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SCIENCE AS DISCOURSE: THE ROLE OF DISCOURSE IN CONSTRUCTING UNDERSTANDING IN A THIRD GRADE SCIENCE CLASS

By

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ABSTRACT

SCIENCE AS DISCOURSE: THE ROLE OF DISCOURSE IN CONSTRUCTING UNDERSTANDING IN A THIRD GRADE SCIENCE CLASS

By

Kathleen L. Peasley

This dissertation draws upon ideas from literacy, linguistics, and science education reform documents to develop a definition of scientific literacy which is then used in an analysis of classroom discourse and student learning.

The purpose of this qualitative study was to determine the nature of students' talk, the norms for participation in the talk, the individual student's science knowledge construction, and the relationship among and between these factors in a classroom in which the teachers were supporting the development of scientific literacy. The discourse during class discussion was examined and two cases were developed which closely examined the learning and discourse of two students in the classroom.

There was a clear discourse pattern during the whole class discussions which was considerably different than the teacher initiation- student response- teacher evaluation (I-R-E) discourse pattern seen in traditional science classrooms. This social constructivist pattern, which was very flexible, was both context and content dependent. Each discourse move was dependent on the content and the context of the previous move. There was also a blurring of the roles and responsibilities of the students and the teacher in the social constructivist discussions, with students taking on roles that were traditionally assumed only by the teacher. Furthermore, in addition to the traditional moves of initiation, response, and evaluation there were four other moves present in the social constructivist discussion: probing, reasoning, revoicing, and redirecting.

One of the student cases illustrates a student who is able to control and use the unique pattern of discourse in the classroom to make sense of the science content as he engages in exploratory talk. The other case illustrates a student who is not yet able to control and use the discourse to make sense of the science content as she engages in presentational talk. The extent to which these students are able to use the talk to make sense of the science content is reflected in their post-assessment scores.

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The last word has been written and I have finally completed all the revisions and edits. I now have the opportunity to thank all the people that have supported me throughout this process. I found that writing a dissertation is a difficult and time consuming endeavor. But most of all it is a lonely process. Were it not for the support of family, friends, and mentors I doubt that I would have finished my Ph.D. This dissertation truly is a social construct. Many of the ideas contained in it are a direct result of conversations that I had with each of the people acknowledged below.

Most important I want to thank the teachers and students in the third grade team-room at "Atlantis" Elementary. Ms. Lawson and Mrs. Runner willingly opened their classroom to me. They always had copies of their plans available for me and were willing to take time from their very busy day to talk to me about the decisions they were making, potential target students, and some of the issues they were struggling with as they integrated science and literacy. I also appreciate the candor of the students as I interviewed them individually and in small groups. Without them, there would be no dissertation.

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I owe many of the ideas about Science as Discourse which appear in this dissertation to the suggestions of Cheryl Rosaen. Like Kathy, Cheryl has been far more than a committee member and assistantship supervisor. Cheryl has a gift for listening to me ramble about my thinking and ideas in a disorganized fashion, and helping me pull the pieces together. More than once I went into her office to discuss my dissertation feeling very confused about focus and direction only to leave an hour or two later with a far greater clarity than I would have thought possible. In this way, Cheryl provided a great deal of the focus for my originally proposed data collection. She also spent many hours reading and providing feedback on drafts of chapters.

Once I had a proposed dissertation I became concerned about locating a site in which there was science teaching which was undergirded by a social constructivist perspective. I am indebted to Ed Smith for helping me find, and gain access to, my lost "Atlantis", the third grade classroom in which I collected my data. I am also grateful to Ed for allowing me access to the unit pre- and post-assessment data which he had collected as part of another research project and also for our early conversations during data collection which led to the development of the rubrics that I used to score the pre- and post-assessment data.

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Chapter 1

CREATING A SCIENCE CLASS IN WHICH UNDERSTANDING IS CONSTRUCTED THROUGH THE DISCOURSE

KP: Does it sometimes help you to think of new things to hear other people's ideas?

Padma: Yes because when I listen to them talk people might say things about it and think "yeah, that would be a good idea".

KP: So even though there are forty two kids sitting there on the floor you can still kind of listen and figure out what people are saying and get ideas from them?

Padma: Umhmm right...like if I have a different idea and they have a different idea we can kind of get together and see what's the idea and then you come up with the best idea together.

KP: Okay. Do you ever disagree on the best idea?

Padma: No, we never disagree. We just kind of, well we kind of talk about it, and I don't care if I have the best answer or not. But lots of my friends don't care about that either. All I think about is if I really get it.

(Transcript from an interview with a 3rd grade student, March 15, 1993)

Introduction and Overview of the Chapter

Scientific literacy is the goal of the on-going reform efforts in science education (National Academy of Sciences, 1996; AAAS, 1989; BSCS, 1993; Michigan Dept. of Education; 1989). The definition of scientific literacy developed in greater detail in the literature review portion of this dissertation is based upon a social constructivist theory of learning. From this perspective science is discourse and scientific literacy is the ability to control the discourse of science such that it can be used to describe, explain, predict, and design everyday phenomenon in ways consist with the canons of science.

Currently there is a small but growing body of research in science education which examines the role of discourse in constructing understanding in elementary science. There are two main lines in this research; one group of researchers has examined the talk that takes place in science class (Lemke, 1990; Roth, Anderson, and Smith, 1987; Vellum 1995; Yerrick, 1994, Eichinger; 1992; Hazelwood and Roth, 1992; Peasley, 1992) and another group has considered ways to incorporate discourse into the science curriculum itself (Smith, 1995; Duschl and Petasis, 1995; Rosebery, Warren and Conant, 1992). This research in science education has been influenced by the body of research conducted in linguistics and literacy education (Barnes and Todd, 1995; Edwards and Westgate; 1994, Gee, 1989; 1995, Michaels & O'Connor, 1990) which has looked at classroom discourse from the perspective of linguistics and literacy.

The majority of these studies focus on describing the classroom discourse, the factors influencing the classroom discourse, and what is communicated about learning and about the nature of science through the discourse. There are few studies which consider the ways in which the nature and structure of the discourse helps or hinders students as they attempt to use the science content learned to describe, explain, predict, and design real world phenomena. Therefore, the purpose of this study was to examine the discourse that took place in an elementary science classroom in which the teaching was being conducted from a social constructivist perspective, and to examine the relationship between the discourse and science content learning.

This first chapter provides an overview of the purpose of the study and the research questions in greater detail. This is followed by a theoretical rationale for the study based upon the changes in science education over the past forty years and the calls in the literature for an approach to science teaching of which there are scarce examples in practice. The chapter concludes with a discussion of the significance of this study and the organization of the remaining chapters.

Purpose of the Study

The purpose of this study was to describe and analyze the ways in which a classroom of third grade students and their teachers participated in science class discussions

in order to uncover and explain the relationship between the classroom discourse and science content learning over the course of one instructional unit of study. Issues examined were: (1) the nature of the students' talk in science class, (2) the norms for participation in the talk in science class, (3) the nature of the science knowledge found in the talk , 4) individual student's science knowledge construction and, (5) the relationship among and between these four factors.

We know little about the relationship between elementary students' participation in science classroom talk and its role in helping or hindering science concept development. This research was designed to provide empirical data on the role of oral discourse in constructing scientific knowledge in an elementary science learning community. Thus the purpose of this study was to provide a "snapshot" picture of a social constructivist learning community in action, to examine the ways in which the students participated socially as a community of learners, and to analyze how this participation helped or hindered their science concept development.

A Historical Perspective

Since the mid- 1950's there have been a number of elementary science initiatives, each designed to help elementary school students learn science content, the processes of science, or both, with understanding. The majority of the earlier science programs (1960-1980) sought to enrich students' understanding of science by engaging them in hands-on activities and inquiries. In contrast, more recent approaches to science education (1978-present) have emphasized individual student cognition and have sought to enrich students' understanding of science by focusing instruction on eliciting, and in some cases helping, student's modify their existing conceptual frameworks. Another current emphasis (late 1980's- present) in science education is having students use classroom discourse as a knowledge construction tool (Smith, 1995; Duschl, 1995; Peasley, 1995).

The emphasis on discourse in science is the result of several fields of study in education converging in the late 1980's. Beginning in the 1970's, education researchers began drawing on the works of theorists such as Vygotsky (1962) and Harre (1976) to develop the view that learning is a social and cultural process in which language plays a critical role (Lemke, 1990). This view of the importance of the role of discourse in learning was supported by research done in literacy education, (Barnes,1976; Barnes and Todd, 1995; Edwards and Westgate, 1994; Au, 1986; Gee, 1989; Michaels and O'Connor, 1990), psychology (Bruner,1990; Gallimore and Tharp, 1990) and on classroom discourse more generally (Edwards and Mercer, 1987; Cazden, 1986, Mehan, 1979).

At the same time that these different lines of research -- all of which involved discourse-- were converging, researchers in the conceptual change paradigm in science were beginning to go beyond individual cognition and focus on the role of individual cognition within the social setting of the classroom. This led naturally to a focus on discourse which drew on, and expanded, these earlier, more general, works on classroom discourse (c.f. Lemke, 1990; Rosebury, Warren, and Conant, 1992).

To date, however, there has been little research done in elementary science classrooms which focuses explicitly on the relationship between classroom discourse and science content learning. There is some research evidence that suggests that "talking-to-learn" may be a powerful tool for helping students learn science (Barnes and Todd, 1995; Edwards and Westgate; 1994); however, there is also evidence that the nature of the talk in some secondary science classes may actually hinder the science learning of many students, particularly language minority students (Lemke, 1990; Warren & Rosebury, 1992). Furthermore, because much of the research on classroom talk has been conducted at the middle school and high school level, little is known about the relationship between oral discourse and science learning in an <u>elementary</u> science classroom.

Discourse for this study was broadly defined as language in use in any context, in any oral form (Tannen, 1991). Thus the context for language includes both social and academic talk and could take place inside or outside of the classroom. This study, however, focused on the academic talk inside the classroom. The form of language

examined included language during class discussion, language during small group work, and language during individual interviews. The term "discourse" in this dissertation refers only to oral discourse unless otherwise indicated.

The approach to elementary science teaching described in this study is one in which a hands-on inquiry approach and an emphasis on fostering students' conceptual change was combined with an emphasis on discourse as a tool for learning science. The discourse was an explicit and central part of the science curriculum. This approach builds on lessons learned from the earlier inquiry-based science curriculum reform efforts while considering ways in which the more recent body of research on children's thinking and social constructivist learning theory can inform the development of science curriculum and pedagogy. The result is a new approach to elementary science which appears to have many of the elements of scientific literacy that are called for in science reform documents around the country (e.g. Rutherford and Ahlgren, 1989; AAAS, 1994) and are described in greater detail in the literature review chapter.

The importance of oral discourse in a science class undergirded by a social constructivist perspective raises many questions about the students' participation in a learning environment in which the intended social task structure (Erickson, 1982) for classroom talk emphasizes new roles, responsibilities, rights, and duties for the participants. Of particular importance in thinking about developing curricular materials and pedagogical strategies are questions which focus on how the students' ways of participating in a science learning community influences their ways of knowing science and the science content knowledge learned.

A limitation in much of the research on student learning in science is that it is not informed by a conception of the social organization of the classroom nor by a conception of the influence of the social participation structure (the norms for participation, including the rights and duties of both teacher and students) in shaping the individual students' opportunity to learn (Erickson, 1982). The cognitive science and constructivist

perspectives emphasize that the learner constructs knowledge but do not take into account how the social context of the classroom influences this construction (Marshall, 1989). Thus a critical factor is the classroom learning community: Its social organization and practices including the relationship of discourse to science learning.

Therefore the purpose of this research is to learn more about how students perceive and participate in an elementary science learning community in which the teaching is undergirded by a social constructivist epistemology with an emphasis on talking- to-learn, and how this participation shapes student understanding of science content.

Research Method and Questions

This study was an interpretive, descriptive study of a third grade science class over the course of one teaching unit on "Changes in Matter" (methodology is described in detail in Chapter 3). In this unit the teachers explicitly supported their students in using oral discourse as a tool for collaborating with their peers to construct their understanding of science. The focus in this study was on understanding the interactions among the teachers, the learners, the science content knowledge, the classroom discourse, and the ways in which the social context (specifically the norms for participation) influenced these interactions. The participation of two very different students will be examined and described against the backdrop of the entire class. Following are the questions which guided this research:

In an elementary science classroom in which the teachers are attempting to support student construction of knowledge socially through the use of oral discourse:

a. **What science knowledge do the students in this science class construct?**

b. **What is the nature of the students' talk in science class? What are the implicit and explicit rules for discourse in science?**

c. **What is the participation structure in this classroom (including the rights, roles, duties, and responsibilities of the participants)?**

d. **What is the relationship between the students' science learning and their participation in the classroom discourse?**

The Setting

Data collection took place from late February through April in a third grade classroom in an elementary Professional Development School in which there was a school/university collaboration taking place. The school was located near a major university and had an ethnically diverse student population -- a large percentage of the students spoke English as a second language. The classroom was actually a double class -- the wall between two classes was knocked out -- which functioned as a single learning community with two teachers and forty two students. In addition to the two full-time classroom teachers, there was also a student teacher who had been in the room part time since September and full-time since January, and two Midwestern University[1] faculty members who had been part of the third grade teaching team since September.

The two classroom teachers had been planning and teaching collaboratively all subjects except mathematics since the fall. The student teacher was from Midwestern University's "Literacy Education" program, a small thematic teacher education program which placed an emphasis on the role of discourse in the social construction of understanding. One of the classroom teachers was also a graduate of this teacher education program. One of the Midwestern faculty on the team had expertise in communications. She provided planning support for the teachers as they constructed their science and literacy unit and also taught a small group during science time during the month of March. The other Midwestern faculty was a science educator who participated in the planning of the science and literacy unit but did not participate in the actual teaching.

Both of the school-based teachers had been active participants in the third grade professional development team meetings during the school year. The focus of these meetings was on developing a science teaching unit in which there was an emphasis on the use of discourse as a tool for learning science in a conceptual change instructional framework. This was consistent with the school wide professional development year-long

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[1]To ensure confidentiality all names are pseudonyms.

theme of "Science and Literacy". During the spring, a science and literacy unit on the topic of "Changes in Matter" was taught concurrently by all the teachers in the school. The unit "Changes in Matter" was not a published text-based unit but rather was one that the teachers developed with the support of the Midwestern science educator and the Midwestern literacy educator working with the project. This unit was the culmination of the year-long, school-wide focus on literacy in science and had as its final activity a school-wide science conference, one of the first of its kind at the elementary level.

Significance of the Study

This study has potential value for elementary science teachers, for teacher educators who work with elementary science teachers, and for elementary science curriculum developers. The research provides a rich description of an elementary science classroom in which the curriculum materials and the teaching were undergirded by a social constructivist philosophy of science knowledge, of teaching, and of learning with an emphasis on the role of discourse. In this discourse-rich context, the study enables us to examine the impact of a new kind of classroom talk on science learning.

This work has potential for synthesizing three important movements in elementary science education -- inquiry learning with its emphasis on discourse and action, conceptual change learning with its emphasis on individual cognition and personal sense-making, and social constructivism with its emphasis on discourse and sense-making with members of a learning community. It provides a snapshot of social constructivism in practice in an elementary science classroom and the students' ways of participating in such a classroom while simultaneously tracing students' conceptual learning. To date this kind of science teaching has been largely theoretical with many reformers calling for movement towards a social constructivist view of scientific literacy with an emphasis on the discourse but limited examples of what this might look like in practice.

