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ABSTRACT

During the 1980s increasing attention was paid to writing-to-learn elementary school subjects outside of traditional language arts courses. The concept of writing-to-learn in science has much in common with the concept of a science learning community premised upon a social constructivist epistemology. This paper reports on research designed to provide evidence that oral and written discourse can play an important part in student learning of science concepts. The researcher conducted research on her own teaching of 25 fifth-grade students, using a social constructivist epistemology to guide her teaching. Analysis of classroom interactions and interview data revealed that in order for students to participate in a learning community in which there is social construction of science knowledge, there needed to be a change in a number of classroom norms including those for the roles traditionally played by teacher and students, the source of authority for the knowledge learned, and the purpose of and audience for classroom talk and writing. In addition, there needed to be an opportunity for teacher and students to explore genuine questions together as members of a learning community. When a change in these norms took place, students over time were able to use their science knowledge in a flexible manner in multiple contexts across the school year, rather than in one context for purposes of a test and then forgotten. (MDH)

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Kathleen L. Peasley
with
Literacy in Science
and Social Studies Colleagues

Center for the Learning and Teaching of Elementary Subjects

Institute for Research on Teaching

College of Education

Michigan State University

MSU is an affirmative action/equal opportunity institution

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Center for the Learning and Teaching of Elementary Subjects

The **Center for the Learning and Teaching of Elementary Subjects** was awarded to Michigan State University in 1987 after a nationwide competition. Funded by the Office of Educational Research and Improvement, U.S. Department of Education, the Elementary Subjects Center is a major project housed in the Institute for Research on Teaching (IRT). The program focuses on conceptual understanding, higher order thinking, and problem solving in elementary school teaching of mathematics, science, social studies, literature, and the arts. Center researchers are identifying exemplary curriculum, instruction, and evaluation practices in the teaching of these school subjects; studying these practices to build new hypotheses about how the effectiveness of elementary schools can be improved; testing these hypotheses through school-based research; and making specific recommendations for the improvement of school policies, instructional materials, assessment procedures, and teaching practices. Research questions include, What content should be taught when teaching these subjects for understanding and use of knowledge? How do teachers concentrate their teaching to use their limited resources best? and In what ways is good teaching subject matter-specific?

The work is designed to unfold in three phases, beginning with literature review and interview studies designed to elicit and synthesize the points of view of various stakeholders (representatives of the underlying academic disciplines, intellectual leaders and organizations concerned with curriculum and instruction in school subjects, classroom teachers, state- and district-level policymakers) concerning ideal curriculum, instruction, and evaluation practices in these five content areas at the elementary level. Phase II involves interview and observation methods designed to describe current practice, and in particular, best practice as observed in the classrooms of teachers believed to be outstanding. Phase II also involves analysis of curricula (both widely used curriculum series and distinctive curricula developed with special emphasis on conceptual understanding and higher order applications), as another approach to gathering information about current practices. In Phase III, models of ideal practice will be developed, based on what has been learned and synthesized from the first two phases, and will be tested through classroom intervention studies.

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Abstract

During the 1980s increasing attention was paid to writing-to-learn elementary school subjects outside of traditional language arts courses. At the same time the idea of a social constructivist classroom, with an emphasis on creating a classroom learning community in which the talk and writing are viewed as tools for creating knowledge in the social aggregate rather than as tools for displaying knowledge learned individually, became increasingly prevalent in the literature. The concept of writing-to-learn in science has much in common with the concept of a science learning community premised upon a social constructivist epistemology. Unfortunately one commonality is the lack of evidence to support the claims being made that writing in elementary school science will improve science knowledge and that the creation of a social constructivist learning community will improve students' understanding of science.

This paper reports on research designed to provide evidence that oral and written discourse can play an important part in student learning of science concepts. The researcher conducted research on her own teaching of elementary school science using a social constructivist epistemology to guide her teaching. Analysis of classroom interactions and interview data revealed that in order for students to participate in a learning community in which there is social construction of science knowledge, there needed to be a change in a number of classroom norms including those for the roles traditionally played by teacher and students, the source of authority for the knowledge learned, and the purpose of and audience for classroom talk and writing. In addition, there needed to be an opportunity for teacher and students to explore genuine questions together as members of a learning community. When a change in these norms took place over time students were able to use their science knowledge in a flexible manner in multiple contexts across the school year, rather than in one context for purposes of a test and then forgotten.

WHY DID WE DO ALL THIS WRITING AND TALKING IF YOU ALREADY KNEW THE ANSWER? THE ROLE OF THE LEARNING COMMUNITY IN CONSTRUCTING UNDERSTANDING IN AN ELEMENTARY SCIENCE CLASS[1]

Kathleen L. Peasley with LISSS Colleagues:
Cheryl L. Rosaen, Corinna Hasbach, Constanza Hazelwood, Elaine Hoekwater, Carol Ligett, and Barbara Lindquist[2]

During the 1980s the writing across the curriculum movement swept across the country advocating teachers to use writing in subject matters both as a tool for learning and as a way to improve students' ability in writing. At the same time social constructivism, with an emphasis on oral discourse and the importance of the learning community, was rapidly becoming a popular way to think and talk about teaching and learning in the classroom. However, to date little has been written on the way in which writing can be used as a tool to help elementary students understand science. Typically writing activities designed for elementary school science tend to be isolated activities which emphasize the writing process rather than the science content. For example, students in an elementary science class might be asked to write a story about bats at Halloween time. Likewise, little has been written about how a classroom in which the teacher is using a social constructivist epistemology to organize the teaching and learning might look in general, much less how this approach might look in an elementary science classroom.

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[1] An earlier version of this report was presented at the annual meeting of the National Association for Research in Science Teaching, March 1992, in Boston.

[2] Kathleen Peasley, a doctoral student candidate in teacher education at Michigan State University, is a research assistant with the center for the Learning and Teaching of Elementary Subjects. Kathleen J. Roth, associate professor of teacher education at MSU, and Cheryl L. Rosaen, assistant professor of teacher education at MSU, are senior researchers with the Center. Corinna Hasbach and Constanza Hazelwood, doctoral candidates in teacher education at MSU, are research assistants with the Center. Elaine Hoekwater teaches fifth grade, Carol Ligett third grade, and Barbara Lindquist fifth grade at an MSU Professional Development School. The authors work together in the Literacy in Science and Social Studies Project at an MSU Professional Development School. The principal author gratefully acknowledges the support of Kathleen Roth, who provided extensive comments and suggestions on earlier drafts of this report.

As a result there are many unresolved questions about bringing these two perspectives, writing to learn and talking to learn with members of a learning community, into the elementary science classroom. For example, given existing school norms, how does a teacher go about establishing a learning community in which there is genuine exploration of science concepts through talk and writing? How is student learning of science content assessed in such a classroom? How are the students perceiving the writing tasks and talk in such a classroom? Howdo these perceptions influence their participation in science class? To what extent do the talk and writing help students learn the science content? What is the science content that students learn in a classroom which emphasizes talk and writing as learning tools? These and other questions led to the research project reported in this paper.

