.V. (1998). Sociology of science as a means to a more authentic, inclusive science education. *Journal of Research in Science Teaching, 35*, 483-499.

Council of Ministers of Education, Canada. (1997). *Common framework of science learning outcomes, K-12.* Toronto, ON: Author.

Denzin, N. (1997). *Interpretive ethnography: Ethographic practices for the 21st century.* Thousand Oaks, CA: Sage.

Dalton, B., Morocco, C., Tivnan, T., Mead, P. (1997). Supported inquiry science: Teaching for conceptual change in urban and suburban science classrooms. *Journal of Learning Disabilities, 30*(6), 670-684.

Driver, R., & Bell, B. (1986). Students' thinking and the learning of science: A constructivist approach. *School Science Review, 67*(240), 443-456.

Driver, R., & Easley, J. (1978). Pupils and paradigms. *Studies in Science Education, 5*, 61-84.

Ellis, C., & Bochner, A. (Eds.). (1996). *Composing ethnography: Alternative forms of qualitative writing.* Walnut Creek, CA: AltaMira Press.

Gallas, K. (1994). *The languages of learning: How children talk, write, dance, draw and sing their understanding of the world.* New York: Teachers College Press.

Gallas, K. (1995). *Talking their way into science: Hearing children's questions and theories, responding with curricula.* New York: Teachers College Press.

Gallas, K., Anton-Oldenburg, M., Ballenger, C., Beseler, C., Griffin, S., Pappenheimer, R., & Swaim, J. (1996). Talking the talk and walking the walk: Researching oral language in the classroom. *Language Arts, 73*, 608-617.

Halliday, M.A.K., & Martin, J.R. (1993). *Writing science: Literacy and discursive power.* London: Falmer Press.

Johnson, M., & Lawson, A. (1998). What are the relative effects of reasoning ability and prior knowledge on biology achievement in expository and inquiry classes? *Journal of Research in Science Teaching, 35*(1), 89-103.

Kelly, G.J., Brown, C., & Crawford, T. (2000). Experiments, contingencies, and curriculum: Providing opportunities for learning through improvisation in science teaching. *Science Education, 84*, 624-657.

Lemke, J. (1990). *Talking science: Language, learning, and values.* Norwood, NJ: Ablex.

Marlow, M., & Stevens, E. (1999). *Science teachers' attitudes about inquiry based science.* Paper presented at the annual meeting of the National Association of Research in Science Teaching, Boston.

Moje, E.B. (1997). Exploring discourse, subjectivity, and knowledge in a chemistry class. *Journal of Classroom Interaction, 32*, 35-44.

Mortimer, E., & Scott, P. (2000). Analysing discourse in the science classroom. In R. Millar, J. Leach, & J. Osborne (Eds.), *Improving science education: The contribution of research* (pp. 126-142). Milton Keynes, UK: Open University Press.
Mueller, A. (1998a). Creating "spaces of inquiry": Participation in elementary school science. *Alberta Journal of Educational Research, 44*, 333-335.
Mueller, A. (1998b). *A desire to inquire: Children experience science as adventure*. Unpublished doctoral dissertation, University of British Columbia.
National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press.
Prain, V., & Hand, B. (1996). Writing for learning in the junior secondary science classroom: Issues arising from a case study. *International Journal of Science Education, 18*(1), 117-128.
Rogoff, B. (1993). Children's guided participation and participatory appropriation in sociocultural activity. In R.H. Wozniak & K.W. Fischer (Eds.), *Development in context: Acting and thinking in specific environments* (pp. 121-153). Hillsdale, NJ: Erlbaum.
Rogoff, B. (1994). Developing understanding of the idea of communities of learners. *Mind, Culture, and Activity, 1*(4), 209-229.
Roth, M., Tobin, K., & Ritchie, S. (2001). *Re/constructing elementary science*. New York: Peter Lang.
Solomon, J. (1991). Group discussions in the classroom. *School Science Review, 72*(261), 29-34.
Solomon, J. (1998). About argument and discussion. *School Science Review, 80*(291), 57-62.
Wassermann, S., & Ivany, J. (1996). *The new teaching elementary science: Who's afraid of spiders?* New York: Teachers College Press.

Appendix

Science Adventure #1—Biosphere 3

The Canadian Scientific Council has announced a competition for the creation of the Biosphere 3. The tendering process is now open to all companies or universities that are interested. If your proposal is to be accepted, deadlines for submission of each stage of the project are listed below. The objective of the Biosphere 3 project is to create a self-contained environment that will support six individuals for a period of two years. On entering the building, the participants will not be permitted to have contact with the outside world. This means that all supplies necessary must be brought into the facility before the experiment begins. Designing a structure that will meet these objectives is a difficult task. The Canadian Scientific Council will evaluate each design on its merits. Has your submission considered the "systems" necessary to support life? How is this reflected in the design of your building? Please remember that each group will have the opportunity to present their entire package to the panel during the third week of December. During this presentation be prepared to defend the decisions you have made.

Science Adventure #2—Vehicle Visions

Congratulations! Your company has been selected by the Canadian Science Council to participate in the prestigious North American Automobile Exhibition. The event this year will be held in Vancouver, British Columbia during the week of March 11-15th. The focus of this exhibition is to showcase innovation and design within the automotive industry. The objective of your company is to develop a unique vision for the future. When you are creating this vision you should be able to answer these types of questions: Who is this vehicle designed for? Have you considered future sources of energy? Has this vehicle addressed environmental concerns? Is it possible to mass produce this vehicle?

Designing a vehicle that will meet your objectives is a difficult task. The Canadian Science Council will evaluate each design on its own merits. We expect each company to conduct in-depth research on the energy source selected for your vehicle. Please remember that space will be provided to each company to present and display their concepts. Your company will be asked to submit the following:

1. A one-page typed write-up summarizing the vision of your company.
2. A short research paper outlining the scientific concepts associated with the energy source of the vehicle.
3. Two different conceptual drawings of the vehicle. These drawings should be drawn to scale.
4. Two 3-dimensional models of your concept.

Science Adventure #3—Create An Amusement Park

The Pacific National Exhibition (PNE) will be closing permanently at the end of the season. The exhibition has decided to relocate on a parcel of land in the Fraser Valley. The board of executives is seeking innovative ideas from the public to help plan their new facility. Your class has been selected to participate in this unique opportunity. We would like teams of students to create a new innovative ride or redesign an existing structure. Each submission should include research, detailed drawings and a simple mechanical model of your design. Please remember that space is limited and your group will have one half of a table top to present your model.

Timeline

1. Research and Sketches (May 14)—one page of research on the mechanics of your model; a clear sketch on 8.5" x 11" paper.
2. Final Drawings (May 17)—a detailed drawing of your design on 11"x17" paper; diagram should include a title, labels, and scale; this drawing will be used in your final presentation.
3. Models (May 28)—a simple model that demonstrates how the mechanical system works; the model should be displayed on cardboard no larger than half a table top.
4. Presentation (May 29)—each group will be required to pitch their design to an audience (2-3 minutes); each member of the group should be prepared to respond to questions from the audience related to the mechanics of their selected systems.