This study seeks to provide empirical evidence for the value of oral discourse as a tool for elementary students to use to learn and understand science concepts. Although

there is a growing body of research looking at the role of talk in constructing understanding in science (c.f. Lemke, 1989), there is little work in the science education literature which examines the norms for participation in the talk in elementary science class and the relationship of these norms to student understanding of science concepts. Thus this study will also provide evidence of the ways in which classroom talk at the elementary school level in one context helped, or hindered, student learning of science content knowledge. This analysis raises some caveats that teachers should be aware of when working with students to construct this type of a learning community.

Organization of this Dissertation

The remaining chapters of the dissertation are arranged in the following fashion: Chapter 2 presents a review of relevant literature on science education and the role of discourse in science learning historically. Chapter 3 describes the data collection and methods of analysis. Chapter 4 describes the teaching and learning context for this study. It was this context which led me to describe this classroom as one which had many of the aspects of social constructivism as it is described in the literature. Chapter 5 contains a description and analysis of the discourse in a whole class discussion. The purpose of this description is to provide an image of the type of interactions that were taking place in the learning community and to provide a context for the two cases of the target students which appear in Chapter 6. The case studies presented in chapter 6 examine the relationship between student participation in the discourse and student learning. Chapter 7 provides additional evidence about student science concept learning based on an analysis of the pre- and post- unit tests of all students in the class. Finally, Chapter 8 summarizes the findings and draws conclusions from these findings. In it I also discuss the limitations of a qualitative, descriptive study such as this, the educational implications of this study, and the need for further research.

Chapter 2

SCIENCE AS DISCOURSE: A HISTORICAL PERSPECTIVE ON SCIENCE EDUCATION

> In a world filled with the products of scientific inquiry, scientific literacy has become a necessity for everyone. Everyone needs to use scientific information to make choices that arise everyday. Everybody needs to be able to engage intelligently in public discourse and debate about important issues that involve science and technology....Other countries are investing heavily to create scientifically and technically literate work forces. To keep pace in global markets the United States needs to have an equally capable citizenry. (National Academy of Sciences, 1996)

> Yet the fact is that general scientific literacy eludes us in the United States. A cascade of recent studies has made it abundantly clear that by both national standards and world norms, U.S.education is failing to adequately educate too many students - and hence failing the nation. By all accounts, American has no more urgent priority than the reform of education in science mathematics and technology.
> (AAAS, 1989)

Introduction and Overview

This chapter is about scientific literacy. Developing scientifically literate students is the focus of most major reform efforts in science education in the United States. However, recent studies reveal that we are currently failing in these efforts (AAAS, 1996). This chapter begins by drawing on the literature to develop one definition of scientific literacy. I then use this definition to consider the strengths and weaknesses of various science education reforms historically. This analysis will be used in later chapters to illustrate the ways in which the teachers in this dissertation study built upon the successes of earlier reform movements to create a new social constructivist approach to science education.

Science as Discourse: A New Perspective on Scientific Literacy

Over the past decade a line of science education research informed by constructivist and social constructivist theories of learning has emerged. Science education researchers in this area have focused on the social nature of learning in science by examining the discourse that

occurs in science class (Roth, Anderson, and Smith, 1987; Lemke, 1990) and considering ways to structure this discourse so that students are learning to appropriate and use scientific Discourse[1] (Duschl and Petasis,1995; Smith, 1995; Rosebery & Warren 1992). For example, Roth, Anderson, and Smith (1987) described the nature of three elementary teachers' talk during science class. Lemke (1990) considered the structure of the talk in secondary science classes, examining the ways in which knowledge is communicated, and the values and attitudes that are communicated about science through the discourse, and Smith (1995) examined the role of the teacher in supporting consensus building in science discussions.

Some of this recent work on classroom discourse in science education is based upon Gee's (1989, 1994) notion of literacy (c.f. Duschl and Petasis, 1995; Rosebery, Warren, and Conant, 1990). According to Gee, literacy (including scientific literacy) can be understood as the control of discourses that go beyond whatever discourse we first acquired within our family (1989). Thus scientifically literate students are those who are able to control and use the discourse of science when they are participating in science class. Rosebery, Warren, and Conant (1990) base their work on Gee's notions and the Vygotskian perspective that "knowledge and understandings are socially constructed through talk, activity, and interaction around meaningful problems" (Rosebery et. al., 1990) . Believing that science is Discourse and is a culturally accepted way of talking, Rosebery et. al. (1990) developed a curriculum in which language minority students were explicitly supported in appropriating a scientific discourse. Similarly, Duschl and Petasis (1995) and Smith (1995) worked with teachers to develop a discourse pattern that would support students in developing scientific explanations - and thus to appropriate a scientific discourse.

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[1] I am spelling Discourse here with a capital "D" to represent Gee's notion of Discourse. Gee makes the distinction between discourse which is strictly speech and Discourse which encompasses ways of "talking, acting, valuing, interacting, thinking, writing and reading, carried out with certain objects, technologies, and symbolic expressions, in certain physical spaces in order to enact particular recognizable social identities".

This view of scientific literacy is consistent with the recently published National Science Education Standards (National Academy of Sciences, 1996) which describes scientific literacy in the following way,

> ...a person who can ask, find, or determine answers to questions derived from curiosity about everyday experiences. It means that a person has the ability to describe, explain, and predict natural phenomenon...A literate citizen should be able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it. Scientific literacy also implies the capacity to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately.

Embedded in this view of scientific literacy is the assumption that the person will notice and be curious about natural phenomenon and will want to engage in making sense of this phenomenon using scientific concepts. Thus, from the perspectives described above, scientific literacy is being curious about natural phenomenon and appropriating, controlling, and using the discourse to describe, explain, and predict this phenomenon. .

Outside of science education, classroom discourse and linguistics researchers have contributed to the notion that scientific literacy is a process of appropriating and controlling the discourse about meaningful problems --such as developing explanations about real world phenomena. These researchers sought to describe the nature of students' talk in classrooms (including, but not limited to, science class) and the ways of participating in these classes --the participation structure (Wells, 1996; Gee, 1994; Edwards & Westgate, 1994; Michaels and O'Connor, 1990; Middleton and Edward, 1990; Gee, 1989; Cazden 1988; and Edwards & Mercer, 1987). In their work, Michaels and O'Connor argue that knowing isolated pieces of information such as facts, terms, and definitions is not sufficient to understand content. They state:

> Beyond vocabulary and background facts, there are discourse-specific ways in which arguments are made, in which certain kind of information must be foregrounded and used as evidence. There are discourse-specific ways in which you must infer connections or "get the point".

They illustrate this point with an example drawn from a science lesson on the topic of balance using a balance scale with small metal weights hung at different points of the

scale on both sides. In the lesson the students wee posed with a problem in which the weights were to be hung on the balance in a certain arrangement. The students were asked whether the scale would tip to the left, the right, or balance. In response to this question the students had to make and explain a prediction regarding the behavior of the balance. The study focuses on the responses of a Creole girl who gave the correct prediction but did not give the scientifically correct explanation and appeared not to understand the concept of balance. However, when probed in a later interview, it is clear that she does in fact understand the science. Michaels and O'Connor concluded that although she knew the requisite facts and how to apply them in reasoning through the problem, she did not control the discourse of school science. Consequently she misinterpreted the teacher's questions leading her to give an inappropriate response.

In this body of research on classroom discourse, the discourse is in the foreground and the relationship between the discourse and science learning is either not considered, or is only considered indirectly. For example, in their example of the Creole girl, Michaels and O'Connor (1990) considered the ways in which the structure of the discourse inhibited the girl from being able to represent her knowledge to the teacher, but did not consider the ways in which the form of the discourse may have actually hindered or helped her in learning that science knowledge.

Another feature that characterizes the studies on classroom discourse is the focus on social constructivist theories of learning. This is reflected in the emphasis on the importance of considering the discourse that takes place in science as an integral component of the science curriculum. From this perspective science is discourse and scientific literacy is developed through learning to participate in the classroom science discourse in meaningful ways.

In the existing literature, the emphasis on discourse and a social constructivist view of learning is often presented as a "new" idea without careful consideration of its connections to previous research. Since the mid-1950's there are have been a number of curricular and pedagogical initiatives which have been designed to help students learn science concepts with understanding. It is important to consider this history because current approaches to science education, including the social constructivist approach used by the science teacher in this study, build on the strengths of these earlier approaches to science education curriculum and teaching.

For this reason I take a historical approach to this literature reivew and look at four main perspectives on science teaching --didactic science, inquiry science, conceptual change/constructivism, and social constructivism -- using the discourse patterns associated with each perspective as a framework for discussion and analysis. In this way I consider what we have already learned and know about discourse in elementary science -- the different forms it can take in the classroom and the view of knowledge that is represented by the different forms. This analysis will then be used to inform later chapters in which the teaching, and the discourse, draw on the successes of earlier science education initiatives.

The Importance of Discourse in Socially Constructing Meaning

This dissertation is based upon on the belief that all learning, in and out of school, is essentially a social process. Learning is a way of making sense of experience in terms of extant knowledge (Tobin, Tippins, and Hook, 1992). From this perspective knowledge is the product of language-based interactions (oral or written) which take place in a social environment and is influenced and shaped by an individual's prior knowledge.

The social context of the classroom, which includes both the form and function of the discourse and the participation structure, communicates to students what aspects of knowledge are valued, what counts as learning, what form the knowledge takes, and what sorts of learning activities are valued (Marshall, 1989). The students receive value messages such as these both explicitly and implicitly through their daily interactions in the classroom with the teacher (Kohn, 1989).

In these ways the social context of the classroom has a major influence on the form that the knowledge ultimately takes in the individual's mind. For example, if the classroom setting is one in which the teacher is primarily telling students the scientific "facts", and the students are individually doing seat work which emphasizes recall of these facts, the students will probably tend to view science knowledge as a series of facts to be memorized individually and repeated at the appropriate time to the teacher who is the ultimate authority for knowledge in such a classroom. However, if the classroom learning community is instead primarily one in which scientific knowledge is viewed as tentative and open to debate, in which collaboration, sharing, and public revisions of ideas is stressed, in which students write and talk with one another in order to make sense of scientific phenomena, students will be more likely to view scientific knowledge as being a social construct which is a best explanation for real-world phenomena.

Historically, philosopher Herbert Mead (1934) was one of the first to formulate a social constructivist perspective. Not surprisingly language, specifically in the form of oral discourse, played a central role in Mead's thinking. Mead believed that meaning is constructed within the act of communication. Furthermore, Mead postulated that this communication is absolutely necessary if meaning making is to occur. Psychologist Jerome Bruner (1966) expanded further on Mead's ideas about the necessity of discourse in learning, theorizing that oral language allows children to take elements of their experience and organize them into increasingly more sophisticated thought structures, a necessary condition of learning. This is in agreement with Russian philosopher, Lev Vygotsky (1962), who believed that thought is the internalization of dialogue and in order for students to be able to think through new ideas they must first talk through the ideas with a "more knowledgeable other".

Recent research conducted with language minority students and with students who speak "non-standard" English has provided empirical support for the theories of Mead, Bruner, and Vygotsky. Researchers in this field have concluded that part of learning to make sense in science is appropriating a new discourse -- a new way of talking, and thus of thinking, about their ideas in science (Rosebery, Warren, and Conant, 1990; Michaels and O'Connor, 1990). These researchers believe that science knowledge, for example, is "a socially and culturally produced way of thinking and knowing, with its own ways of talking, reasoning and acting, its own norms, beliefs and values, its own institutions, its shared histories and even shared mythologies" (Rosebery, Warren, and Conant, 1990). Language is used by the interlocuters to think and act as members of a science community.

Rosebery et.al. based their work upon James Gee's notion of learning and acquiring a discourse (1989). According to Gee, the process of learning disciplinary knowledge, such as science, is a process of acquiring the discourse used by people within that discipline. From Gee's perspective the discourse within the discipline is not just the talk but is:

> ...a socially accepted association among ways of using language, of thinking, acting, and of valuing that can be used to identify oneself as a member of a socially meaningful group or "social network" (Gee, 1989).

Support for the importance of oral discourse in learning comes not only from the fields of philosophy and psychology but also from sociolinguistics and literacy education. Barnes (1969) argued that the more a learner is able to control his own language strategies, and the more that he is enabled to think aloud, the more he can take responsibility for creating explanations. Talk is much more than just a window upon mental processes and metacognitive concepts -- which is a traditional way in which language in the classroom is viewed. Conversations are a significant environment in which such thoughts are formulated, justified, and socialized (Middleton and Edwards, 1990); thought itself is enabled by language (Winogard and Flores, 1987).

Taking a Historical Perspective on the Discourse in Science Class

Rather than assume that previous research paradigms ignored the importance of discourse and social construction of knowledge, I have re-examined the earlier literature from a discourse perspective. In the next sections I describe what research has revealed about different approaches to science teaching and learning (didactic, inquiry science, conceptual change, and social constructivism) highlighting what these bodies of research revealed about clasroom discourse and its relationship to student learning.

View of Science Learning and Knowledge Represented by Didactic Science

Prior to the 1950's science education, when science was taught at all, was primarily didactic in nature and characterized by what I will call a traditional perspective on teaching and learning. The teacher presented information to the students in the form of lists and formulas. Students memorized this information and repeated it back to the teacher at appropriate times. The teacher did most of the talking. Students responded to the teacher's questions only when called upon and rarely, if ever, questioned the teacher or a peer.

Didactic teaching represents science knowledge as being composed of facts and definitions which have been "discovered" by scientists and defined by the teacher and the text. In a didactic classroom the students are presented with a great deal of science - facts, theories, words - but do not learn how to use these tools. In these classrooms, students are generally exposed to large numbers of facts and vocabulary words, tested for recall, and moved on to the next topic (Anderson & Smith, 1984; Anderson and Roth, 1988). From this perspective the role of the teacher is to transmit facts and the role of the student is to "absorb," and often memorize, these facts. From this perspective learning is considered to be a straightforward process. The teacher "gives" the student the information which they then "have" or.

Learning in a traditional didactic classroom is frequently equated with acquiring many pieces of information. The usefulness of the knowledge or the real-world application of the knowledge is not emphasized. I refer to this as the "traditional" approach to teaching science because it is the most common and was, with the exception of nature study, virtually the only approach used to teach science at any level prior to 1950.

In traditional didactic school science, students do not typically engage with the phenomena they are expected to understand in any direct or meaningful way (Rosebery, Warren, and Conant, 1990). Scientific knowledge is portrayed as absolute and unproblematic, and the learner is viewed as a passive recipient of the knowledge being transmitted. Science from this perspective is considered to be a discrete body of "facts", and the transmission of these facts from teacher to student is the goal of teaching (Gallagher, 1991). The role of the teacher is to provide the facts and the role of the the students is to try to reproduce on a test what the teacher and the textbook had told them to think.

Role of Discourse in a Didactic Science Class

It follows that most of the discourse in traditional elementary science classrooms is monologic in nature (Tharp and Gallimore, 1988). In these classes the teacher is the center of attention. The scope, development, and direction of the class are controlled by the teacher. Recitation and the teacher dominated initiation-response-evaluation (I-R-E) format are found in most science discussions held in a traditional science classroom (Mehan, 1979; Cazden, 1988; Lemke, 1990). In the I-R-E format the teacher is the center of the discourse. The teacher initiates by asking a question to which there is a specific answer he or she is seeking, the students respond to the question, and the teacher evaluates the accuracy of that response.