Research Questions

Three years ago I began working as a graduate assistant with a group of teachers and researchers who were exploring ways to teach for understanding in science and social studies, with an emphasis on studying the ways in which oral and written discourse could be used effectively to promote understanding in these school subjects. This project, known as the Literacy in Science and Social Studies Project (LISSS), was a collaborative effort in which both the school- and university-based participants took on the role of teacher-researcher. In this capacity I taught science and did qualitative research on my teaching and my students' learning in a fifth-grade classroom across the fall (Labor Day through Thanksgiving). Corinna Hasbach (a research assistant doing research in the same classroom in social studies), Cheryl Rosaen (a researcher who was conducting research on this group of students in writers' workshop), and Elaine Hoekwater (the fifth-grade classroom teacher) assisted in the data collection.

My particular interest was in trying to help students change their existing norms for participating in and using classroom talk and writing from the more traditional purpose of knowledge display (Cazden, 1988; Roth, 1987; Scardamalia & Bereiter, 1986) to the purpose of using them as tools for learning science. Therefore specific research questions I was exploring included the following:

*How do students participate in the science activities?
*How do students use the writing and discussion as tools for learning science?
*What type of a learning community is needed to support knowledge construction in science?
*What is the science knowledge that the students learn, and to what extent is this learning influenced by the talk and writing?

This paper will focus primarily on the classroom talk and writing of two students, Brenda and Billy, the classroom interactions they had with one another and with other members of their learning community, and the scientific understandings they were able to construct through their talk and writing. Billy's classroom interactions provide insight into the difficulties of using oral and written discourse as tools for constructing science knowledge in an elementary classroom. Brenda's talk and writing, taken together with her perceptions of the role of talk and writing in this classroom, provide insight into the way in which the students are perceiving and using the talk and the writing as tools for learning science and the impact that these have on their science content knowledge.

Methodology

The Students

The fifth-grade class at the elementary school[4] included 25 students, the majority of whom were Caucasian. However, there were two students of Native-American descent. The students live in a semi-rural and semi-industrial, blue-collar community located adjacent to a midsize city. Michigan State University is located 10 miles from the small community. Emerson Elementary is considered to have the largest number of "at-risk" students of the five elementary schools in the district. Many of the students come from low income families living in one of several nearby trailer parks. There is a growing professional population in the larger community; however, only a small percentage of the students in the class had parents who had completed college educations.

[4]Names of school and students are pseudonyms.

Data Sources

Field notes taken by Hasbach, Rosaen, and Hoekwater focused on both whole-class and targeted small-group interactions. These interactions were also audio- and videotaped and transcribed. The teacher documented her reflections through the use of a reflective journal. All written documents associated with planning and teaching were saved.

Formal interviews with five selected target students were held the first week of school, midway through the fall (late October), in December, and again in February. These interviews were designed to probe students' understanding of the science content, of the role of writing in learning science, and their ways of participating in a science learning community. Detailed notes were taken during the interviews and interviews were audiotaped (and frequently videotaped) and transcribed.

All target student written work was collected and copied across the fall. This writing included dialogue journal entries, science workbook writing, and additional writing tasks such as group-constructed concept maps. Formal assessment measures such as pre- and post-unit tests were also collected.

Curriculum and Instructional Framework: Towards a Social Constructivist Model

The curriculum was initially organized around a conceptual change model of instruction. Science education researchers have shown that students have a wealth of experience-based conceptions of natural phenomena (Clement, 1982; Dai, 1990; Driver, Guesne & Tiberghien, 1985; Erickson, 1979; Stead & Osborne, 1980; van den Berg, & Sandaura,1990). These conceptions are variously referred to as misconceptions, alternative conceptions, naive conceptions, commonsense notions, everyday knowledge, personal theories, and so forth. These ideas, although not necessarily congruent with scientifically accepted ideas, make sense and therefore "work" for the students in that they are able to use them to describe and explain phenomena in the natural world.

In a conceptual change model of instruction these ideas are not ignored as if the student were a "blank slate." Rather they are taken seriously and the students are supported through a process of comparing their conceptions with scientific conceptions as they reconsider and reconstruct their explanations until they are more closely aligned with the scientific conception; although it is stressed to the students that their everyday conceptions are valid in that they have worked for them for many years by the fifth grade.

As our work progressed, an important piece was added which is not an explicit part of the conceptual change model: Through the reading and study group discussions in which all members of the LISSS group participated, we became aware of the importance of the social context that supported and motivated student construction of knowledge. As a group we came to view the social context of the science classroom as a science learning community. Thus efforts in the classroom focused on creating a learning community in which students felt safe enough to share and puzzle over their uncommon ideas about scientific concepts (their "misconceptions") through their classroom talk and writing, and to work together to socially construct their science understandings. This learning community of scientific inquiry is not one which is explicitly addressed in the conceptual change model, yet is one which is much more consistent with the way in which scientific knowledge is constructed by scientists.

An important aspect of the learning community in science was collaboration. Rather than the science knowledge being something that was personal and private--the property of a single individual--science knowledge in the classroom learning community was something that was created by students working in collaboration with one another, in pairs, in small groups, or in whole-class discussion.

This emphasis on collective cognition and consensus building, rather than on the individual and competition among individuals, is consistent with a social constructivist epistemology of science in which the scientific knowledge rests not external to the individual but rather within the discourse community, "within the corps of human beings with a common intellectual commitment" (King & Brownell, 1966, p. 68). This view of scientific inquiry was embedded in the science classroom and shaped the conceptual change model in a social constructivist direction.

The first unit in the fall was a short unit on the nature of scientific inquiry, which was a thread that would continue throughout the fall term units. From the first it was emphasized to the students that science is a social endeavor, and, rather than being a collection of facts to be memorized, science is constructed through social interactions among people. In this respect science was represented to the students as being a "discourse community" (King & Brownell, 1966). The students were encouraged to think of themselves as scientists in that they would be working with others in the class to construct their understanding of science much the same as scientists work together to construct their understanding of the natural world.

A second unit on adaptations of desert plants and animals followed this initial unit on the nature of scientific inquiry. This second unit took approximately one month and built up to a unit on photosynthesis which continued from the second week in October through January 1 (see Appendix for a daily overview of the topics for discussion and writing). Unlike many elementary science units which are organized around a series of disconnected facts to be memorized, such as the names for the phases of the moon, this early unit on adaptations was organized around a question to which there is no clear answer and a set of concepts to be developed while exploring this question.

On the first day of the adaptations unit the students were posed the question, "Are there more different kinds of organisms in the desert or in Michigan?" At different times during the unit, which focused on the structure and function of various body parts of plant and animal species found in Michigan and the desert, the students were asked to write their developing answer to this question and support it with the evidence acquired over the course of the unit to date. It was made clear to the students from the start that I, the teacher, did not know the answer to the question, that I didn't know if anyone knew the answer to the question, and that the answer wasn't as important as the reasons they gave to support their answer. In this way the nature of scientific inquiry, often referred to in the science education literature as the *process* of science, was an integral part of learning the science content.

The way in which this second unit was organized with its emphasis on exploring a question for which there was no known answer, set a precedent for learning in this classroom which led to some tension in the next unit on photosynthesis as the questions posed during that unit were less open ended and were intended to lead students toward developing an explanation consistent with the scientific conception.