The image that immediately comes to mind is of students sitting in neat tidy rows with the teacher asking a "known answer" question such as, "What are the three types of rock?". Students then raise their hands vying for the opportunity to recite the three types of rock. The teacher calls on students one after the other until someone successfully answers her question (gives her the response as listed in the teacher's guide - sedimentary, igneous, metamorphic). She will then continue on with the lesson - asking more known answer questions or presenting more information.

Although the I-R-E format is time efficient, allowing for a lot of content to be covered in a short period of time, this format leads to problems. Students get the message that science discussions are supposed to lead to one correct answer -- the answer

determined by the teacher or the text. In addition, this traditional format promotes competition among the students as they attempt to find the answer the teacher wants and bid for a chance to show their knowledge (Shoft, 1990).

In the I-R-E format opportunities to build upon one another's thinking and ideas are sacrificed in the quest for the "right answer". This creates one authority for knowledge in the classroom -- the teacher -- and the students miss out on the opportunity to learn from one another's thinking and ideas. And, indeed, in this setting there is no reason why the students would want, or need to, learn from one another. The students' attention is focused on the teacher who is the source of the "right answer", and they tend to ignore the contributions of their peers. These interactions discourage dialogue among the students and do not create an atmosphere in which the students can learn from one another.

The transcript segment below taken from "Curriculum Materials, Teacher Talk, and Student Learning" by Roth, Anderson and Smith (1987) illustrates a lesson in which the teacher uses known-answer questions to determine if the students are taking in, and remembering, the information that was presented. Roth et.al. noted that when the teacher in this classroom asked questions that demanded the students respond with an explanation rather than with just a fact or opinion, the students had difficulty answering the questions. The teacher, Ms. Lane, handled this problem by rephrasing the question so that the students would come up with the "right answer"-- the answer she was looking for. In the transcript segment below Ms. Lane began by asking a question (initiation) which required the students to explain a phenomenon (response). However, when they were unable to do so, she changed the question into a series of factual response questions that she asked in a rapid, drill and recitation format which closely followed the I-R-E sequence.

Initiation	Ms. Lane:	What is the function of the optic nerve? (waits, no response) What is it that a nerve does? What do they do?
Response	Heidi:	Tells whether it is hot or cold.
Evaluation	Ms. Lane:	Uh, OK..
Initiation	Ms. Lane:	They send what?

Response Students: (calling out) Messages.

Initiation Ms. Lane: Where do they send them?

Response Students: (calling out) To the brain

Initiation Ms. Lane: Without the optic nerve, could you see?

Response Students: (unison) No.

Statement Ms. Lane: Because it sends messages of the image to the brain. (She writes on the board: Optic nerve leads from the back of the eye to the brain).

There are several aspects to this transcript which mark it as representing a traditional didactic approach following the I-R-E format . First is the amount of teacher talk compared with the amount of student talk. The teacher asks the questions and, ultimately, gives the explanation. The students are not given an opportunity to ask questions or to puzzle through their ideas. The questions the teacher asks are "known answer" questions -- there is one specific response that the teacher is seeking. She does not probe student thinking or ideas about the phenomenon. The teacher asks the question (initiation), the student answers the question (response) and the teacher evaluates the accuracy of the response. In this case a correct response is indicated by the teacher saying "OK" or by simply going on to the next question, implying the response to the question had been correct. The segment concludes with the teacher stating the response that she was originally looking for.

Criticisms of a Didactic Science Approach

The traditional didactic approach to science education, which remains the predominant mode of instruction in science today (Stofflett & Stoddart, 1994), has been consistently shown by researchers to be ineffective in engaging student interest or developing conceptual understanding of the science content (Anderson & Smith, 1987; Driver, 1983; Hewson & Hewson, 1988). In fact, large numbers of American students graduate from college holding many of the same naive conceptions about the world as those held by elementary children (Stofflet & Stoddart, 1994), even though they have studied the topics and even gotten good grades in science (passed the tests with flying colors).

Often science classes were "parade grounds where students are endlessly drilled in multiple-choice questions that impart information without context" (Leslie & Wingert, 1990). Generally in a didactic science class, scientific knowledge is misrepresented as being absolute and unproblematic with no indication that the knowledge being learned has a history, is tentative, and is the product of a social, human endeavor. Philosophers of science such as Kuhn (1971), Toulmin (1972), and Mayr (1982) emphasize that science does not reside as an objective body of knowledge external to the individual but rather scientific knowledge consists of a "body of shared beliefs among a community of scientists" (Anderson, 1988).

In a traditional, didactic classroom the students are presented with a great deal of science - facts, theories, and scientific terminology. However the students are rarely given an opportunity to use these new tools except to answer questions on a test. In these classrooms students are generally exposed to large numbers of facts and vocabulary words, tested for recall, and moved on to the next topic (Anderson & Smith, 1984; Anderson & Roth. 1988). For example, Roth (1987) found that one elementary teacher covered the following concepts in one class period on light: light as energy, light for seeing, light travels fast, the speed of light, atoms, photons, sources of light, bioluminescence, uses of light, animals that give off light, reasons light travels fast, lightning, amplitude, wavelengths, light travels in straight lines, intensity of light, pioneer uses of candles, electricity provides artificial light, watts, volts, fluorescence, and light cannot curve.

Thus, there is generally a tremendous amount of information presented with no time for the student to make sense of, and use, the concept in a real world context before the next concept is introduced. Accordingly, the student is more likely to memorize a few isolated terms (such as "reflected light") than to develop connected understanding of central concepts (like how light enables us to see).

Another criticism of the didactic approach is the view of the learner as being a passive recipient of this barrage of information and a view of learning as a straightforward

process of "taking in" and remembering information. This view of learning does not acknowledge that students already have ideas or constructions about the world which might influence their interpretations of the knowledge the teacher is presenting. Furthermore, the idea of learning as passive reception does not acknowledge the importance of the role of discourse in learning. The only discourse that takes place many days in a didactic classroom is the teacher's discourse. Rather than learning from talking to teacher and peers, the students in a didactic classroom are assumed to learn from listening to the teacher talking.

View of Science Learning and Knowledge Represented by Inquiry Science

Beginning in the 1950's scientists and science educators began to look for alternatives to the traditional didactic approach -- a process that continues today. A common alternative was to move away from teacher-centered didactic teaching and initiate a hands-on approach to directly involve the students in the process of inquiry.

Additionally it was at this time that cognitive science began to influence science education beginning with the writings of cognitive psychologist Jean Piaget. These two factors -- a move towards "hands-on science" and the influence of cognitive science -- resulted in the design of several different inquiry-based approaches to science education which drew from the Piagetian theory of assimilation and accommodation and the notion of cognitive development stages (pre-operational thought, concrete operational thought, abstract formal operational thought).

According to Piaget (1929), who focused on individual cognition in his early work, meaningful learning takes place when the learner is able to recall appropriate schema from their memory and "fit" the new information they have learned in with that schema. Piaget theorized that this assimilation of new information into an existing schema is a straightforward process which requires accessing and recalling appropriate schema. However, once in a while the student becomes dissatisfied with the existing schema and

must modify or make accommodations in the existing schema before they can assimilate the new information. Piaget viewed this as being a fairly straightforward process as well.

It was during the Post-Sputnik era of National Science Foundation (NSF)-funded curriculum development efforts that inquiry science made its appearance. Collaborations among scientists, psychologists, and educators led to the creation of several NSF inquiry based science curriculum programs: Science a Process Approach (SAPA, Thier, Karplus, Lawson, Knott, and Montgomery, 1978), Science Curriculum Improvement Study (SCIIS, AAAS, 1975), and Elementary Science Study (ESS, Educational Development Center, 1971) . These elementary science programs emphasized the importance of the learner being actively engaged in science through the manipulation of materials. Students were encouraged to see themselves as "young scientists" who participated in science processes in the same way "real" scientists did. According to Bruner, who spearheaded one of these early NSF programs, "the schoolboy learning physics *is* a physicist, and it is easier for him to learn physics behaving like a physicist than doing something else" (1960).

Inquiry science teaching represents science knowledge as being composed of ideas which can be "discovered" by students through active manipulation and exploration of the materials under study using scientific inquiry processes. The various inquiry programs focused on supporting students in developing understanding and acceptance of scientists' ideas through the interpretation of empirical data. From this perspective the role of the teacher is the facilitation of inquiry and (in the SCIIS project) the introduction of the scientific concept. The role of the student is exploration and discovery of scientific ideas. Although it was not the intention of curriculum developers, many teachers in inquiry classrooms interpreted inquiry science as a pure "discovery" process in which you never tell the students the concept. Thus the teacher may have viewed her primary responsibility as helping students "feel comfortable" with the content and "feel good" about science:

> We need to make students feel comfortable with the things, ideas, and processes of science. Just as we want them to feel comfortable and accepted in their own neighborhood. They need to develop confidence that they can ask questions (Rutherford, 1986 as cited by Roth, 1987).

If the students were engaged in the processes of science, it was believed, learning would necessarily follow (Saunders, 1987; Linn and Thier, 1975; Puiser and Renner, 1983; Schneider and Renner, 1980)). With the support of the National Science Foundation, a great deal of time and money was spent beginning in the 1950's and the 1960's to design curricula that promoted student inquiry by allowing students to undertake investigations focused on a real world phenomenon such as growing plants, to engage in hands-on activities such as rolling balls down ramps, and to create stories which explained the phenomenon under study.

The result were three major national, and influential, elementary curriculum projects which were very different in their theory, approach, and emphasis.[2] However, they all had some similarities; a) they were all hands-on, process-focused programs, b) the curriculum writing was dominated by scientists and c) the driving goal was to rapidly produce more scientists (Duschl, 1990). Two of these, the Science Curriculum Improvement Project (SCIIS) and the Elementary Science Study (ESS) were influenced psychologist Jean Piaget's ideas about how children learn. The other, Science A Process Approach (SAPA) was based upon Gagne's theories of learning hierarchies (1977).

The basis of SCIIS is a Piagetian developmental approach which stressed that the students go through a linear series of developmental stages -- pre-operations, concrete operations, and formal operations -- but that this is not necessarily an automatic process. The philosophy reflected in SCIIS was that an elementary science program needed to provide an emphasis on concrete, hands-on experiences in order for students to reach each developmental stage at an age-appropriate time and to develop a richer picture of the scientific process.

Activities were the core of the SCIIS program and were closely linked to class discussion during which time students raised questions about the topic under study and

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[2]There were other national and local science curriculum projects, however these three represent the three most well known. These three were also selected because they represent three very different approaches to inquiry science. Of the three, SCIIS is the most enduring with several school districts in Michigan still using the program.

brainstormed ways to answer their questions. One important role of the teacher during these discussions was to introduce the scientific concept that connected to their exploration and discussion. Therefore, the activities provided a concrete context for the students to learn the science concept. In this way the SCIIS program was an improvement over the straight transmission model reflected in the didactic approach. The program emphasized the importance of eliciting and building on students' prior knowledge.

The conceptual framework of ESS was based largely on Bruner's belief that every topic can be taught in some intellectually honest form to any student. Bruner also stressed the act of discovery, which he defined as obtaining knowledge for oneself by the use of one's mind. There was no single author for ESS. Rather different units were developed by different members of the scientific and teaching community. The role of the teacher in ESS is one of a guide and a resource person. It is the teacher's responsibility to raise questions but not answer them, only to verify answers or ask leading questions. What is learned depends entirely upon what the student does.

The conceptual framework of SAPA was based upon Gagne's theory of learning heirarchies (1977). According to Gagne, process skills such as observing, classifying, and formulating hypothesis are skills used by all scientists, are applicable to investigation in all the sciences, and they can be learned by students and be transferred across science content domains. The emphasis in SAPA was on hierarchical process skill building and there was little discussion of students' interpretation of the phenomenon under study. Accordingly, SAPA was designed to develop the reasoning skills scientists use in their investigations (AAAS, 1967). It focused on process rather than conceptual learning.

The Role of Discourse in an Inquiry Science Classroom

In an inquiry classroom using curriculum materials such as the three described above, the children were given the opportunity to do many things. The role of the teacher was to serve as a guide or a facilitator as the children asked questions and invented their own answers to their questions (Roth, 1987). An additional role of the teacher with SCIIS in particular, was to introduce the scientific concept to the children as part of the discussion (the invention phase of SCIIS). The discourse pattern seen in the inquiry classrooms, consistent with the way in which teachers interpreted its philosophy, tended to be an open sharing and acceptance of all student ideas. The students did much of the talking with probes and questioning from the teacher.

The typical discourse pattern in an inquiry science classroom reflected this belief. The teacher facilitated discussion and probed ideas, however, unscientific ideas were not challenged and the students were allowed to continue holding their non-scientific ideas.

The following transcript segment, excerpted from "Learning to be comfortable in the neighborhood of Science" by Roth (1987) illustrates a common discourse pattern associated with inquiry science teaching; in which everyone's ideas are elicited and accepted as equally valid:

Ms. Kain: What do you think now about what light does for a plant? What do you think it does for a plant? Jeff?

Jeff: Well, I think that it gives its, the, uh, rays of the light gives the plant the extra food it needs to produce the chlorophyll...

Ms. Kain: What do <u>you</u> think it does for the plant? John?

John: Well, I'm not sure. It's like us. If we stay outside and you get sunburned. It's sort of like what the sun does for us.

Ms. Kain: OK, looks healthier maybe. I'm not sure we can make that analogy. OK, any other comments about that? Andy?

Andy: The heat.

Ms. Kain: The heat from the light you're saying?

Andy: Yeah, the...grabs all the light and uses all the heat.

Ms Kain: Uh-huh, OK. Melanie?

Melanie: Well, I think kinda, maybe it gives it a little bit more food. I mean not like food but uh like it gives it green. Green looks more healthy.

Ms. Kain: OK, one more. Heidi?

(Heidi gives her ideas and the discussion ends).

This discussion took place at the end of an inquiry science unit on plants as food producers (photosynthesis). Even at the end of the unit the teacher is encouraging students to share their ideas and is accepting all ideas as being equally valid. This discourse pattern characterizes the discourse in many inquiry science classrooms where much of the emphasis is placed on encouraging students to share their theories and stories and accepting all ideas without making progress toward scientific understanding. Because the goal of inquiry science is for students to "discover" the information the way that scientists do, the inquiry teacher often believes that she should ot tell the student information the way that the didactic teacher did. This is in striking contrast with the focus on "known answers" in the didactic approach.

These early inquiry programs with their emphasis on hands-on manipulation and sense-making of the objects under study continue to influence current elementary science curricular and pedagogical practices. Many current pedagogical practices are adaptations of, or variations on, these early inquiry programs. For example, the theory that children (indeed all people) learn through active construction of their knowledge and understanding that emerged during the inquiry science era is a theory that continues to heavily influence current science curriculum and teaching.

Criticisms of an Inquiry Science Perspective

During the late 1970's and through the 1980's it became evident to science educators and researchers that the inquiry programs were not fulfilling their promise. Although the students often enjoyed and felt comfortable with science and were actively engaged with the materials of science, researchers found that they still were not making the conceptual connections and developing the rich scientific understandings that the developers of inquiry science had intended and anticipated (Roth, 1985; Lee, Eichinger, Anderson & Berkheimer, 1993; Novick & Nussbaum, 1978). Students knew how to conduct experiments and knew lots of experimental data, such as an embryo will only develop into a plant if it is attached to at least half of a cotyledon and a plant will begin to grow in the dark, but they were unable to use this data to explain everyday phenomena such as where a developing plant embryo gets its energy until it is above ground and can begin the process of photosynthesis.

The conclusion reached by science education researchers was that meaningful learning in science involves more than just being able to give a definition or memorize a formula. Meaningful learning of science also involves more than just being able to complete the activity or enjoy doing the experiment and being comfortable with science. Meaningful learning of science involves coming to understand scientific ideas as they are used for their intended purposes, including description, prediction and explanation of real-world phenomenon. Although this was an intention of the inquiry programs, they never fulfilled their promise. Researchers concluded that science teachers need to encourage students to ask questions about the world around them and then support them in designing activities that help them answer their questions and make sense of the world through description, explanation, and prediction. Conceptual issues cannot be avoided in favor of rote procedures (or recipe style directions) or hands-on fun activities that are also not "minds-on".

Barnes argues (1976) that much learning may go on while children manipulate science apparatus but "learning of this kind may never progress beyond manual skills and slippery intuitions unless the learners themselves have an opportunity to go back over such experiences and represent it [the knowledge] to themselves", p. 30. This opportunity to go back over the experiences and represent the knowledge to themselves was not built into most of the inquiry science programs and so was not generally present. This may explain why students appeared to learn so little from inquiry science. They may have had fun in science, but their conceptual understandings of the world around them did not grow. The idea of hands-on manipulation of the objects under study was a sound one; it just wasn't enough in and of itself.

View of Science Learning and Knowledge Represented by a Constructivist Perspective: Conceptual Change Teaching and Learning

Over the past 15 years advances in the field of cognitive science and in our understanding of the processes of knowing and learning began to affect views of school and of schooling (Duschl & Petasis, 1995). Many consider psychologist Jean Piaget to be a "foundational figure" in advancing the field of cognitive science (Phillips, 1995). The application of cognitive science to education undergirds not only the ideas of inquiry science but the ideas for the development of schools for thought (Bruer, 1993), the creation of thinking curriculums (Resnick & Klopfer, 1989), and the design of classrooms as communities of practice (Brown & Campione, 1994). Additionally, the cognitive science perspective is seen in conceptual change theory (Posner, Strike, Hewson, & Gertzog, 1982), which many science educators would argue was one of the most influential ideas in science education in the 1980's.

As science educators and researchers basing their work on Piaget began to focus on individual student cognition, they became aware of the importance of knowing and addressing a student's prior knowledge and patterns of thinking in science as they supported the student through a process of constructing understanding. This was something alluded to but not explicitly done in the inquiry science approach and not considered relevant in the traditional, didactic approach.

As described above, one of the most widely studied and adopted perspectives from cognitive science is conceptual change theory[3]. Conceptual change theory is a powerful construct because it represents not only a cognitive science perspective but also a constructivist perspective. Constructivist learning theory supports the notion that in order to construct personal understanding of a concept the learner must go through a process of conceptual change (Driver, 1994). Thus, conceptual change theory brings together the

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[3]At this time "conceptual change" is primarily a pedagogical rather than a curricular approach. Extensive (and expensive) research is needed in order to develop conceptual change curriculum materials. For this reason the strategy used by science educators has been to help teachers learn a conceptual change pedagogy through workshops and seminars. Teachers, ideally, are then able to adapt current curricular materials to a conceptual change approach.

ideas of about learning derived from cognitive psychology and the ideas about the nature of science and science learning derived from a constructivist epistemology.

A constructivist perspective has implications for the classroom. From a constructivist perspective meaning is viewed as something being made by the individual and the meaning that is made will depend on the individual's conceptual framework. Science learning from this perspective is seen as an activity in which students go through a process of conceptual change (Driver, e.al., 1994). Unlike earlier views of learning in which there was an assumption that learning was simply a process of "taking in" the ideas presented by the teacher, constructivist theories of learning acknowledge the active role of the learner in constructing meaning. This knowledge construction process is influenced by students' existing conceptions which influence how the learner makes sense of instruction. For learning to occur, these existing conceptions may need to be changed, modified, or abandoned by the student. Thus constructing personal meaning involves going through a process of individual conceptual change.

Teaching from a constructivist perspective focuses on providing children with the experiences and activities necessary to engage them in a meaning making process which may include cognitive conflict, or dissatisfaction, with their prior knowledge. The teacher then supports the learners in developing new knowledge schemes that are more fruitful for them than their prior knowledge. "Real world" activities, such as planting seeds under different conditions to determine the requirements necessary for life, supported by careful structured group discussion form the core of a constructivist-based conceptual change approach to teaching (Nussbaum & Novick, 1982).

Over the past decade, science education researchers have found that students often maintain their fundamental naive conceptions and patterns of thinking about a concept even while learning the appropriate vocabulary and doing well on unit tests. Thus, it often appeared on the surface that they understood the science concept - assuming traditional methods of assessment were employed - when in fact they had not altered their existing naive conception in any way. Although they could give the scientifically correct answer on a test, they were still using their naive conceptions to make sense of everyday phenomena.

Conceptual change theory, therefore, highlights the importance of emphasizing the ideas that children form about natural phenomena. As described earlier, these ideas have been called by a number of terms including "misconceptions" (Novak, 1983), "children's science" (Gilbert, Osborne, & Fenshaw, 1982), "alternative frameworks" (Hewson, 1985), and "preconceptions" (Osborne & Freyburg, 1985). Traditional didactic and inquiry-based curricular approaches and teaching methods failed to uncover and/or address these naive conceptions (Berkheimer, Anderson, & Blakeslee, 1990; Roth, 1986; Ramadas & Driver, 1989; Minstrel, 1985; Osborn & Freyburg, 1985; Roth, Smith, and Anderson, 1983; Posner, Strike, Hewson & Gertzog, 1982) which resulted in students resorting to memorizing terms and definitions (traditional, didactic science), relying on following step-by-step procedures (inquiry science), or relying on their (inaccurate) prior knowledge.

Researchers believe that knowledge construction can be made intentional through instruction interventions such as using a conceptual change model (Nussbaum & Novick, 1982), making idea prompting statements (Scardamalia, Bereiter, & Steinback, 1984), and using various teacher questioning procedures (Duckworth, 1994). In these studies learners were coached by the teacher to think about the material under study in such a way that they transformed that material, thus constructing knowledge (King, 1994). Additionally, King (1994) found that knowledge construction and meaning making were further promoted when children were taught how to construct a good explanation via teacher questions that guided students to connect ideas within a lesson or to connect the lesson to their prior knowledge. When students have to explain themselves or defend their own positions, they begin to examine their understanding in detail (Hatano & Inagaki, 1987). As they examine their comprehension in detail, students become aware of the inadequacies in their understanding, which may lead them to reconstruct their conceptual framework (Roth and Roychoudbury, 1993). Students in such a classroom would be encouraged to puzzle

through their ideas in writing and aloud so that they can examine their idea and reconsider it.

Conceptual change models are similar in many ways to Piagetian theory (Pintrick, Marx, & Boyle, 1993). Teachers who are using a conceptual change approach elicit and take seriously students' ideas about real world phenomena. Conceptual change theory differs somewhat from Piagetian theory, however, in that it assumes that ontogenetic change in an individual's learning is analogous to the nature of change in scientific paradigms that is proposed by philosophers of science such as Kuhn (Pintrick, Marx, & Boyle, 1993). Furthermore, the conceptual change approach problemetizes Piaget's idea of accommodation by showing that the process is not a straightforward process but rather is a complicated and difficult process that needs to be carefully supported by the teacher.

From a constructivist perspective, such as conceptual change, students are not the traditionally assumed "tabula rasa" ready to take in all information presented by the teacher. Rather, students enter the science classroom with a wealth of ideas about how the world works. Many of these conceptual schemes however, are at odds with scientific ideas and, often persist following instruction (c.f. Anderson & Smith, 1987; Driver & Erickson, 1983; Helm & Novak, 1983) because they are not explicitly addressed.

According to a conceptual change model, if the student's conception is in conflict with the scientific conception, there needs to be a radical transformation of the individual conception if learning is to occur. Without this transformation, the student will alter the information presented in science class so that it fits with his or her existing conceptual framework - even if that framework is in conflict with the accepted canons of science. Furthermore, researchers such as Posner et. al. (1992) have found that unless the teacher challenges the student's existing conception, they will prefer, and use, their naive conception over the scientific conception. Students often ignore counter-evidence or they interpret it in terms of their own naive views (Muthkrishna, Carnine, Grossen, & Miller, 1993).

was an educational anthropologist who specialized in sociolinguistics and did research examining the social context in which learning took place. Because of her research interests on the social construction of knowledge in the classroom there was a strong social constructivist orientation in this program. Thus, the role of oral and written discourse as tools for making sense of the content in all subject matter areas was emphasized in Ms. Lawson's teacher preparation.

Ms. Lawson had been a student teacher at Atlantis and was hired as a full time teacher the following year. Mrs. Runner told me that Ms. Lawson quickly earned a reputation as an excellent language arts teacher, and this was the reason Mrs. Runner approached Ms. Lawson about teaching collaboratively. Although a veteran teacher, Mrs. Runner felt that she would learn more about teaching language arts from Ms. Lawson. Thus, despite a vast difference in their years of experience, it was a true collaboration from the perspective that each felt she could learn from the other and each had knowledge and skills to contribute to the collaboration. It was clearly not a relationship in which Mrs. Runner was mentoring Ms. Lawson despite the difference in age and experience.

Ms. Smith, Dr. Nettings, and Dr. Jones

Ms. Lawson and Mrs. Runner were part of a five member team involved in the planning and/or teaching that took place in this classroom during the afternoon science and literacy time - which varied from 1-3 hours per day. In addition to Ms. Lawson and Mrs. Runner, the members of the team included a student teacher who had been in the room part-time since September and full-time since January, and two university faculty members, one of whom had been part of the team since September, the other had been working on PDS projects with the building teachers for several years.

The student teacher, Ms. Smith, was a student in the same alternative teacher education program at the university from which Ms. Lawson had graduated. Ms. Smith, like many students enrolled in this program, had a strong language arts background. Although she did not have a strong science background she researched the topic and

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An example of the strength of children's naive conceptions is given in a descriptive study by Schneps (1987) which was documented in the video entitled "A Private Universe". Schneps found that Harvard graduates - including one just receiving a degree in a branch of physics - hold the same naive conceptions about the cause of the seasons as high school students who had not had any formal instruction. Schneps illustrated how instruction can be viewed as being entirely consistent with a student's naive conceptions in his study of one student, Heather, and her learning about the seasons. Schneps gave the following description of Heather[4]:

> Before instruction, Heather believed that summer occurred when the earth was further from the sun, that the sun's rays bounce when it is summer, and that the shape of the earth's orbit around the sun was a curlicue. After classroom instruction that showed the orbit of the earth, Heather now realized the earth's orbit had an elliptical shape. It is not surprising that the classroom instruction failed to correct Heather's naive conception that the sun's rays bounce though, because it used the word "bent" to describe indirect rays, with no illustration. "Bending" can be "bouncing".
>
> In a second attempt to correct this naive conception, Heather was presented with a drawing showing sun rays hitting the earth at a slant.Heather now readily accepted that information, but also maintained her naive conception that rays bounce: She stated that winter occurred because the sun's rays both hit at a slant and bounce off other parts of the earth. This naive conception is consistent with a drawing which did not show the entire length of the ray from the sun. There is no evidence from these instructional interactions that a clear, unambiguous explanation, inconsistent with all misinterpretations, and followed by application exercises would not have been sufficient to bring about conceptual change in Heather.
>
> As Heather indicated, she learned about these confusing bouncing sun rays in her eight-grade science class. Part of Heather original naive conception seems to have resulted from understanding "indirect" to mean "not straight" or "bouncing" - a reasonable interpretation of the English language. Heather explained that her ideas about the curlicue orbit of the earth were also formed by erroneously associating a diagram in her eight-grade science book with the information about the earth's orbit.

In the celebrated study described above, the emphasis is on Heather and her failure to go through a process of conceptual change even though she has been presented the

[4]I am including this lengthy quotation because the "Private Universe" video has became extremely well known. It is frequently used with both pre-service and in-service teachers as an illustration of the failure of traditional science to change students' conceptions. The teachers in this dissertation study had also viewed this video.

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concept of the cause of the seasons by her teacher. This study is typical of those done by conceptual change researchers. Although there is a social component to constructivism, the social aspects of scientific understanding in the classroom have not been a concern of cognitive researchers who have studied student knowledge construction in science education. Rather, in the tradition of Piaget, these researchers have generally focused on what is labeled the individual dimension of scientific understanding (Lee, et. al., 1993).

However, another school of constructivism is beginning to emerge in the literature. This school of thought has recently been described as "Emergent Constructivism" (Cobb, 1995). While this perspective agrees with the psychological or Piagetian constructivist perspective, it adds the idea that acts of individual meaning making can be seen to occur as students participate in and contribute to the development of practices established by a local community such as a science classroom learning community (Cobb, 1995). Thus the existence of a social context in which meaning making occurs is beginning to be acknowledged by constructivists.

As Smith (1995) points out, constructivists are not interested only in the isolated individual while ignoring the social context. For example, Rogoff and Lave (1984) view constructivist science education as an apprenticeship into a community of practice. And British science education researcher Rosalind Driver suggests that it is particularly important to adopt a perspective that embraces both the constructivist and the socio-cultural (social constructivist) position (Driver & Scott, 1995). To this end she is focusing her current research on the ways in which school students' informal knowledge is drawn upon and interacts with the scientific ways of knowing introduced in the science classroom (Driver, et.al. 1994). In this research Driver takes a strong position that all knowledge is socially constructed and validated (Driver, et.al., 1994). Driver believes that although students must construct meaning individually, they need to be introduced to the construction process in a social setting. Thus, Driver subsumes a social view of knowledge construction and meaning making within her view of constructivism. This merging of

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constructivism and a more social constructivist perspective is seen in the following quote by Driver in which she describes the constructivist classroom as being a

> "...place where individuals are actively engaged with others in attempting to understand and interpret phenomena for themselves and where social interaction in groups is seen to provide the stimulus of differing perspectives on which individuals can reflect. The teacher's role is to provide the physical experiences and to encourage reflection. Children's meanings are listened to and respectfully questioned" (p. 7).

Pedagogical Implications of a Conceptual Change Model

Conceptual change theory began with a focus on learning -- what conditions must exist in the learner's head for successful learning to occur? Thus, Posner and his colleagues (Posner, Strike, Hewson & Gertzog, 1982; Hewson & Hewson, 1984; Strike & Posner, 1985; Strike & Posner, 1992) outlined four conditions necessary for conceptual change. The conditions, which are modeled on the conditions necessary for a scientific paradigm shift, are:

1. There must be dissatisfaction with the existing conception.
2. A new conception must be intelligible or minimally understood.
3. A new conception must appear initially plausible.
4. A new conception must be fruitful.

The requirements outlined by Posner et.al. (1982) are cognitive conditions that must exist in order for the student to develop a complete understanding of a conception that directly conflicts with a persons initial beliefs. These cognitive conditions do not, however, directly define what the teacher or the students should do in the classroom. However, teachers must help students to meet the criteria of dissatisfaction, intelligibility, plausibility, and fruitfulness if they are to successfully engage in the process of conceptual change.