The Photosynthesis Unit

The first two units led up to a unit on photosynthesis, which began in mid-October and continued until January. Because all the students in the fifth-grade class had observed plants and had many commonsense ideas about plant life, the photosynthesis unit provided the ideal opportunity for me to study the role that oral and written discourse could play in helping students begin to give up their naive conceptions and adopt a scientific conception as being more intelligible, plausible, and fruitful (Posner, Strike, Hewson, & Gertzog, 1982).

The text used for the photosynthesis unit was *Food for Plants* (Roth, 1985a) which adapted the activities in the SCIIS Producers unit (Thier, 1978) to a conceptual change approach. This text was supplemented with the use of supplemental dialogue journals and extensive class discussions, which highlighted the role of the learning community in constructing the ideas in the text. Thus, the unit was intended to reflect a social constructivist approach.

Over the course of the unit there were many rich class discussions and lively debates as students made explicit to themselves and to other members of the science learning community their often implicit ideas about food for plants. During these discussions there were many opportunities for the students to share their commonsense ideas (or "misconceptions") about food for plants and compare and contrast these ideas to the scientific conception both verbally and in writing. There were also many opportunities for them to use the scientific conception both verbally and in writing in a variety of situations.

The unit began by having each student examine their own ideas about food and compare and contrast these commonsense ideas with one another's ideas and with the scientific definition of food. The premise behind this is that until they have an understanding of what constitutes food in general from a scientific perspective (in which the definition of food is the same for all living organisms, plant and animal) it is difficult, if not impossible, for students to understand the idea of photosynthesis or food for plants. Beginning this first day, and continuing throughout the unit, it was stressed to the students that although their commonsense ideas work for them in everyday life and are therefore valid, people have many contradictory notions about the same concept, such as what "counts" as food. These contradictory notions often make communication difficult, and the students experienced this difficulty for themselves on the first day of the unit as they discovered that what they considered to be food was not necessarily the same as what other members of the class considered to be food. These commonsense notions about food and the source of food for plants, which continued to emerge over the course of the unit, led to many arguments and debates as students considered whether various substances, such as food, water, and fertilizer were food for the plant.

As the students experienced difficulty in communicating their ideas among themselves and in reaching any sort of agreement about what constituted food, they decided that there was a need for a common definition in order to facilitate communication among themselves a members of a common discourse community. Once they realized this need for a common definition of food, they read and considered a scientific definition of food given in the text. This approach to introducing the scientific definition was used to highlight the social nature of science. It was emphasized that this was not the "right" definition, rather it represented a construction that had been consensually agreed upon by members of a common discourse community, scientists.

Following this the students read the scientific definition of food in their *Food for Plants* text--"anything that provides an organism with the energy needed to live and grow and keep its body parts working" (Roth, 1985a, p. 3). At this point students could begin to understand the usefulness of this scientific definition for purposes of communication; however, they did not yet feel ownership over this definition and thus there was a tendency to revert to their commonsense definition given any new situation. Therefore over the next two weeks they did a series of activities in which they used the scientific definition of food in multiple ways as part of their small group discussions, whole class discussions, and in their writing. Once they had used this definition repeatedly and were beginning to feel ownership for this scientific definition, evidenced by their automatically using the definition in their own words to help explain why something was or was not considered food, they were ready to begin learning about food for plants and the process of photosynthesis.

The next several weeks of the photosynthesis unit were spent doing and talking about a series of experimental activities designed to get students thinking about potential sources of food for plants while at the same time leading them to question some of their commonsense notions about food for plants, including the commonly held ideas that dirt, water, and fertilizers provide plants with their energy (Roth, 1985a). As can be seen from the teaching summary for science (Appendix), there was a great deal of writing and small and large group discussion interspersed with the experimentation. The purpose of the experiments was to help students begin to question some of their existing conceptions about food for plants and to develop a new explanation of the source of food for plants that was supported by the experiment. From this, the writing and discussion surrounding the experiments was designed to focus the students on developing explanations. We wanted to avoid the common elementary science trap of doing experiments simply because this was science and experiments are fun to do, with an unclear sense of purpose. The talk and writing also served as tools to help the students puzzle through their ideas both independently and with other members of their learning community. This purpose for writing was repeatedly discussed with the students as I worked to help them figure out ways to use the talk and writing to support their science learning.

Establishing New Norms for Classroom Discourse

There was a second curriculum strand during the fall which was a companion to the science content. The focus of this strand, as was alluded to above, was on helping the students use their classroom talk as well as their writing not as ways to display their knowledge, as is typically the purpose of student talk and writing in science, but rather as tools for constructing science knowledge with other members of their classroom learning community. There is evidence from the history of science to suggest that this is the way in which knowledge is constructed within the discipline. There is further support for this approach from cognitive psychologists who have postulated that learning occurs through social interaction.

Since Kuhn (1962), it has become generally accepted by the scientific community that scientific knowledge is not absolute but rather is the product of consensus among the scientific community to accept a given construct as the truth as best we know it at that time in history. According to Kuhn, the history of science is a series of paradigms which are governed by clear assumptions, rules, and methods of research. Therefore scientific laws, rather than being fixed and valid for all times, are temporal in nature and are determined by the assumptions, language, and activities of the community of scientists (Seixas, 1992). In this way Kuhn highlighted the social nature of knowledge growth in a discipline.

Vygotsky (1978) highlighted the social nature of knowledge growth more generally with his theory that learning is fundamentally a communal activity carried on within a shared culture. Therefore, the development of an individual's thought is a social process which is dependent on interaction within a community. Finally, Bruner (1986) has suggested that students learn by making sense of scientific knowledge within a community which shares a common culture, much like Kuhn's community of scientists, and much like an elementary science classroom.

Kuhn, Vygotsky, and Bruner all emphasize the importance of language in learning. Unfortunately, however, although elementary students are typically adept at using language in general they are typically not very adept at using the language of science, which has its own structure and syntax (Edwards & Mercer, 1988; Lemke, 1990). Thus it cannot be assumed that they will automatically know how to use oral or written language tools for constructing scientific knowledge with others.

Typically talking to learn, or talking for the purpose of constructing scientific understanding with members of one's discourse community, is not the norm in science class. More typically the norm for classroom talk follows the initiation-response-evaluation format (Cazden, 1988) in which the teacher poses a question, a single student answers the question, and the teacher evaluates the accuracy of the response. Thus the student's responsibility is to provide the answer the teacher is looking for and the teacher's responsibility in her role of evaluator is to determine whether the student has given *the* correct answer. Even very young children learn this traditional norm for classroom talk within a few months of entering school (Edwards & Mercer, 1988). Throughout schooling this discourse norm is reinforced and expanded so that by the time the students are in fifth grade it is very strongly held and difficult to change.

If students are to learn to carry on a dialogue with members of the learning community there needs to be explicit teaching to help students learn to ask good questions, to develop good explanations which go beyond mere description, and to use the canons of evidence and proof which guide scientific inquiry in their talk. Learning to use classroom talk as a way to puzzle through ideas with others may also require explicit teaching about who is to be the audience for, and evaluator of, their talk.