Because the process of conceptual change is a difficult one for students to undergo, there must be a compelling reason for them to be willing to do so. A number of recent research studies have focused specifically on teaching strategies and the kinds of activities sn

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that are necessary for bringing about conceptual change. Roth, Anderson, and Smith (1987) suggested a set of five teaching strategies for bringing about conceptual change:

1. Eliciting and responding to students' misconceptions.
2. Focusing on explanations.
3. Probing after student responses.
4. Balancing open-ended and closed discussions.
5. Providing practice and application.

And Nussbaum and Novick (1982) investigated a two-part teaching strategy where students are first made aware of their own relevant prior conceptions and then engaged in "conceptual conflict" or "cognitive dissonance," triggered by a "discrepant event".

In general these teaching strategies portray a style of teaching in which both teachers and students are cognitively active and engaged (Smith, Blakeslee, & Anderson, 1993). Teachers encourage students to express their ideas and interpretations orally and in writing, to the teacher and with their peers, as they try to explain and understand the world. Teachers who use this strategy also constantly encourage students to think more rigorously about familiar phenomena, to modify their explanations in the light of new information, and to develop explanatory and problem solving skills (Smith, et.al., 1993).

According to Smith (1993) this teaching approach represents a more "honest" image of the nature of science. This image is composed of at least three parts.

1. Science has a complex structure or "conceptual ecology". It is composed of sets of interrelated ideas, not lists of facts, definitions, or formulas. Thus knowledge of science lies as much in the complex and dynamic relationships among concepts as in the concepts (or facts, skills, etc) themselves.

2. Explaining phenomena is a fundamental purpose of science. When students engage in making explanations, they are engaging in a central task of science.

3. Scientific conceptions explain real-world phenomena, not just special laboratory situations. Neither scientific conceptions nor the phenomena that they explain are beyond the grasp of students' personal understanding.

The key to successful conceptual change teaching is finding out about the student's naive conceptions both prior to instruction as well as throughout instruction so that

situations can be created in which the naive conception fails the student. This does not typically happen in the traditional didactic approach or in the inquiry approach, although its importance is alluded to in the theoretical framework of SCIIS. In the *traditional didactic approach* prior knowledge was treated as irrelevant and was ignored. Students were also not given the opportunity to actually use the scientific knowledge they memorized. In the *inquiry approach* the students were encouraged to show and use their prior knowledge. However, teachers too often were unaware of the ways in which students continued to use their faulty prior knowledge to apparently (to them) successfully complete tasks. Their prior knowledge was never fully challenged nor was a plausible, fruitful alternative made available for them to consider and use.

The Role of Discourse in a Conceptual Change Classroom

A conceptual change, constructivist view of learning sees students as taking an active role in building their own knowledge by modifying their existing conceptions through the process of conceptual change (Pines & West, 1986; Posner, Strike, Hewson & Gertzog, 1982). Students' prior and developing knowledge is central in the discourse. Thus the discourse pattern in a conceptual change lesson is one in which the teacher elicits the students' ideas about everyday phenomenon and provides opportunities for students to puzzle over and question their ideas. This pattern is illustrated in the transcript segment below which is taken from "Discourse Analysis as a Window Into the Classroom and Into the Minds of Students" presented by Duschl and Petasis at the 1995 AERA conference. In this segment the teacher elicits students' conceptions about whether the height of a boat's sides affects its ability to float when something heavy is added to the boat:

Teacher: Ok. so, the sides matter.

S: Yes.

Teacher: You just told me no, they didn't

S: They do but not that much.

Teacher: What do you think Monica? What do you think about the sides?

S: In our group when we made the boat the one with low sides held more (washers).

Teacher: A lot more? How many did the one with the low sides hold? The big one with the low sides? Do you remember? The big one with the real low sides.

S: Eighty.

Teacher: The one that is not folded with the real high sides.

S: Sixty

Teacher: And how about the little one with the lower sides? Did you remember? You don't remember. Let's look in your...

S: Twenty

Teacher: It held out about twenty. Is that a big difference?

S: Yes

Teacher: Yeah, it sure is. So, sides do matter, do you think?

(conversation continues with different students explaining why there needs to be a balance between side height and surface area of boat).

In the didactic example earlier in this chapter all the questions asked were known answer questions such as "what is the function of the optic nerve"? The questions in this example do not fall into that category. The teacher is asking for observations, "how many did the one with the low sides hold", and opinions based upon evidence "do sides matter, do you think?" Rather than the teacher presenting information directly, she is asking the student to provide the evidence from the experiment and to draw conclusions from that evidence.

Similar to the inquiry approach the teacher asked the students to share experimental findings and conclusions they have reached. However, in contrast to the way in which the inquiry approach was enacted, with a tendancy toward unquestioning acceptance of all ideas, this teacher did not unquestioningly accept each student's ideas. She challenged the student who said that sides matter, pointing out that a moment earlier the student had said th

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that they didn't matter. Following this challenge she asked the class a series of questions which help them reach the scientific conclusion that yes, the sides do matter up to a certain height.

Furthermore, unlike the inquiry approach, this teacher was helping the student clarify, or make explicit, her thinking for herself. When the student said that the height of the sides don't matter the teacher challenged her, noting that she just said a minute ago that the height did matter. In this way the teacher is helping this student make her thinking explicit for not only the teacher, but for herself. She was then able to go on and clarify that the sides do make a difference but that there is a point of "diminishing returns" with respect to the height of the sides. This probing of student thinking, making ideas explicit, and challenging an individual student's thinking is the hallmark conceptual change discourse.

Eleanor Duckworth (1987) focuses more specifically on the discourse of the teacher (rather than teacher-student interactions) and describes the types of teacher interventions that are helpful in a class discussion in which the goal is individual knowledge construction through a process of conceptual change:

> "...What do you mean? How did you do that? Why do you say that? How does that fit in with what she just said? Could you give me an example? How did you figure that? In each case these questions are primarily a way for the interlocuter to try to understand what the other is understanding. Yet in every case, they engage the other's thoughts and take them a step further" (1987, pp. 96-97).

Notice in the teacher questions that Duckworth advocates, the emphasis is on probing the individual student's thinking so that both teacher and student better understand the sense the student is making of the lesson. This is probably most clearly seen with the question, "could **you** give **me** an example?". Although the other students may be sitting listening to this conversation, and may indeed benefit from such a conversation, there is not an explicit attempt to draw them into the conversation with questions such as "What do other people think about her idea - do you agree or disagree?" or "Did everyone hear what he just said? Did you all do it the same way?"

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Criticisms of a Conceptual Change Model

At this point one weakness in much research on student learning in science is that it is not informed by a conception of the social organization of the classroom interactions nor by a conception of the influence of the social participation structure (the norms for participation including the rights and duties of both teacher and students) in shaping the individual's opportunity to learn (Erickson, 1982). Cognitive views such as the conceptual change model suggest that the *learner* constructs knowledge but does not take into account how the *social context* of the classroom influences this construction (Marshall, 1989). Thus a critical variable to be examined in better delineating this process of conceptual change in science is the classroom learning community and its social organization and practices including the role of discourse in science learning.

Although researchers on student cognition often suggest specific teaching strategies or ways of approaching content that could be employed to help students make sense of the new science content in light of their less sophisticated prior knowledge (Ramadas & Driver,1989; Roth, 1986; Posner, Strike, Hewson & Gertzog, 1982), little work has been directed at identifying the ways the learning community in which these activities take place is supporting or hindering student sense making in science. Thus little is known about the way in which classroom interactions shape, or are shaped by, student learning in elementary science.

Cognitive science models and a constructivist perspective have been very productive as tools for conceptualizing student learning. However, there are those who argue that the classroom context may influence students' cognition and moderate conceptual change (Pintrich, Marx, and Boyle, 1993) considerably more than the focus on individual cognition would lead us to believe (Driver, et.al., 1994). There is mounting evidence which suggests that individual learning in classrooms is not isolated but greatly influenced by peer and teacher interactions (Pintrich, Marx, and Boyle, 1993). The conceptual change process, for example, may be influenced by being situated within different classroom

contexts and shaped dramatically by the nature of the interactions between students and teacher (Pintrich, Marx, and Boyle, 1993). Indeed, in a revision of their original paper on moving towards a conceptual change model, Posner, and Strike (1992) conceded that a wider range of factors than the individual student's cognition needs to be taken into account when describing a learner's conceptual ecology (or conceptual framework) and "the idea of a conceptual ecology thus needs to be larger than the epistemological factors suggested by the history and philosophy of science (p. 162) (Posner and Strike, 1992).

Few good models currently exist for understanding how social processes affect student learning in classroom. However, there is widespread consensus that research on social context should focus on teacher-student and on student-student discourse (Tharp & Gallimore, 1988).

View of Science Learning and Knowledge Represented by a Social Constructivist Perspective

While the cognitive science and constructivist perspectives continue to help us better understand the ways in which knowledge is structured by the individual many researchers have begun to consider the social constructivist perspective and the role of the classroom context, specifically the classroom discourse, in elaborating and shaping individual conceptual change (Pintrich, Marx & Boyle, 1993).

Before discussing a social constructivist perspective, however, I want to take a step back and define my terms. The ideas of "constructivism" and "social constructivism" have literally taken the science education community by storm in the past decade. However, this is not without its price. When examining the science education literature from the late 1980's and early 1990's it becomes clear that these terms have come to mean different things to different people. Thus, before beginning a discussion on the view of science learning and knowledge and the role of discourse when teaching from a social constructivist perspective, I want to explain the way in which I am using the terms

"constructivism" and "social constructivism" to clarify how I am distinguishing between the two.

The similarities between constructivism and social constructivism are many while the distinctions are subtle but important and are generally related to issues of classroom discourse. I believe that social constructivism can be considered a logical extension of constructivism. A social constructivist perspective builds on the ideas of constructivism and expands on them, taking into account the social context of the classroom which includes an emphasis on classroom discourse. Cobb (1994) holds the position that rather than being two mutually exclusive or contradictory perspectives, the distinction between constructivism and social constructivism is primarily a result of which perspective the observer chooses to take. For example, if a researcher taking a constructivist perspective was conducting research on students' conceptions about changes in matter, he or she might choose to conduct clinical interviews with individual students. In these interviews the researcher would elicit students' prior knowledge about change of state and attempt to understand the ways in which individual students were making sense of instruction.

By contrast, if a researcher taking a social constructivist perspective was conducting research on students' conceptions about changes in matter, he or she might choose to study transcripts of class discussions in order to determine the ways in which the discourse in the classroom learning community was helping or hindering the students, as a class, as they worked to understand the concept of change of state. This researcher might be interested in tracing the development of a scientific concept through the discourse across the course of one or more class discussions and the meaning that the students, as a social group, are making of the idea.

Similarly, a teacher who is holding a constructivist perspective would choose to focus his or her attention primarily on the sense-making of individual students in the class. He or she would provide many opportunities for individual students to write about their changing ideas and the sense that they made of a particular experiment. A teacher holding a constructivist perspective would probably make sure that there were multiple opportunities to talk with individual students during the lesson. During these conversations the teacher might probe, challenge, create conceptual conflict, and so on with the individual student. This teacher is not necessarily denying that the social context influences learning. He or she is simply paying more attention to individual construction of understanding.

By contrast a teacher who was holding a social constructivist perspective on teaching and learning would choose to focus primarily on the sense-making within the larger group -- either during class discussion or during small group time. This teacher would create many opportunities for students to listen to and challenge one another's thinking and ideas. Small and large group discussions and group written products would form the cornerstone of the social constructivist teacher's classroom. Because the social constructivist perspective represents an emphasis on the social context rather than on the individual, the teacher's attention would tend to be on the group rather than on the individual. However, this is not to say that individual construction of understanding is unimportant to the social constructivist teacher -- it is the ultimate goal.

From these examples, an image should emerge in which social constructivism is a version of constructivism in which the observer (researcher, teacher) pays close attention to the social context in which learning takes place. What should also be clear from these descriptions is that the distinction between constructivism and social constructivism is not a clear cut distinction but rather is a question of degree. The more a teacher focuses on individual cognition, the closer on the continuum he or she is to representing a constructivist perspective while the more a teacher emphasis the social context of learning, the closer on the continuum he or she is to representing a social constructivist perspective. The view of knowledge as being a construct which is social and changing is the same as the constructivist perspective.

A major school of thought on social constructivism derives from the works of Vygotsky. Knowledge, from a Vygotskian perspective, is a collaborative construction between individuals from which each individual then appropriates the knowledge. Researchers such as Lemke (1990) and Edwards and Mercer (1987), base their work on a Vygotskian perspective and represent the knowledge construction process as one in which the learners are enculturated into a scientific discourse community.

Learning and thinking from this perspective are "situated in physical and social contexts" rather than occurring solely in an individual's mind" (Greeno, 1989 p. 135 as cited in Marshall, 1989) as the cognitive perspective could be taken to imply. This thinking led curriculum theorists to draw on the philosophical and epistemological work done on the social construction of knowledge as a useful way to think about knowledge development in science and the ways in which students could learn science in school.

Learning, from this perspective, is a social process of making sense of experience in terms of extant knowledge (Tobin, Tippins, & Hook, 1992). Thus knowledge, from a social constructivist perspective, is the product of language-based interactions that take place in a social environment and is influenced by a person's prior knowledge.

Language, in the form of oral discourse, plays a central role in the social construction of understanding. Mead (1934) was one of the first to formulate a social constructivist approach to philosophy and psychology. Language played an important role in Mead's thinking. Mead believed that meaning is constructed within the act of communication. This communication is necessary if meaning making is to occur. According to Bruner (1966), it is oral language which allows children to take elements of their experience and organize them into increasingly more sophisticated thought structures, a necessary condition of learning. Vygotsky (1962) theorized that thought is the internalization of dialogue and that in order for students to be able to think through new ideas, they must first talk through the ideas with a "more knowledgeable other".

Researchers with language minority students have found that part of learning to make sense in science is appropriating a new discourse (Rosebery, Warren, and Conant, 1990). Barnes (1969) argues that the more a learner is able to control his own language

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strategies, and the more that he is enabled to think aloud, the more he can take responsibility for creating explanations, a central goal of science. Talk is much more than just a window upon mental processes and metacognitive concepts. Conversations are a significant environment in which such thoughts are formulated, justified, and socialized (Middleton & Edwards, 1990) and thought itself is enabled by language (Winogard & Flores, 1980). Thus there is a recursive relationship between learning to talk science and "knowing science" (Lemke, 1990; Bruner, 1966; Barnes, 1969; Vygotsky, 1962).

Rosebery, Warren, and Conant (1990) conceptualize scientific literacy itself as discourse. They believe that science knowledge "is a socially and culturally produced way of thinking and knowing, with its own ways of talking, reasoning and acting, its own norms, beliefs, and values, its own institutions, its shared histories and even shared mythologies". Language is used to think and act as members of a science community. Thus, from a social constructivist perspective language plays a critical role in learning and is part of what is learned.

According to Marshall (1989), a "social constructivist conception implies that we need to focus on the social context within which academic tasks are presented and within which academic cognitions are constructed". The social context of the classroom communicates to students what aspects of knowledge are valued, what counts as learning, the form knowledge takes, and what sorts of learning activities are valued. These are messages that students receive both explicitly and implicitly through their daily interactions with the teacher in the classroom as well as in the classroom discourse patterns established by the teacher. In these ways the social context of the classroom has a major influence on the form that the science knowledge ultimately takes in an individual's mind.

For example, Roth (1992) describes how her vision of the cognitive science approach to teaching and learning has been broadened to include the learning community. Rather than focusing on only the individual cognitive aspects of teaching for conceptual change in her teaching of fifth-grade science, she explicitly situates these aspects within

what could be considered a social constructivist learning community (See figure 2.1). Thus, although a conceptual change model guides her instructional decisions and actions, she emphasizes that a community which explicitly values characteristics such as collaboration, public sharing and revision of ideas, and valuing and respecting others' ideas plays an integral role in supporting learning.

The social context of the classroom has an important influence on the form the science knowledge takes in the individual student's mind. For example, if the classroom setting is one in which the emphasis is on the teacher telling students the scientific "facts", and students getting work done individually and often in competition with peers, students will tend to view science knowledge as a series of facts to be memorized and repeated at the appropriate time to the teacher who is the ultimate authority for knowledge in such a classroom. However, if the classroom learning community is instead one in which scientific knowledge is viewed as tentative and open to debate, in which collaboration, sharing, and public revision of ideas is stressed, in which students write and talk with one another to make sense of scientific phenomenon, students will be more likely to view scientific knowledge and understanding as being socially constructed by themselves with the support of their peers in the learning community.

Social constructivism represents science knowledge as being something that people construct together through language. It also recognizes that all knowledge is social in nature. From this perspective teaching involves eliciting different representations of the knowledge and facilitating discussion and debate about these representations. Learning involves a willingness to share your thinking and engage in discussion about different representations of the knowledge.

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The Role of Discourse in a Social Constructivist Classroom

A social constructivist classroom with an emphasis on discourse has a markedly different participation structure[5] than a more traditional classroom in which the teacher didactically presents the scientific "facts". For example in a "traditional" classroom language is most commonly used as a tool for knowledge display; the students demonstrate that they know the correct "answer" during class discussion or on a worksheet or test. Students in such a class are responsible for providing answers in response to questions posed by the teacher. The teacher, in the role of an authority on classroom knowledge, then takes on the role of evaluator with responsibility for determining whether the response given by the student was correct or incorrect. In a classroom such as this the teacher may ask a lot of questions. However, the questions asked are not questions designed to stimulate discussion and debate as the teacher and the students puzzle together over the ideas. Rather they are questions to which the teacher already knows the answer, often as given by the teacher's manual. The responsibility of the student is to provide the answer the teacher seeks (Cazden, 1988; Edwards and Mercer, 1987) as a way to display their knowledge (Roth, 1986) to the teacher who is in the role of evaluator.

In contrast, in a classroom guided by a social constructivist epistemology, language could be used as a tool for making ideas explicit by puzzling through these ideas with other members of the learning community as part of the sense-making process. For example, rather than giving finite answers, orally or in writing, the students would puzzle through many ideas to explore alternative solutions to open-ended questions. And rather than the teacher being the authority for determining the accuracy of a particular fact, the members of the learning community would puzzle over many ideas together until a consensus is reached by the group as to which ideas make sense and will become part of their newly constructed knowledge. In this way all knowledge is viewed as tentative and

[5]Participation structures are the norms for participating in the classroom learning community including the roles, rights, and duties of the participants. For a detailed description of the role of the social and academic participation structure of the classroom see Erickson, 1984 . For purposes of this paper, the ways in which students participate in science (the participation structure) constitutes the learning community.

constantly evolving and the members of the learning community play a role, through their talk and writing, in shaping the knowledge that is learned in the classroom.

The discourse in a social constructivist classroom is often dialogic in nature. This is best exemplified by highly interactive discussion in which the scope, development, and direction of discourse are shaped by the interaction of what the teacher plans and what the students say. Classroom discourse is negotiated by the conversants. Student responses are more sustained, and the discourse is more coherent as both teachers and students speak in response to each other. In dialogic instruction the teacher questions are authentic (no pre-specified answers). Dialogic instruction is characterized by uptake, defined as the teacher's incorporation of a student's answer into a subsequent question (uptake refracts the student's voice through the teacher's) (Tharpe & Gallimore, 1988).

The following brief example was taken from a whole class discussion in Mrs. Runner's class and illustrates the dialogic pattern in which the teacher refracts the student's response to her open-ended question back to the students:

Ms. Lawson: And if you find something you want to share, raise your hand and Ms. Smith is going to record it on the overhead. Okay... Reiko?

Reiko: We believe the ice cube on the table takes longer [to melt] because our ice cube was bigger.

Ms. Lawson: So you are saying that since your ice cube was bigger it took longer?

Reiko: Yeah

Ms. Lawson: Anybody have any thoughts about that? What do you think about that? They thought their ice cube was bigger so that would mean it would take longer. Zane?

Zane: Probably..like..if they were by the window and like..the window was here and they were right there and then the ice cube was right here...if they were by the window it would get more heat.

Ms. Lawson: Comments about that? Okay..Manny?

Manny: I have a comment for Zane..um..Reiko says they weren't sitting by the window

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Notice that the questions that Ms.Lawson asks are not ones with a pre-specified right or wrong answer. Rather she begins by asking the students to share what they noticed in the experiment. From here she builds on students' responses as they respond to the original statement and to each other. Although all turns are clearly negotiated through the teacher (with students raising their hands and waiting for the teacher to call on them), students are not giving brief answers in response to the teacher's questions but rather are listening and responding to one another.

Although the literature on social constructivism is largely theoretical, it can be drawn on to create an image of an elementary science classroom. This elementary classroom would emphasize that knowledge and understandings are constructed through talk, activity, and interaction around meaningful problems and tools. Students in this classroom would be taught how to challenge one another's thoughts and beliefs. They would learn how to be explicit about their meanings so that others could challenge them. In such a classroom children would need to negotiate conflicts or discrepancies in their beliefs or evidence and they would need to share and synthesize their knowledge together in order to achieve understanding (Rosebery, Warren, & Conant, 1990).

A social constructivist epistemology represents science knowledge as being a social construct created through language by members of a scientific discourse community. From this perspective teaching is facilitation of classroom discourse and learning comes about through participation in classroom discourse.

Criticisms of a Social Constructivist Perspective

At this point the primary criticism with teaching from a social constructivist perspective is that, although the ideas are sound in theory, there is not a lot of empirical evidence to support the assertion that students in a science classroom being taught by a teacher holding a social constructivist perspective are going to learn, and understand, the science concepts any better or in different ways than with a constructivist approach. One reason for the lack of empirical evidence is that there are not a great deal of science classrooms where the teaching is undergirded by a social constructivist perspective. Thus, there are no concrete images for the teacher who is trying to put the theoretical ideas into practice.

Another potential problem with teaching from a social constructivist perspective is the possible interepretation that since all knowledge is socially constructed, then the knowlege that students construct with their peers in science class is appropriate and valid knowledge regardless of whether it agrees with the canons of science. This "anything goes" relativism is very similiar to what happened in the inquiry-based classroom where the teacher held all ideas as equally valid if the students had "discovered" them for themselves and did not push or challenge the student.

Summary of the Discourse in Science from a Historical Perspective

The four perspectives on science teaching and learning --a didactic perspective, an inquiry perspective, constructivism/conceptual change, and social constructivism --all represent different perspectives on the role of discourse in learning.

Didactic teaching represents science knowledge as being composed of facts and definitions which have been "discovered" by scientists and defined by the teacher and the text. From this perspective teaching is the transmission of the fact and learning is the passive reception of these facts.

The discourse reflects this perspective. The teacher does most of the talking and developing of scientific explanations while the students listen. When the students are asked a question, it is typically a "close-ended" question to which there is a specific answer the teacher is seeking. In this manner the discourse generally follows the traditional Initiation-Response-Evaluation (IRE) format often seen in elementary classrooms. Rarely, if ever, do the students question one another or the teacher on anything other than procedural information.

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Inquiry teaching represents science knowledge as being composed of ideas and/or processes which can be "discovered" by the students through active manipulation of the materials under study. From this perspective teaching is the facilitation of inquiry and support of the invention of scientific conceptions. Learning from this perspective is exploration and discovery of ideas.

In this classroom the students do a great deal of the talking. The teacher encourages them to share data and ideas and it was intended that he or she would provide information which would help the students "invent" the scientific conception. However, in practice, this information providing often did not happen and the discourse became one of open sharing of ideas and "stories" with not challenge of these conceptions.

A constructivist/conceptual change approach represents science knowledge as being composed of ideas constructed by individuals which are consistent with the canons of science. Often these ideas are counter-intuitive and are constructed only after students more naive or non-scientific conceptions have been challenged and the scientific conception has been presented as an intelligible, plausible, and fruitful alternative to their naive conception. From this perspective teaching involves eliciting and challenging students' conceptions and providing intelligible alternatives which they help the student see as plausible and fruitful.

The discourse in this classroom involves students sharing their everyday conceptions as in the inquiry classroom. However, in the conceptual change classroom the discourse resembles a conversation between the teacher and the student to a greater extent than in the inquiry approach. There is more coaching of cognitive processing by the teacher. In addition to eliciting students' naive conceptions the teacher also challenges students' conceptions and provides instances and situations where the students' conceptions do not work for them

A social constructivist perspective represents science knowledge as being a social construct which is created through language by members of a scientific discourse

community. From this perspective science is discourse and scientific literacy is achieved by being able to control and use the discourse to explain everyday phenomenon.

The discourse in a social constructivist class also looks like a conversation; however, it is not just a conversation between the teacher and one student, rather it is a conversation among the group which includes the teacher and all the students. Students listen to, and question, not only the teacher but also each other's thinking and ideas as they struggle to make sense of the scientific phenomenon under study. One role of the teacher is to support the students as they learn to appropriate this discourse by teaching specific ways of talking in science, such as ways to agree and disagree. In this way the discourse is part of what is learned.

Discussion and Conclusions

One way to conceptualize scientific literacy is as Discourse (Rosebery, Warren and Conant, 1990; Gee, 1989; Gee, 1995). From this social constructivist perspective, in which all learning is considered a social and cultural process (Lemke, 1990), *the discourse is a central part of what is learned in science*. It is only once students have learned the discourse that they are able to control and use it to describe, explain, predict, and design real world objects, systems, and phenomena, which are the activities in which scientifically literate adults engage (AAAS, 1989). Which is the ultimate goal of science education (MEGOSE, 1994).

Discourse in science class can take many forms. For example, the classroom discourse could be limited to the students giving short information-based responses to "known answer" questions asked by the teacher. Alternatively, the discourse in science could take the form of an open-ended discussion in which students share their thinking and ideas in response to situations posed by the teacher. It follows that the form of the classroom discourse will influence what students learn about both science content and the nature of science. For example, students may learn that science consists of facts and information and has little to do with the everyday world. Therefore, they learn a number of disconnected lists and facts and isolated pieces of information. Or students may learn that the purpose of science is to make sense of everyday phenomenon by puzzling through ideas with teacher and peers. From this perspective they may view all science as consisting of connected and related ideas with no artificial separation of the disciplines as they learn to use evidence to support assertions about real world phenomena.

Because discourse does influence both the science content learned and the nature of that learning, one way to analyze science education historically is to consider the discourse engaged in by the participants -although discourse analysis was not the focus of this research historically. This look at the approaches to elementary science over the last forty years reveals a progression that can be seen as beginning with the teacher as the controller of the discourse, shifting to more student control of the discourse, and then moving to the idea of the classroom discourse as a conversation first between the teacher and a single student and eventually between all members of a classroom learning community. In this way the discourse and learning in science class is becoming more consistent with the view of scientific literacy described in documents such as Science for All Americans (AAAS, 1989) and with a social constructivist view of teaching and learning.

One of the criticisms of teaching using a social constructivist perspective is that it is still highly theoretical. Because social constructivism is a theory of learning which informs a pedagogical approach as opposed to a strict pedagogical or curricular approach, there is not a concrete set of "steps" or guiding principles or a teacher's manual which teachers who wish to teach from this perspective can use.

The best way to support teachers who wish to teach science from a social constructivist perspective is to provide them with images of what a social constructivist science classroom might look like. Currently, however, as described in the literature review, there are many images of what teaching from a social constructivist perspective does not look like but scant images of what it does look like. For example, it is clear that teachers who are holding a social constructivist perspective do not lecture didactically or merely facilitate experimentation, and they do not engage in an Intiation-Response-Evaluation (I-R-E) mode of discourse. However, because there are not many classrooms in which the teaching is undergirded by a social constructivist perspective, there are far less descriptions of what such a teacher might do. If the role of the teacher is not that of providing information or serving strictly as a facilator then what is the role of the teacher? What form would the discourse take? If the discourse does not follow the I-R-E pattern what pattern does it follow? In other words, what is the teacher in a social constructivist classroom saying and doing?

In addition to the lack of concrete images needed to support a teacher wishing to teach from a social constructivist perspective, there is limited empirical evidence to support the theoretical claims that the discourse in a social constructivist classroom supports student learning of science concepts in more meaningful ways than didactic, inquiry, or even conceptual change teaching. This lack of compelling evidence may serve to discourage teachers from being willing to engage in teaching from a social constructivist perspective, especially given the lack of concrete images to support them in this endeavor. Thus, in addition to concrete images of a classroom in which the teaching is undergirded by a social constructivist perspective, there is a need for compelling evidence that the discourse in a social constructivist classroom is going to promote student understanding of science concepts in a more powerful way than current teaching perspectives.

Scientific literacy, in which science is conceived of as Discourse, was a framework that the teachers in this study used for their planning and teaching. The result was a classroom in which the discourse pattern was consistent with the discourse described in the literature on social constructivism. This study examines and describes the discourse seen in that classroom, comparing it to the discourse patterns seen with the different perspectives analyzed for this literature review. In this way this study provides one concrete image of a classroom in which the teaching is undergirded by a social constructivist perspective.

However, unlike many of the existing studies of discourse in science, which have focused almost exclusively on describing the discourse, (Lemke, 1990; Anderson, Roth, and Smith, 1988; Rosebury, Warren, and Conant, 1990), this study also examines the relationship between the discourse and science content learning and the extent to which the discourse helps, or hinders, science content learning. In this way this study also provides empirical evidence that teaching from a social constructivist perspective helps some students develop a powerful understanding of science concepts such that they can use the concepts to make sense of everyday phenomenon.

In these ways this study brings together the research done on social constructivism, classroom discourse, discourse in science, and science content learning, and extends them to provide an image of a classroom in which science is Discourse and the planning and teaching are undergirded by a social constructivist perspective, and examines the nature of the science content learned in such a setting.

Chapter Three

METHODS AND ANALYSIS PROCEDURES

Introduction and Overview of the Chapter

This study was a qualitative, observational study of a third grade science class over the course of one teaching unit on "Changes in Matter". According to Erickson (1988), qualitative, or qualitative, research is most appropriate when the researcher wants to know more about what is happening in a particular case rather than across a number of places. Interpretive field work is well suited when answering questions such as 1) What is happening, specifically, in social action that takes place in this particular setting?, and 2) What do these actions mean to the actors involved in them at the moment the actions took place? (Erickson, Florio, and Buschman, 1980). I was interested in what was happening in this particular setting, because the teachers were making an explicit attempt to support their students in using oral discourse as a tool for working with their peers to construct their understanding of science.

The purpose of this study was to describe and analyze the ways in which the students and teachers participated in the discourse in science class in order to uncover and explain the relationship between the classroom discourse and science content learning over the course of one instructional unit of study. Issues explored included: (1) the nature of the students' talk in science class, (2) the norms for participation in the talk in science class, (3) the nature of the science knowledge found in the talk , 4) individual student's science knowledge construction and (5) the relationship among and between these four factors.