Because "talking-to-learn" is not typically the norm for classroom discourse in science, it will probably not be enough to simply *tell* the students that they are to use the classroom talk in different ways, much the same as it is not enough to tell them that they are to use the writing in different ways (Peasley, Rosaen, & Roth, 1992). It is likely that extended discussions between teacher and students throughout the year about the role that the discourse is to play in their learning and explicit teaching about how to puzzle through ideas and make connections orally will be needed. Therefore, part of the curriculum in this fifth-grade science class was an explicit focus on the role that talk plays in learning science. To this end, students examined other purposes and other audiences for their talk than knowledge display for the teacher. Students were supported in learning to ask questions, develop explanations, and use evidence to support their assertions.

The following brief transcript segment illustrates the way in which the audience for, and the purpose of, the talk was made explicit to the students.

> KP: You weren't looking for me to give you the answer, you were arguing back and forth trying to figure the answer out.... Arguing got you to think more about your ideas and some people said that they were changing their ideas as they were arguing

with other people... I think I heard you say, Chris, "Let's keep arguing, I like to argue."

Chris: It helps me learn. (11/7/90)

This excerpt also illustrates an emphasis on the science knowledge as tentative and developing, rather than as a fixed and unchanging "right answer." Students were encouraged to listen to the evidence provided by their peers and to rethink and possibly change their ideas to reflect each new piece of evidence encountered. It was emphasized that rather than being embarrassed by their commonsense notions and the way in which they had changed these notions based on evidence, this change was something they could celebrate as it was evidence of their own growth as a learner of science.

Establishing New Norms for Classroom Writing

There was a similar explicit curricular focus on the role that writing could play in helping students learn science. Because writing can serve to focus thinking and can be used to help students make connections and to gain an awareness of how the fragments of scientific information they learn are related, it has the potential to be a powerful learning tool in science. It has been hypothesized that carefully constructed writing tasks can help students understand the structure (the flexible "web" of related ideas) and the function (the way in which the knowledge is used) of scientific knowledge. In writing, one's thoughts are laid out in a linear fashion which makes it easier for ideas to be arranged and rearranged until a clearer thought structure is constructed.

However, the value of writing in science as a tool for learning is often underestimated by teachers and thus by students. I found at the start of the year that rather than using the writing in their science journals as a way to help them think, students tended to write very brief journal entries seeking only to give the one "right answer." This knowledge display is not a very powerful tool for learning science (Scardamalia & Bereiter, 1986), and the focus on coming up with the right answer tended to limit their thinking. Therefore, my goal with the writing, as with the classroom talk, was to help the students use writing as a way of puzzling through multiple possible ideas based on the scientific evidence to date, rather than as a way to show the teacher what they knew. For example, one of the writing tasks in the unit involved revisiting the commonsense definition of food written on the first day of the unit and writing how their ideas had changed. This revisiting was done not once but several times during the unit and became a way for students to track their changing ideas. This revisiting also emphasized to them that there was no reward given for having a single "right" answer as they were perhaps more accustomed to in other classes, but rather that being able to rethink and change their ideas was what was valued in this classroom.

Another writing task done frequently included looking in their science dialogue journals at a particular piece of writing they had done on another day and developing one question in writing that they could ask themselves based on what they had written. They were taught to pretend they were the teacher and to ask the sorts of questions they thought I might ask them if I read their entry and were encouraged to have imaginary conversations with me as they were doing this. I also suggested that as a model they look back over questions that I had asked them previously in their journals. This task was developed after I became frustrated with asking students to look at what they had written and see if they could add anything new. Invariably they could not: They felt that they had already given "the only right answer." However, when asked to look at what they had written, and taught how to question their thinking in writing, they gradually learned how to question their ideas and to think of additional ideas on their own.

Evidence that students were beginning to use the writing as a tool for learning science and also that they were viewing the writing not as a final form but as a temporary form of recording their changing ideas was provided by comments made by Brenda during an interview done mid-fall in which she was asked about the role of writing in her learning of science:

> KP: Can you describe the writing you do in science?
> Brenda: If you write them [your ideas] you will be able to see what you think ... and I like writing my ideas as much as I do telling them to somebody because if I tell them to somebody they [sic] might forget it but if I write it down I can't forget it. So if I forget what I said the week before because I changed my answer so much I wouldn't know what I said at first so I couldn't say I changed my answer from what to what. I wouldn't know what I had before.

Brenda's comments about the writing in science show that she has integrated into her thinking several important ideas about the role of writing in learning. First is the idea that if you write your ideas you will be able to see what you are thinking. This is one of the strengths of writing in the content areas. Written work can serve as a visual, concrete record of the developing understanding of scientific relationships which are easily accessible (Fulwiler, 1985) both to the student and to others in the student's learning community. It is clear that Brenda considers not only the importance of making her thinking visible for herself as she works to construct understanding but also the importance of sharing her thinking in writing with other members of her learning community when she states that if she just tells her ideas to someone they might forget them (possibly before they have had time to think them over and respond thoughtfully to them).

Brenda views her writing as different than the traditional knowledge display for a "teacher/evaluator" and describes it as being a record of her changing ideas. She sees the writing as a temporary form of ideas to be revisited, evidenced by her statement that she needs to write what she was thinking last week so that she can keep track of how her thinking is changing. Another clue that she is thinking about writing as a way to puzzle through *ideas* rather than as a way to display ***the answer*** is in the words that she uses. She begins by talking about writing ideas rather than writing the answer. Later in her statement she does fall back on using the term "the answer." However, she does not appear to be thinking about it as an absolute answer that is either right or wrong as she talks about the answer in terms of how it has changed in her thinking. These are telling pieces of evidence that Brenda is using the writing as a place to record and play around with ideas, rather than as a place to display knowledge.

<u>Source of Knowledge and Authority in Elementary Science</u>

The issue of who was to be the authority for the science knowledge eme[illegible] [illegible]ly in the year when students realized that the more traditional teacher-as-evaluator was not to be the audience for their talk and writing. It was clear to the students that their text and their teacher were providing more questions than answers. This initially led to some conflict as new roles and responsibilities for the teacher and the students began to emerge. The teacher's role was not the traditional one of an authority with responsibility for telling the student whether their ideas at any given time were correct or incorrect. Rather, my responsibility as the teacher was to elicit students' ideas, help them learn to listen and respond in nonthreatening ways to one another's ideas and to ask (and to help students learn to ask) the sorts of questions which would push their thinking and the thinking of others in the leaning community in a productive direction. This also involved reading and responding to students' writing not from the position of an evaluator but as a "more knowledgeable other" (Vygotsky, 1962) who could ask probing questions designed to get the students questioning and thinking further about the ideas they had written. I need to emphasize here that this does not imply that all ideas were given the same validity, that every answer was accepted as correct, or that there was an "anything goes" atmosphere in the class. Rather there was an emphasis placed on those ideas which brought us as a learning community closer to understanding the scientific conception.

In a similar manner the students' responsibility was not to provide the answer that the teacher was looking for but to listen to their peers' ideas, respond to and question those ideas, and share their own ideas orally and in writing as a way of puzzling through the concepts. My goal for the class was that eventually the locus of authority for the science knowledge would rest not with the teacher alone but with the learning community, which consisted of both teacher and students. Reaching that goal, however, was a lengthy and difficult process because it required students to abandon many strongly held school norms.

The next section illustrates the difficulty that one student, Billy, had in changing his view of science knowledge and what it meant to learn in elementary school science. This section will also highlight the way in which another student, Brenda, learned to deepen her understanding of science through her participation in the learning community.

The Case: Billy's and Brenda's Learning About Social Construction of Knowledge

Billy, who is a white male from a middle-class family, represents a typical "school smart" student. He generally was well behaved in class, completed all his classroom work in a timely manner, frequently volunteered answers in class discussion, and genuinely tried hard to get the "right answer" and please the teacher. He knew that he was "smart" and a good student and his peers tended to defer to him in class discussion on the assumption that he had the right answer.

At the beginning of the year Billy clearly saw the source of authority for knowledge in very traditional, objectivist ways. In this respect Billy was a "separate knower" (Rosaen, 1992). Knowledge resided external to him as something to be "uncovered." This is consistent with the way that science knowledge is typically represented in science classrooms--from a logical positivist perspective in which knowledge exists external to the individual and is something which the individual can somehow discover. This perspective contrasts with a social constructivist perspective in which knowledge is developed by the members of the learning community. A logical positivist view of science and scientific inquiry had served Billy well in the past; he had been very successful in science. As a result he was not entirely willing to give up this view of science.

In addition to viewing knowledge as being an uncovering of nature that exists outside himself, Billy saw the text and the teacher as the authorities for the science knowledge he learned in school. He frequently read ahead in his science book although he had been asked not to do so, so that he could give the right answer (as given by the text) during class discussion. During class arguments Billy cited the text or the teacher, whenever available, as the final authority. For example, he would often appeal to the teacher during an argument to verify that his answer was correct rather than relying on evidence provided through his own experimentation. From his perspective the teacher and the text represented truth and were not to be questioned by himself or others.

Is Candy Food? Who Knows?

The transcript segment below was recorded during Billy's small-group discussion during the second week of the photosynthesis unit. It illustrates the expert role that Billy typically played in science class and also demonstrates the struggle the students, including Billy, were going through as they tried to decide who was to be the authority for determining the accuracy of the knowledge in this science class. The students' difficulties in learning to adopt new roles and responsibilities in what had been a familiar setting, that of science class, are evident in this lesson.

The students in Billy's group are Brenda, Don, and Kelly. Like Billy, Brenda is a "school smart" student who is viewed by teachers and her peers as a good student who works hard to produce the "right" answer. Both she and Billy do well on traditional measures of school ability such as standardized testing. By contrast, Don has difficulty with school, does not do well on traditional measures of school ability, and is viewed by teachers and his peers as "slow." This image of Don may be fostered by the fact that he tends to suck his thumb when frustrated, a behavior viewed as babyish by his teacher. The fourth member of this group, Kelly, sat quietly throughout the discussion, neither offering her thoughts nor being asked what she thought by other group members.

All the members except Kelly, who remained characteristically silent, are participating as they argued over whether or not candy was food according to the definitions they had written the previous day. Don has just called me over to the group;

Don: (To KP) Billy said that only his and Brenda's definitions are right.
Brenda: Candy can be food.
Don: No it can't, because it is candy.
Billy: To be food it has to be nutritious.
(10/16/90)

Billy's assertion that there is indeed a "right" definition for food and that he and Brenda have produced it is telling evidence that Billy is viewing scientific knowledge from an objectivist epistemology. In this instance there is not an authority source such as a textbook or a teacher that Billy can go to for the "right answer" to the question of whether candy is food. Instead, he cites himself and Brenda, the two peer-acknowledged "smart students," as the authorities.

In this segment Billy has just finished telling Don that they, Billy and Brenda, have the correct answer. In fact he and Brenda are directly contradicting one another; Brenda says that candy is food while Billy says that to be food something has to be nutritious. Billy and *Don* are much closer to being in agreement; both are saying that candy cannot be food, although their reasons why this is so are different. At this point Billy is not valuing the contribution that Don can make towards constructing scientific knowledge in the same way that he is valuing Brenda's contribution. This leads him to accept Brenda's ideas as more valid than Don's even when hers are contradictory to his own.

There are two additional factors that may contribute to Billy's devaluing of Don's contribution. First, according to traditional measures, Billy and Brenda are successful students, while Don is not. In the culture of the classroom this automatically makes Billy and Brenda the authorities when in conversation with Don. Therefore, rather than listening closely to Don, Billy makes the immediate assumption that Don is wrong while they, Billy and Brenda, are right. This was extremely frustrating to Don who said in a later interview in reference to this interaction that,

> We all had our own ideas but Billy thought he was the one that had the best idea out of everybody.... He thought that he was the smartest person in the whole group ... but everybody was smart. Everybody is smart. (12/10/90)

Second, although Billy and Don are both arguing that candy cannot be food, there is a critical difference in their arguments. Billy is using the "language of science" (Lemke, 1990), giving evidence to support his answer, that candy is not food because it is not nutritious. Don is not using this language, presenting the circular argument that candy cannot be food because it is candy. This gives Billy the appearance of being more knowledgeable than Don and reinforces the perception that Billy is "good at" or an expert at science relative to Don. It is possible, however, that if explicitly taught to do so, Don could also produce evidence to support his assertion rather than the circular argument he presented. At this point Don has simply not mastered this way of automatically talking science as Billy has. And indeed, as the unit progresses, and as Don is explicitly taught how to provide evidence to support his assertions, he does learn how to talk science, and his subsequent contributions are valued more by both Billy and the rest of his peers.

Finally there is the issue of Kelly's silence during this discussion. Although she had written a definition of food in her science book and in her journal, she does not contribute this definition. There is no indication what sense she is making out of the group discussion, if any at all. Although in this interaction her group members made no effort to get information from her, there were subsequent occasions on which they made attempts to get her to joining the group debate. As Don stated in an interview, "I wish that Kelly would share her ideas. She has really good ideas but she doesn't tell us what they are." This raises some unresolved issues surrounding participation in the discourse. What did Kelly learn from the group discussion? Is it possible to learn from the discussion without actually doing any of the talking? What is learned from talking that Kelly might not have learned due to her silence? Why didn't Kelly talk?

Puzzling Thorough the Issue in Discussion and Writing

The issue of whether candy could be food was returned to the next day during the whole-class discussion in which the groups shared their ideas, which led to much debate and little agreement as it became obvious to the students that whether a candy bar was food depended on how you were defining food. Following this discussion the students read and discussed a scientific definition of food, compared it in writing to their original definition of food, and then used this new definition to address the question of whether candy is a food. As they dealt with this question they utilized both talk and writing as they wrote their new ideas in their journal and held a class vote on whether a candy bar was food. Table 1 summarizes the talk and writing that took place during this two-day period and illustrates the interaction between the talk and the writing as students talked, then wrote, then used the writing to support further discussion, then wrote some more based on the discussion.

The following case of Brenda illustrates her perceptions of the role of talk and writing in constructing scientific understanding and the way in which she used the talk and writing with other members of her learning community to construct her knowledge of photosynthesis.