Although there is a growing body of research on discourse in science, most of this research focuses on describing the patterns of talk in science (c.f. Lemke 1990; Roth,

Anderson, and Smith, 1987; Yerrick, 1994; Hazelwood and Roth, 1992; Peasley, 1992) or on developing curriculum and pedagogy to support students in learning or "appropriating" the discourse of science (c.f. Rosebery, Warren, and Conant, 1990; Smith, 1995; Duschl and Petasis, 1995; Gee 1994). To date there have been few studies which have focused specifically on the extent to which the classroom discourse helps or hinders student learning of science content when learning the discourse of science is an integral part of the curriculum and teaching. This study, which provides a qualitative description of an elementary science learning community in which science is discourse (Gee, 1989), was designed to provide this missing data on the extent to which the discourse helped or hindered two students' science content learning.

This chapter begins with the research questions. I then give a rationale for using qualitative research as a method. Following this is a description of the study participants, a summary of the data collected and the data collection procedures, and a description of the approach to data analysis that I used. The chapter concludes with a summary of the data collection and analysis procedures.

Research Questions

The questions about classroom discourse and science learning which guided this study were:

In an elementary science classroom in which the teacher is attempting to support student construction of knowledge socially through the use of oral discourse:

a. What science knowledge do the students in this science class construct?

b. What is the nature of the students' talk in science class? What are the implicit and explicit rules for discourse in science?

c. What is the participation structure in this classroom (including the rights, roles, duties, and responsibilities of the participants)?

d. What is the relationship between the students' science learning and their participation in the classroom discourse?

Rationale for Using Qualitative Research

I chose qualitative research as a method because I wanted to look closely at the actions that took place in this classroom and the meanings of these actions to the participants. Science is not traditionally taught with an emphasis on discourse. Students in a traditional science classroom are not necessarily encouraged to listen to and challenge the ideas of their peers Most of the discourse in science class is monologic in nature with the teacher talking and the students listening (Tharpe and Gallimore, 1988). Furthermore, rather than being represented as a set of ideas to be questioned and puzzled over, science is traditionally represented as being composed of discrete facts to be "learned" -- often through memorization -- and repeated on a test or to the teacher at an appropriate time. Students are often exposed to large numbers of facts and vocabulary words, tested for recall, and moved on to the next topic (Anderson and Smith, 1984; Anderson and Roth, 1988).

I was curious about the ways the children in this non-traditional science class would participate in the class discussion, and where and how the science content would appear in the talk. I was also curious about the impact of the discourse on student learning of science content and the ways in which different students engaged in the discourse and thus in the science content learning. Interpretive research was one way of getting at all three of these -- the nature of the talk in science, the students' perceptions of their talk in science, and the relationship of the talk to science learning.

My goal was to look for patterns of participation and learning that could be connected to the discourse and the classroom learning community in this setting. The students in this class are unique individuals. There will never be another class exactly like this one. Therefore, events in this classroom cannot be used to predict events in other classrooms. No other classroom is going to have the same composition of students with the same personal and academic histories. However, it is possible to search for and identify general patterns of interaction among the participants. If these patterns are shown to be productive in enabling the students to make sense of the science content in some unique or sophisticated ways, a description of the classroom context and the interaction patterns that were established could be established by other teachers in other classrooms. A description of productive patterns of interaction around science content could help other teachers consider ways they might interact with their students as they are making sense of the science content. This study could also serve as a call for other researchers to begin to examine the relationship between different forms of classroom talk and science content learning.

Shifting Focus in Qualitative Research

One characteristic of field work is that although the researcher identifies a conceptual focus in advance, this conceptual focus sometimes shifts and changes in response to specific events occurring in the field (Erickson, 1986). Unlike a pure quantitative study, qualitative research does not seek to control variables. Thus, it is impossible to predict with total accuracy exactly what is going to happen in the setting. In addition, data analysis and data collection become closely intertwined as data collection proceeds (McMahon, 1992). The collected data is analyzed immediately upon leaving the field by listening to tapes, expanding field notes, and writing vignettes. This analysis then guides decisions regarding further data collection; this data collection then informs the ongoing analysis, and so on. For this reason the researcher must occasionally shift her focus in response to events in the field.

This study was originally intended to be a study of the role of talking-to-learn and writing-to-learn in science. However, although there was an intended oral and written literacy focus during science in this classroom, the emphasis shifted early in the unit teaching to a predominant focus on oral discourse and the role of oral discourse in supporting learning in science. To this end many class discussions were held in which the students were encouraged to think through their ideas orally and were implicitly and explicitly taught a discourse pattern of making assertions supported by evidence.

By contrast, most of the writing that took place during science was in the form of data recording and procedure writing. During the actual unit there was limited opportunity for the students to write about their thinking and ideas about the phenomena under study. As a result of this shift in emphasis in the teaching, the focus of this research also shifted from an intended focus on written discourse and the role of writing-to-learn science, to a nearly exclusive focus on oral discourse and the role of classroom talk in learning science.

The Study Participants

The third grade team room at Atlantis Elementary was an unusual setting, created primarily by the two lead teachers -- Mrs. Runner and Ms. Lawson -- who had decided to work together as they engaged in professional development activities. The class was actually a double class--the wall between the two classrooms had been knocked out-- which functioned as a single learning community with two teachers. There were 42 students in the class, evenly distributed between the girls and the boys. Mrs. Runner and Ms. Lawson collaboratively planned and taught all 42 students throughout the day except during mathematics time. At this time there was an accordion divider that was drawn between the rooms to separate the two groups of students.

Many of the students in this class were foreign students whose parents were graduate students at the adjacent Midwestern University. The majority of these students were from a country other than the United States, spoke at least one language other than English as their first language, and would return to their homeland in 3-6 years.

Of the 42 students in the double class I observed, five were English as a Second language (ESL) students. Although all five of these students were new to the country the previous fall (6 months earlier), they were very much a part of life in this classroom -- participating in all class activities and playing with the other children at recess time. Many other students in this class had participated in the ESL program at some previous time but were proficient enough in the English language that they no longer participated in this program.

From this class of 42 students I selected two target students at the end of the second week of observation with the help of Mrs. Runner. I decided to follow the science learning and talk of an Indian girl who Mrs. Runner considered to be very bright and articulate about the role of discourse in her learning. The girl, Padma, is the focus of one of the case stories in this dissertation. A second target student was originally selected to provide a contrast to Padma, however because this target student was a special education student he was not in the classroom during many of the science discussions. Additionally, over the course of the unit a another boy emerged as being intriguing because of the ways in which his learning and discourse contrasted with Padma's learning and discourse. This boy, Casey, is the focus of the other case story in this dissertation.

Data Collected and Data Collection Procedures

To understand the ways in which the students participated in the talk and the sense they made of the science content through their talk, I collected multiple types of data including 1) field notes, 2) audio and video taped class discussions, 3) audio and video taped teacher-led small group discussions, 4) informal discussions with the teachers about their perceptions of the ongoing class discussion, 5) copies of the teachers' unit plan and daily plans, 6) three formal interviews with one of the target students, 7) student documents.

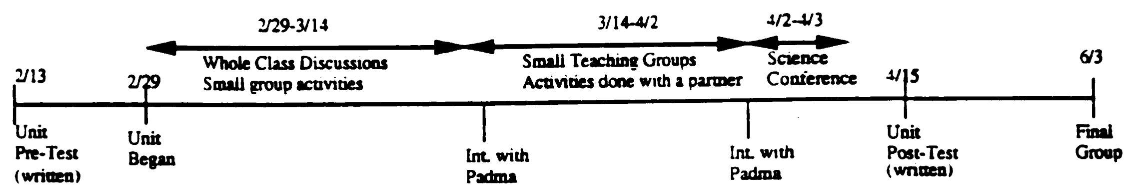
The remainder of this chapter outlines the data collected in greater detail and describes the analysis process I followed.

Observing and Recording Field Notes

I observed science during most of the days it was taught beginning in late February and continuing through a school-wide science conference held on April 2-3. The timeline in Figure 3.1 summarizes the unit teaching and data collection time frame.

Figure 3.1

"Changes in Matter Unit "Timeline



Although there was a block of time allotted to science Monday through Thursday, there were many scheduling conflicts due to an assembly or other interruption during the day as is typical in many elementary schools. Further complicating the schedule were the student teaching requirements of Ms. Smith who had to teach a science unit that she had created in her coursework at Midwestern University. To make up for the days on which there was a schedule conflict or Ms. Smith was teaching, there were days on which science lasted

longer than the scheduled forty minutes. However, on average, science was taught two hours per week generally across 2-3 days for a total of twelve science lessons. Each observation was audio- and videotaped.

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There were several days I was unable to attend science class because of schedule conflicts. On those days a video camera recorded the interactions of the participants. I was then able to observe and take field notes from the videotapes. Altogether I observed science a total of 12 days with many of these days consisting of a larger time block, the equivalent of 2-3 lessons.

Whole class discussions conducted by Ms. Lawson and Mrs. Runner were observed from February 29 to March 14. During these observations I sat off to the side near the front of the room at a round table and took field notes. From this position I was able to see the students from much the same physical perspective as the teacher's. Frequently the teacher who was not the lead teacher for the lesson sat at the table with me, occasionally interjecting comments into the lesson and also commenting to me --telling me something about a particular student or comment that she found interesting. I included these comments as data in my fieldnotes.

I also observed the students as they worked on small group activities -- small group experiments were a part of the majority for the lessons during the period from February 29-March 14. Unfortunately, the groups were fluid and the students were assigned by the teacher to different groups for each activity. Rarely were the same group of students together for more than one activity. At this point in the unit Casey -- who is the subject of a case later in this dissertation -- had not yet emerged as a target student. Therefore, my observations were exclusively on whichever group Padma, who was one of my original target students, was assigned to on each day. Padma and Casey were never in the same small group during this period

Beginning on March 15 the class was divided into four small, teacher-led, discussion groups with 10-11 students and 1 teacher per group. Padma was a member of Mrs. Runner's small group. Casey was also a student in Mrs. Runner's group, and it was during this time period that he began to emerge as a potential case. Therefore, from March 15-April 3 I observed only Mrs. Runner and her group of 10 students. Although these were sma

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were smaller groups, the discourse patterns and ways of interaction were the same as with the large group. The groups were still teacher led, and most discourse was negotiated through the teacher as it had been in the whole class discussions. Figure 3.1 on the next page shows a time line of the enacted unit.

During the small teaching group observations I sat at a student desk near, but not part of, the group of students. Because both Casey and Padma were in the same small group I was able to focus my observations on their participation and interactions in the group. As with the whole class observations, I audio- and videotaped all interactions and took detailed field notes during the small group discussions. Because both Padma and Casey were in Mrs. Runner's group, I was able to focus my observations and field notes on their participation and interactions in the group. Although my focus was on recording the verbal and non-verbal communications of Padma and Casey, I was able to observe and record information about the other participants in the group as well. In particular I was interested in the extent to which Casey and Padma interacted with members of the learning community other than the teacher, and the nature of those interactions.

Reflective Vignettes

Following each class I supplemented my field notes by listening to the audiotape and writing vignettes about different moments in the lesson that were intriguing to me at the time. Typically these were instances in which Padma and/or Casey participated a great deal in the discussion, or were times when the students in general seemed particularly engaged in the discussion and were listening to one another and agreeing or disagreeing and generally building on each other's ideas in the way that the teacher intended. I also wrote vignettes about instances which were marked because they were the opposite of this. Equally intriguing were the days in which Padma and/or Casey appeared to be disengaged from this lesson - possibly never volunteering or refusing to participate when called upon. I was particularly interested in the events that proceeded and may have precipitated either of these two instances - intense student engagement in the discourse and apparent lack of engagement in the discourse.

Writing the vignettes was primarily a tool for my personal reflections on my observations. One way that I make sense of anything is to puzzle through it in writing. Just as writing can help a student make sense of the science content, writing helped me make sense of my observations. Often the act of writing itself helped me notice something I hadn't noticed before or provided new insight or another way of looking at an interaction that had not occurred to me at the time I was observing.

These reflective vignettes provided an opportunity for me to puzzle through and think further about my observations. Furthermore, they provided a permanent record of my perceptions of the role of discourse in the science class at nearly the same time I was observing it. It was through the writing of these vignettes that the largely invisible Casey emerged as a fascinating participant in the learning community. However, even this was a gradual process. I didn't initially realize how much Casey was capturing my attention until I began to reread the vignettes several weeks into the Changes in Matter unit and noticed that Casey had began to play a greater and greater role in my reflections on my observations. Without realizing it I had begun to write increasingly more about his participation in the discussion, although he was not intended as a target student up until this point. It was at this point --around March 14-- that I began to pay more attention to Casey's contributions in class discussion.

Discussions with Teachers About Their Plans and Copies of Unit Plan and the Daily Plans

Each day I visited the classroom I had a conversation with at least one of the teachers about their plans for the day and the purpose of the lesson. These conversations were not audio- or videotaped; however, I took extensive notes during them. On my first visit Mrs. Runner provided me with the written materials that they had done during the initial planning of the unit. These plans included several concept maps as they tried to identify the specific content they would teach. These maps, copies of which are in Appendix A, helped me identify the intended curriculum prior to giving the administration of the pre-assessment. I was then able to use these maps as contextual background. They helped me understand what the teachers had originally intended to teach and the ways in which this originally intended curriculum had been modified in response to the pre-assessment data. The teachers also provided me with copies of their daily lesson plans before each lesson. Samples of these plans for selected lessons described in this dissertation are also included in Appendix A. The informal conversations and the copies of the plans provided me with a context for watching the lesson and also served as a record from which I later constructed an outline of the planned curriculum for the unit (this outline appears at the end of Chapter 4). Having the plans in advance also allowed me to make note of times when the teacher pursued a line of thinking that was not part of the original plan but rather was one that the students had introduced or the teacher had modified based on an earlier class discussion.

Student Interviews

Interpretive research is about the "meaning of actions to the participants" (Erickson, 1986). Therefore, it was important to talk to the students in order to get a sense of their perceptions of the talk and writing that was going on during science and literacy time. Interviews also provided information about the sense that the students were making of the science content and what connections they were making. Padma, who was the original target student, was interviewed three times during the unit. These interviews were conducted on the last day the whole class group discussions were held (March 14), the last day the teacher-led group discussions were conducted (March 29), and the last week of the school year (June 3). Protocols for these interviews can be found in Appendix B.

During the first and last interviews Padma was probed about her understanding of temperature and temperature measurement. In all three interviews she was questioned

about the role of writing and talking through ideas in her learning of science. During these interviews she was asked to point to specific entries in her science notebook to illustrate her comments.

The third interview, unlike the first two interviews, also involved a group problem solving task which Padma worked on with a partner. The way in which Padma interacted with her partner during this task gave many insights into the way in which she viewed herself, her role, and her talk in science class. All interviews were audiotaped and transcribed.

Student Documents

Although I gradually began to become interested in Casey, he captured my attention very subtly and did not emerge as a target student until I had completed data collection and was fully into data analysis. For this reason, I do not have any of Casey's written documents other than his unit pre- and post-test. Therefore, the documents described in this section are primarily those of Padma, the other target student.

Group Written Laboratory Reports

I collected and copied all of Padma's group and individual writing. For each small group or activity conducted, the students completed "laboratory reports" which required them to draw or describe what they observed and to draw conclusions based on their observations. They were also asked to support the conclusions with evidence. Although these were group written products, Padma was often the "reporter" responsible for writing the report. Copies of selected laboratory reports are found in Appendix C.

Padma's Science Notebook Entries

The individual writing was done in a science notebook and was initially much less structured than the group writing. I copied Padma's notebook from the beginning of the year so that changes in her writing across the school year could be considered.