In looking at the writing the students did in their journals and in their science books over this two-day period, Brenda represents a fairly typical case, although her commonsense definition of food was more sophisticated and closer to the scientific definition than many of her classmates. Her original definition of food was the following:

> I think food includes candy, meat, water, powdered substances that are eatable and anything else that is eatable that will not harm you. Also include anything that is drinkable that will not harm you. (Brenda, 10/16/90)

On the second day, following the small group and whole class discussion and reading the scientific definition Brenda wrote:

> I have not changed my answer at all except that it had to help you live and grow and give you energy which led me to the big question is a candy bar a food and I said, "Yes." (Brenda, 10/17/90)

Brenda began writing by saying that she had not changed her original answer at all. However, as she continues to think in writing, she adds the idea that food helps you live and grow and gives you energy (a critical piece of the scientific definition missing from her original definition). She continues her thinking in writing focusing on the earlier question of whether a candy bar is food and now that she has added the idea of food as an energy source to her definition she has decided that it definitely is food. Thus through the process of writing Brenda has determined that her definition has changed and that this changed definition provides evidence that a candy bar is food. This is a realization that she might not have reached, or might not have reached as soon, without the opportunity to think through her ideas in writing.

In contrast to Brenda, Billy was still strongly resisting the scientific definition and maintaining his commonsense notion that in order to be food a substance has to be nutritious. It is interesting that in the following interaction between Billy and Brenda it has now become evident to both of them that they are not agreeing on a common definition of food, as Billy had asserted to Don the previous day.

> Brenda: Does it make a difference in whether something is food if it gives you energy for a long time or a short time?
> Billy: It isn't food unless it is healthy. (10/17/90)

At this point the class discussion continued while Brenda and Billy continued to have a quiet debate off to one side. This is a debate that continued off and on for several weeks as Billy was extremely resistant to "letting go" of the idea that in order to be food something has to be nutritious. Brenda persisted in providing evidence to convince him otherwise. In an interview in December Brenda returned to this debate as she emphasized the importance of carrying on discussions such as this (emphasis added):

Table 1

Summary of Discussion and Writing Topics on the Definition of Food

Date/Topic	Discussion	Writing
October 16 -Eliciting commonsense definitions of food -Using commonsense definitions of food	-Debate in small groups whether candy is food according to their commonsense definitions	-Write commonsense definition of food in science book. -Write in journal why they think candy is or is not food, based on their definition and small-group discussion
October 17 -Learning the scientific definition of food -Comparing commonsense and scientific definitions of food -Using the scientific definition of food	-Read and discuss scientific definition of food in book -Whole-class debate and voting on whether candy is food according to the scientific definition	-Write in book how they would change their commonsense definition based on scientific definition -Write new definition of food in journal

Brenda: We explain what we think is right [the small group] and then we collaborate with the rest of them [the class] about ... um ... things like if soil is food for plants, we went on with that for a long time. *We don't work individually very often. I really like that because you might decide that you like someone else's answer better and you might change your answer, or you might say "No, I like my idea better." But you know what other people's ideas are and you don't have to keep yours all to yourself.*

KP: What do you mean by collaborating with the rest of the class?

Brenda: *You sort of compare your ideas with someone else's. Like I argued that a candy bar has energy and so it is food and um Billy would say, "I don't think it is because it doesn't give you much energy."* So we are collaborating our ideas together. It is sort of like arguing only its a good way of arguing. You are just saying things like, I think this and you think that and you try and take the best of the ideas you all have and you try to get the right answer.

Billy's and Brenda's Conceptual Learning

One of the difficulties in teaching science is helping students to alter or abandon their commonsense notions, such as the idea that in order for something to be considered food it must be nutritious. For example, Roth (1985b) found that often students are able to give the scientific conception on a test, such as the formula for photosynthesis; however, when asked to explain how a plant gets its food they revert back to their commonsense notions. Students seem to have two mental frameworks; one which contains the answer they know the teacher is looking for and one which contains what they really believe, or their commonsense notions about everyday phenomena. Interviews with Brenda at the beginning of the photosynthesis unit and again more than two months after the unit was completed revealed that this was not the case for her in the fall term photosynthesis unit.

When asked at the start of the unit how plants get their food, Brenda replied relying on her commonsense notions gathered through 11 years of observing plants and through things that she remembered from other science classes in the past.

Brenda: I think they use sunlight
KP: How do they get the sunlight?
Brenda: Sunlight will go through the leaves and they will turn a darker or a light color because they don't have any more water. Sun does a different purpose to a daisy. The sunlight is food for them because it gives them energy. It goes into their system through their leaves and then it like gives them energy.

Brenda had told me that she had studied photosynthesis before, and there is evidence of that learning in this description. She has some sense that the sun is a source of energy for the plant and that it enters the plant through the leaf. However, in this description Brenda is thinking that it is the sunlight alone that gives the plant energy directly. There is no sense of the process of photosynthesis in her talk. In another interview she also described the process of gas exchange in plants, saying that they "take in" carbon dioxide and give off oxygen. Yet she has not connected that concept in any way to the process of photosynthesis. Rather, it is another isolated bit of science knowledge that she remembers learning in Health at some point. At this point all Brenda has are some fragmented pieces of knowledge about plants and their food This is in contrast to the more sophisticated explanation that she developed during the photosynthesis unit and still held more then two months after the completion of the unit. This is telling evidence that her knowledge of food for plants, or photosynthesis, was not "memorized for a test and then forgotten."

KP: What is food for the plant?
Brenda: Sunlight, air, and water combine in the leaves to make food for the plant.
KP: Is sunlight alone food for the plant?
Brenda: No, it needs all three things in order to make its own food.
KP: Anything else?
Brenda: When a plant first starts growing it uses the cotyledon for food. An older plant doesn't have a cotyledon any longer it so it makes its own food.

Although Brenda doesn't understand the complex biochemical changes that take place in the plant, her descriptions of how the plant initially uses the cotyledon as a food source until the plant is able to use the sunlight, air and water to make its own food is very different from her initial conception that the plant somehow took in sunlight and used that to make food directly.

Although it may seem that this is not much knowledge to have been gained through nearly two months of instruction, it is knowledge that was gained through talking and writing with other members of her learning community rather than knowledge that was presented to her by the teacher as if she were the proverbial "blank slate." It is also a sophisticated scientific concept which explains a piece of the natural world, and yet it is a concept that many adults do not understand. Researchers have found that conceptions about food for plants, including the ideas that water, dirt, and fertilizers are food, are very strongly held by children and very resistant to change (Roth, 1985b, 1987). Without instruction such as is described in this paper, it is conceivable that students would continue holding their commonsense notions through to adulthood. Brenda does appear to have abandoned her commonsense notions about food for plants and adopted a scientific explanation about the source of food for the plant as her own.

Why Did We Do All This Talking and Writing if You Already Knew the Answer? Students' Learning About Talk and Writing in Science

By late in the fall term there had been a great deal of discussion about the purpose of and the audience for the classroom talk and writing. However, just as subject matter conceptions such as Billy's idea that in order to be food a substance has to be nutritious are difficult to change, the norms for participation in science class are also strongly held by the fifth grade. This made it difficult for students to think of the talk and writing in new ways even after several months in this classroom.

This is illustrated by a question raised by Chris during a debate on whether dirt was food for plants, an idea held by many of the students in the class. Following two days of debate and discussion the students read about van Helmont's experiments in the 1600s which provided convincing evidence that dirt was not food for plants. Chris had actively participated in this debate and seemed to enjoy it. Yet he raised a troubling question afterwards:

> If you already knew that dirt was food for plants and if someone else had already done that experiment, then why did we spend two days talking about whether or not dirt was food for plants? Why didn't you just tell us yes or no? (11/7/90)

This was an important question. Although at this point we had spent two months together during which time we had repeatedly puzzled through ideas orally and in writing, Chris still apparently holds on to the traditional school norm in which the role of the teacher is to provide the student with the answer. In this case it appeared that Chris believed that we had "wasted" two days trying to figure out something that had already been figured out before. In a sense he was arguing that there was no need to reinvent the wheel. Chris raised an important question for me: Why *did* we do all this writing and talking which took up so much time? Did it help the students learn the science content? And if so, how was their knowledge influenced by the talk and the writing? I decided to ask the students both as a class and individually to get a sense of their perceptions and knowledge growth.

KP: I think that is a good question to ask. I think we should spend some time talking about it. A couple of ideas?
Billy: Maybe he's [van Helmont] not right and maybe we can think about some things that he didn't think of.
Don: If you tell us the answer what are we going to learn?
KP: Good point. You might learn to memorize the answer. Sometimes there are things that you can learn from talking that you can't learn if I just tell you the answer. Kelly?
Kelly: We probably learn to think more.
Brenda: Instead of you giving us the answer we could all discuss it ourselves and try to figure it out ourselves instead of you just giving us the answer.
KP: Why might that be important to help you figure out the answer instead of my giving you the answer?
Brenda: So that we don't always expect you to give us the answer. (11/8/90)

I found it interesting that Billy made the observation that possibly van Helmont was not correct. It is consistent with the attitude encouraged in this class of questioning and requiring evidence to support assertions made by text, teacher, and other potential sources of authority. This questioning of traditional sources of authority is something which students are rarely empowered to do in an elementary or even a secondary science class, yet is an important part of the discourse within the scientific community. For Billy, who initially appealed only to authority for "the answer," this is a significant change in his approach to scientific knowledge.

It was also exciting to hear Kelly say that all the talk would help them learn to think more. Kelly was the very quiet student who, although she wrote a great deal in her journal and science book, talked very little, either in class or in her small group with Billy and Brenda. An unresolved question is whether the talk, in which she did not actively participate, helped her learn the science content. It appears from this comment that she did see the value of talk in learning, whether or not she personally felt that she benefitted from the talk of others.

Like Kelly, Don also commented on the role of talk in learning, focusing on the idea that if I gave them the answer they wouldn't learn as much as if they figured it out for themselves. This too is exciting because Don was not a student who traditionally did well in school and yet he was able to think about scientific knowledge as something that he could create rather than as an answer given by the teacher to be memorized.

In this conversation Brenda brought in the learning community, citing the importance of discussing ideas among themselves and working together to figure things out. This theme of constructing knowledge with other members of a learning community appeared again in the interview done with Brenda in December. It is interesting that in this interview the two discussions that Brenda returned to were the one on whether a candy bar is food held in October and the one on whether dirt was food for the plant held in November. These were two important discussions in that the class was truly functioning as a learning community trying to make sense of the science content. These were also both discussions which would have taken less then one class period in a more traditional classroom, but in this classroom each discussion took three to five days during which the students were completely engaged in the discussion the majority of the time.

These responses reconfirmed my belief in the value and importance of helping students use talk and writing to construct scientific knowledge for themselves. I also saw in this discussion, and in Brenda's interview responses, evidence of students viewing themselves as what I would call social constructivist learners. They were not talking about learning in terms of remembering what the teacher or text had told them so that they might display that recall ability on a test. Rather, they were talking about how arguing and writing might help them learn to do more than that. Through the talk they might think of other ideas, might question something van Helmont hadn't considered, and might question their own ideas as they listened to the evidence presented by others. This was what I was hoping they would come to understand about learning in science.

However, there is also a second aspect to Chris's question which needs to be explored further. It is possible that rather than being frustrated because we had spent two days on a question to which I already knew the answer, Chris was frustrated because there already was a known answer to the question in that there was a great deal of evidence that dirt is not food for plants. Chris may have been operating under the assumption that this question, like the one in the previous unit about number of organisms in the desert and in Michigan, had no known answer.

Thus he may have felt betrayed when, after two days of discussion during which time it was clear I valued their thinking, I told them that there was indeed an answer to the question that scientists at this point all agreed upon.

This raises an important issue when thinking about teaching science using a social constructivist epistemology. Should the science curriculum allow students to explore questions not yet answered by scientists? Or should it focus on helping students understand the "answers" (concepts) scientists have constructed. Most elementary science topics are not ones in which there are a lot of unknown questions, such as the question in the adaptations unit, which can be pursued productively. Therefore, rather than constructing knowledge as if they were the first to do so, the students are actually constructing their understanding of the science content together as a learning community. If Chris's possible feeling of betrayal is indicative of how students might feel in his situation, it is important to communicate to students that they will not generally be creating new scientific knowledge as was done in the adaptations unit but rather new scientific understanding as was done in the photosynthesis unit, and in that sense it is new knowledge for them.

Conclusion

Social constructivism has the potential for being a powerful construct for shaping instruction in an elementary science classroom. It is consistent with the way in which knowledge is constructed in the discipline and it allows students to construct their own understandings of the science content rather than merely memorizing to please the teacher. Knowledge that is constructed by the student in this manner is knowledge that is truly learned. This is the knowledge that the student will remember and carry with them for a life time as opposed to the knowledge that is committed to short term memory for the purpose of passing an exam.

In order for students to participate in a learning community in which there is social construction of knowledge, there needs to be a change in a number of classroom norms. The teacher needs to change from the traditional role of authority figure who has the responsibility for evaluating whether students have learned the science content to the role of colearner who works together with the members of the classroom learning community to construct knowledge. As is illustrated with the description of the unit on organisms in Michigan and the desert, the teacher does not have to know all the answers; indeed it is possible to explore questions with no known answer in meaningful ways. However, although a colearner, the teacher in this situation also has another role, that of mentoring the students' learning. The teacher has the responsibility for skillfully helping the students explore their ideas through questioning and probing their thinking, helping them provide evidence to support their assertions, and guiding them to resources that will help them think further about the question.

The students need to take on new responsibilities also. Their responsibility is not to provide the answer the teacher is looking for; rather, their responsibility is to make sense. Making sense depends on listening to their classmates, as well as teacher and text, and to work collaboratively to construct the best explanation of a given phenomenon using the evidence that they have.

There are also new norms that need to be established for the classroom talk and writing. In a social constructivist oriented classroom the main purpose of classroom talk is for puzzling through ideas orally and for sharing ideas with other members of the classroom learning community. Likewise writing is not merely for the purpose of showing learned knowledge to the teacher . Instead, writing is a tool for connecting and changing ideas and a language-based medium for sharing ideas with classmates.

Changing these norms is not easy, however, as Chris' question, "Why did we do all this writing and talking if you already knew the answer?" illustrates. Chris had learned to trust that his ideas were important and valuable to the learning community and had been an active participant in the debate over food for plants. He then felt betrayed when he discovered that he was struggling to solve a problem that had already been solved. Chris' feeling of betrayal raises an important dilemma in teaching science using a social constructivist epistemology: How do you help the students think of their ideas and sense making strategies as valuable and important when there is an accepted "right answer" already available? Can a question be genuine and authentic if scientists have already constructed an accepted response to the question?

I had been successful in teaching Chris to value the ideas of himself and his peers, yet I had failed to teach him that although there was an accepted "answer" to the question his struggle to construct that answer for himself was a valuable part of the learning process. If Chris' reaction is not atypical then it is important to communicate to students not just that their thinking and ideas are valuable but also that their puzzling through ideas together with their peers in the learning community is an important part of their learning, even if they are replicating the process that scientists have already done.

In summary, traditional norms for classroom talk and writing and for the source of authority are strongly held. However, they can be changed as illustrated by the cases of Brenda and Billy. And once these norms change, the science content that is learned is not memorized but rather, because it was constructed by the student, it is learned for a lifetime.

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Appendix
Fall Science Teaching Schedule–
Nature of Scientific Inquiry and Adaptations Units

Unit Day	Date	Discussion Topic	Writing Task
Day One	Sept 10	Introduce journal writing. Discuss their drawings. Begin discussion stereotype	Draw picture of scientist at work. Describe what the scientist is doing.
Day Two	Sept 11	Further discussion of stereotype. S's share stereotype from their drawing. Discussed stereo. of scientists. Group presentation of their pic. of a scientist.	Finish writing about scientist drawn the day before.
Day Three	Sept 12	Watch video of scientist talking about his work. List of scientists work shared and classroom composite list made.	List of aspects of scientists work based on video.
Day Four	Sept 13	Review of stereotypes of scientists. Students share their writing about the picture. Discuss why/why not they think she is a scientist.	Students write about Dorothy Hodgkin picture.
Day Five	Sept 17	Create a brainstormed list of aspects of a scientists work. Discussed purpose of dialogue journals. Discussed organisms in desert & MI	Write "Ways I am like a scientist..., Ways I am not like a scientist." Filled out chart; Plants & animals in the desert and Michigan.
Day Six	Sept 18	Continued working in groups on list of organisms in desert & MI. Discussed where there are the most organisms & possible reasons why.	Put stars by organisms from previous days chart–ones they are sure of.
Day Seven	Sept 19	Talked in groups about where there would be the most number of organ. Discussed question: "Why don't we have all the species of plants and animals in MI?" Discussed in small groups rather than whole class.	Write in journals where they thought there were the most organisms; MI or the desert. Needed to give multiple reasons.
Day Eight	Sept 20	Discussed purpose of journals. Brainstormed things necessary for an organism to live. Predator/prey relat. came up. Read and discussed "desert ecosystems."	Fast write on feedback received on journal.
Day Nine	Sept 24	Discussed adaptations using example of a chameleon. Introduced idea of structure and function.	Made structure/function chart as developed by the class in journal.
Day Ten, Eleven	Sept 25, Sept 26	Continued discussion of chameleon adaptations. Group work in library looking up structure/function of assigned animal..	Group-generated structure/function chart–animal.
Day Twelve	Sept 27	Discussion of survival mechanisms of desert plants. Used books in classroom to do plant structure/function activity (chart). Done in groups.	Group generated structure/function chart–plant
Day 13-16 (KP off sick - CH "subbed")	Oct 1-4	Group work looking at actual plant structures and trying to figure out their function. Videotape and discussion of desert scientists at work.	Described aspects of desert scientists work in their journal.
Day 17	Oct 10	Other fifth-grade students come in and share their structure/function game. Reviewed terms.	
Day 18	Oct 11	Scientific inquiry & Adaptations unit quiz.	

Fall Science Teaching Schedule--
Photosynthesis Unit

Day	Date	Discussion Topic	Writing Task
One	Oct 17	What is food/ everyday definition vs. scientific definition.	In book: write your definition of food
Two	Oct 18		
Three	Oct 22	Group work: sorting cards with words like gum, vitamins, etc., into piles of "food", "not food", "not sure."	In journal: Make a chart of items group decided were food, not food, not sure.
Four	Oct 23	Continued discussion of food/non-food items. Reread definition of food.	In journal: change any of the previous days answers on the chart they now disagree with.
Five	Oct 24	Discussion on whether something has to be nutritious to be food. Set up bean seed experiment.	In book: Began filling out grass seed experiment data chart In journal: Wrote their most recent definition of food.
Six	Oct 25	Picked apart bean seed and looked at parts. Set up bean seed experiment	In journal: Began filling out bean seed experiment data chart.
Seven	Oct 29	Discussion of how plants get their food.	In book: Answer questions on page 5. In journal: Answered two questions: What is food--latest definition? How is food for plants the same or different as food for people?
Eight	Oct 30	Collected bean seed data. Discuss data groups collected. Discussed purpose of exp.	In book: Wrote predictions re: exp. In journal: Answer questions: What do you think this experiment will tell us? What else would you like to know?
Nine	Oct 31	Discussion re: characteristics to look for in grass seed experiment.	In journal: Set up grass seed data chart.
Ten	Nov 1	Data collection and discussion of what they will be able to use the grass seed data to tell them. Discuss other things that might be food for plants.	In book: Answer questions page 7 In journal: Write predication--what each part of the bean seed does for the plant.
Eleven	Nov 5	Data collection: Grass seeds and bean seeds. Discussion of fair test require. Began discusing van Helmont exp.	In book: predication based on Van Helmont experiment.
Twelve	Nov 6		
Thirteen	Nov 7	Discussion of van Helmont exp. as a way to answer debate over whether dirt is ffp. Discussion of the types of comments that teacher has made in their journals.	In journal: What does soil do for the plant? Is soil food for plants? In journal: Play teacher. Read the above response and make comments to it.
Fourteen	Nov 8	Discussed why we had 2 days of discussion on whether dirt was ffp when teacher already knew answer. Began to distinguish between "necessary for life" and "good to have."	In journal: chart on things necessary for life and things that are good to have but not necessary for life. In book: questions on p. 13--van Helmont's experiment.
Fifteen	Nov 12	Collect grass and bean seed data. Discussion of fair test w.r.t. grass & bean seed experiments. Debate on whether soil is ffp based on experi. results.	

Sixteen	Nov 13	Final data collection--bean seeds. Discussion of results. Discussion of what constitutes a good explanation	In book (pg 8): Write results and explanation for results In journal: final results described. In journal: Write whether soil is ffp and reason based on van Helmont experi.
Seventee n	Nov 14	Discussion of whether fertilizer, water are FFP and how this could be determined.	In journal: Write ideas of whether fertilizer and water are ffp and why.
Eighteen	Nov 15	Discussion of why grass in dark grew for awhile than died. Continued argument over whether dirt is ffp. Began discussing whether fertilizer is ffp.	
Nineteen	Nov 19		
Twenty	Nov 20	Continued discussion from Nov 15. Photosynthesis is introduced. Small group discussion of cartoon in book.	In book: Write individual explanation of cartoon.
Twenty One	Nov 26	Group discussion of how water moves in a plant. Discuss how a plant needs air, water, and light to make food.	
Twenty two	Nov 27		In journal: Diagram of how air, and water travel through a plant.