Pre- and Post-Unit Science Assessment

As part of the Changes in Matter unit the students were given a written pre- and post-assessment instrument in order to determine changes in thinking about the science concepts over the course of the unit. These assessment instruments were oriented toward conceptual understanding of the unit concepts and involved a series of "real world" situations or problems. The instruments were specifically designed to examine conceptual change across the unit. Every student in this class took the pre- and post-assessment. Copies were made of all students pre- and post-assessments. This provided important class data about changes in student thinking. Copies of the pre- and post-assessment instruments are found in Appendix D.

Data Analysis: The Search for Patterns

Transcript Analysis -Whole Group and Teacher-Led Small Group Discussions

From the twelve science lessons observed, five whole class and five small group discussions were selected as the focus of the final data analysis. Field note data and the reflective vignettes were used to make the decisions about which lessons, and portions of lessons, to analyze. The other two lessons not included in the final data analysis were predominantly small group experiments which were conducted early in the unit teaching. Although the small group work with Padma was documented and includes some interesting interactions between Padma and her male group members, analysis of the collaborative groupwork taking place during these lessons was beyond the scope and focus of this dissertation.

Furthermore, I narrowed down the remaining twelve lessons by focusing only on the science content discussions. I did not analyze the procedural directions which sometimes took up to 15 minutes at the start and end of science and literacy time, particularly as the preparations for the school science conference intensified. Neither did I analyze time spent doing science seat work or writing in the science journals. Again, while these observations are interesting, they are beyond the focus of this dissertation. The remaining discussions were generally ones in which the students were explicitly being supported in using their talk as a tool for learning science. For example, as will be illustrated in the next chapters, the teacher was teaching them how to agree and disagree with one another and was helping them learn to listen and respond to one another's ideas.

The first step I took in data analysis was to transcribe these five whole group and five teacher-led small group discussions during science and literacy time. These discussions lasted anywhere from 20 minutes to two hours. As I transcribed each lesson I kept a running inventory of things that I noticed. This first pass was a fairly broad cut on the data. Generally the things I noted were "marked incidents" which stood out because they were qualitatively different in some way than what had been taking place in the lesson. Marked incidents, for example, were times when the flow or tenor of the discussion noticeably changed- such as a shift from a discussion in which the students were sharing their thinking and ideas to a more didactic lecture with the teacher providing information, or times when a student participated in a way that seemed different from the participation of other students. These marked incidents were of interest to me because of the effect that they might have on students' perceptions of the learning community and on their science learning. For example, what factors led up the teacher suddenly shifting to a "lecture mode"? What might this shift communicate to the students about the nature of science and science learning? Why does a given student respond differently than other students during class discussion and to what extent, and in what ways, does this different participation structure affect his learning?

Once identified, these marked incidents were then returned to for closer analysis. I watched the lesson videotape specifically for these segments to double check the transcript, confirm the identities of the participants, and to watch for any body language such as hand raising, position relative to the teacher, and so on. I also read through my comments about these incidents in the field notes.

In addition to identifying marked incidents I used the lesson transcripts to identify places in which the two target students, Casey and Padma, participated in the discussion. These instances were carefully studied looking at the content of the talk, how and when they got the speaking floor, and the nature of the interactions. Some of the questions I was considering as I examined the transcript were: What sort of teacher or student moves elicited a bid for the floor from one of them? Did they agree or disagree with ideas put on the floor by their peers? By what mechanism did they receive the speaking floor ? Were they nominated by the teacher or were they self nominated?

Videotape was used to supplement the lesson transcript. One pattern that was noticed in the transcript was that Padma rarely participated verbally in the lesson. The videotape provided information such as whether she was bidding for the speaking floor and simply not receiving it, whether she appeared to be engaged in the discussion, or if she was even present in class on a regular basis. Videotape data also revealed the pattern of Padma's participation with respect to what type of questions elicited a bid for the speaking floor and who had to ask the questions in order for Padma to attempt to gain the speaking floor. Videotape was used in this manner for Casey as well. In his case particular attention was paid to when and how he bid for the speaking floor and how often he actually got the floor.

Analysis of Pre- and Post-Test Data

The questions on the written post-assessment were all constructed response items in which the students were given a situation such as, "What do you think the temperature of a cold glass of water from the drinking fountain is? Explain why you think it is this temperature." The majority of the situations were repeated in exactly the same form on both the pre- and post-assessment so that a comparison could be made pre- and post-unit. However, there was one problem on the pre-assessment which involved content not covered over the course of the unit. This question was removed from the post-assessment and replaced with a new question which involved the concepts studied in the unit.

For each constructed response item on the assessment instruments I developed a multi- point scoring rubric (see Appendix E). I then used the rubric to score the pre- and post-assessment instruments of each student in the class. I determined the total number of points possible on the assessment and calculated each student's pre- and post-assessment score as a percent of the total possible points. I also calculated percent gain scores for those items which were the same on the pre- and post-assessment and descriptive statistics were used to describe and determine the significance of these gain scores.

This data was used to determine whether the students in the class developed a conceptual understanding of the unit concepts and also to determine if Padma and Casey were typical and representative of the students in the class.

Interview Analysis

I only had interview data on Padma. Transcripts were made of the three interviews which focused on her understanding of the science content, her perceptions of the role of talk in her learning, and her perceptions of her role in the learning community. Transcripts were coded according to these three categories. I was then able to compare Padma's verbal explanations of the science concepts in the unit with her written responses on the post-assessment, which were about the same concepts. This triangulation of the data helped ensure that problems with the writing process weren't hindering her from expressing her understanding of the science concepts. I compared Padma's descriptions of the role of talk in her learning and her description of her role in the learning community with transcript segments showing her verbal participation in the whole class and teacher-led small group discussion. I was particularly interested in the times when her perceptions and her participation did not seem to agree.

Chapter Summary

This chapter began with a statement of the four research questions which guided this study and a rationale for the use of qualitative research. I included a description of the participants in the setting, the data collected, and the methods of data analysis. In the next three chapters I will closely examine the classroom context, describe one whole class discussion, and tell the stories of two students perceptions of, and participation in, the learning community and the ways in which these perceptions and ways of participating helped and/or hindered their science learning.

Chapter 4

BECOMING FAMILIAR WITH ONE SOCIAL CONTEXT IN WHICH STUDENTS CONSTRUCT SCIENCE KNOWLEDGE

Introduction and Overview of the Chapter

Atlantis Elementary School was not a typical elementary school, and the science unit studied for this dissertation was not conducted as a traditional elementary science unit. This chapter will introduce you to the school, the classroom, the participants in the learning community, and the science unit itself.

Students Construct Scientific Understanding in a Social Context

Although a visitor's first impression of Atlantis[1] Elementary is one of extreme diversity with many races and cultures represented, Atlantis is not a typical heterogeneous elementary school. In order to understand the interactions that take place in this classroom, the unusual social context needs to be described and attended to because some traditional notions of race and privilege are turned on end in this setting. In addition some traditional norms for what it means to do school science are challenged in this unusual setting.

First I begin with a general description of the school, the surrounding environment, its student population, and its involvement with Midwestern University as a Professional Development School. This is followed by a description of the classroom, the teachers, and the students who participated in this study, and concludes with a description of the "Changes in Matter" science and literacy unit that was studied late February to early April for this dissertation.

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[1]Names of the school, the teachers, and the students are pseudonyms

Welcome to Atlantis Elementary School

Atlantis Elementary is located in the center of a large apartment complex on the western edge of the campus of a large midwestern university with a student population of approximately 55, 000. It is a single story, sprawling, U-shaped red brick structure which has recently been renovated to add a new wing to the school to house the lower elementary classrooms (K-2). There is a playground in the center of the "U" behind the school and all classrooms on the inside of the building open directly onto this playground via a coat room which is between every two classrooms. The classrooms on the outer perimeter of the building have this same coat room which opens to the outside, but they have to go around the building to the playground. The classroom studied is on the inside of the building and the playground is visible from the classroom windows.

Less than 300 students attend Atlantis, which is a true neighborhood school. All of its students live in the campus apartments and walk to school. No students are bussed in from nearby suburbs. The surrounding apartment complex has the traditional "married housing" look of any midwestern university campus, although perhaps on a slightly larger scale. There is a maze of red-brick, two story buildings with each apartment opening directly to the outside. There is evidence of children everywhere. Sitting in front of many of the apartments are Little Tykes® slides and climbing toys. There is playground equipment for every cluster of buildings. On nice spring days there are often mothers and a few fathers out pushing small children in strollers or playing with pre-schoolers on the playground equipment. Although the students at Atlantis all live in these identical-looking apartments, in reality their "homes" are strikingly diverse. The parents of these students are all students themselves (or the spouses of students) at Midwestern University, and they come from all over the world - from Chicago, to Russia, to the Middle East, to study at Midwestern University.

Some of the parents are non-traditional American undergraduate students. Often these are single-parent homes where the parent is both attending college full time and also

working either full or part time. The children of these parents, however, appear to be in the minority.

Many of the parents of students at Atlantis are foreign graduate students at the university. The majority of these parents come are from countries other than the United States, speak at least one language other than English as their first language, and will return to their homeland in 3-6 years. The home life of these Atlantis students is very different than that of their American peers. The customs of their homeland are still celebrated in the home and, in some cases, one parent is a full-time parent while the other is a full-time student. This was evident, for example, when a student brought in a quilt that her mother had recently completed. Mika shared the quilt with the class and told the story of quiltmaking in Indonesia .

Most of these foreign, graduate student parents, unlike the parents who are American non-traditional undergraduates, are attending Midwestern University on some form of fellowship or scholarship and do not hold jobs other than their graduate assistantships. Often these parents are under tremendous pressure (imposed either by themselves or by a number of external factors) to finish their schooling in a timely manner so that they might return to their own countries.

The children of these foreign graduate students have often had many experiences unknown to their American counterparts. Not only have they typically travelled extensively in their homelands, but they have often travelled throughout the United States with their parents on school vacations and en route to the university. In contrast, many of the American students I spoke with had never been out of the Midwest, or even their home state.

Because of the large number of students at Atlantis who do not speak English as their first language, there is a large English as a Second Language (ESL) program at the school. Of the 42 students in the two classes I observed, five were ESL students. Although all five of these students were new to the country the previous fall (6 months earlier) they were very much a part of life in this classroom, participating in all class activities and playing with the other children at recess time. The other children in the class appeared very protective of their peers who were still struggling with the language, perhaps remembering their own struggles, and it was not unusual to see a student helping one of the ESL students understand what was taking place in the class or what was expected of them on an assignment.

Atlantis Elementary thrives on its diversity and the celebration of this diversity is evident from the moment you enter the school. There are bulletin boards in the hallways featuring world globes and announcing that Atlantis celebrates the diversity of its students. Immediately inside the front door is a wall on which the names of students who have read a certain number of books are written on stars. The majority of these names are not Anglo-sounding, but rather are a collection of ethnically diverse names such as Padma, Mohammed, and Chen. Student art work in the style of different countries hangs everywhere- from the ceiling, taped to the walls, and on bulletin boards. In the third grade classroom, where this study took place, there was a large poster listing the countries represented in that classroom and a tally of how many students were from each country:

Brazil	2	Korea	3
China	1	Nigeria	1
India	1	Taiwan	2
Indonesia	3	Thailand	1
Jordan	1	USA	5
Iran	1		

As will be illustrated in a later case, students who might be underserved in a more traditional school setting seemed to thrive in the culture of Atlantis Elementary. For example, one of the target students in this study had come from India with her parents at the age of six and had attended another elementary school in the district for first and second grades. In this first elementary school, which is located in an upper middle class, predominantly white neighborhood, Padma had many socialization problems which in turn affected her learning. Her parents chose to move to the University Apartments just so their daughter could attend school at Atlantis, where she thrived socially and academically. She had many friends, was very conscientious about her school work, and was generally considered "smart" by both teachers and the other students in the class. Padma was also recommended by her teacher to be a target student for this study because she was very verbal and articulate about her thinking and learning.

The School as a Community of Educators

Atlantis is also unusual because of the professional commitments of its teachers. Atlantis teachers participate actively in partnership with Midwestern University in a Professional Development School. The concept of the Professional Development school was developed in response to reform efforts initiated by the Holmes Group (1986). Although other schools around the country have also initiated this type of reform, each Professional Development School is realized in different ways and with differing philosophies. For this reason I will describe the Professional Development School concept only as it is enacted at Atlantis.

The philosophy of the Atlantis Professional Development School is that school-university collaboration in planning, teaching, and research benefits both K-12 students and university students who are learning to teach while simultaneously generating new knowledge for the larger community. In Atlantis many teachers have their work schedules redesigned so that they have blocks of time for collaborative work with colleagues from the school or university. These collaborative efforts focus on such projects as planning for instruction, participation in study/reading groups, study of their teaching, attempting alternative forms of instruction often with support from university faculty, teaching undergraduate courses at the university, learning to support prospective teachers, and so on.

To support this collegial work Atlantis had a restructured work week with school hours Monday through Thursday lasting a little bit longer so that students could be released at noon on Fridays. This arrangement allowed for the teachers to meet every Friday afternoon across the school year for a variety of professional development activities.

<u>The Third Grade Classroom</u>

The third grade classroom was an unusual setting, created by two teachers who decided to work together as they engaged in their professional development activities. The class was actually a double class which functioned as a single learning community with two teachers. In many ways the room was a typical classroom - there were desks in groups, a teacher's desk off to one side, many chalkboards and bulletin boards, an overhead projector, a computer, and a coat room.

Physically the only thing that might have looked different about this room to the casual observer was that it was BIG. It was not one but actually two regular sized classrooms in which the wall between them had been knocked out and replaced by an accordion folding divider - although I only saw this divider closed once in the afternoon during the 6 weeks I observed this class! There were two teachers' desks - one at each end of the room. There were 42 students in the classroom. Two thirds of the students in the third grade at this school were found in this one double classroom.

There were always at least two teachers, Ms. Lawson and Mrs. Runner, collaboratively planning and teaching these 42 students during the day. Although half the students were officially assigned to Ms. Lawson and half to Mrs. Runner, the students appeared to view both Ms. Lawson and Mrs. Runner as their teacher and responded to both teachers in very similar ways. For example, I never had the sense that they respected one teacher more than the other or would only participate if "their" teacher were leading the discussion. Although their desks were located in their "homeroom", the students often were worked in groups that cut across the two classrooms, and they frequently sat in desks other than their "own". As a result, it was difficult to distinguish Ms. Lawson's students from Mrs. Runner's students; the classroom truly functioned as a single learning community with two teachers.

Ms. Lawson and Mrs. Runner had one hour of release time daily for planning and research activities and had been collaboratively planning and teaching all subjects except mathematics since the fall. In addition, the entire staff, or smaller grade groups, could use their restructured Friday time to meet weekly across the year to work on their building-wide focus for the year. This focus was the integration of science and literacy. This Friday afternoon time also gave the teachers an opportunity to engage in cross-grade planning for a "changes in matter" unit which was to be taught as a school-wide unit in the spring. This unit would be taught in some form in each grade at the same time and was to culminate in a school science conference to be attended by all the students.

The Third Grade Teachers and Their Philosophy of Science and/or Literacy

Mrs. Runner: Listening and Responding to Students' Ideas

Mrs. Runner, who was the lead science teacher in this classroom, was an experienced teacher who had taught for more than twenty years. She has always taught and enjoyed science. In describing her science curriculum and philosophy of science education, she said that her goal for science is that, along with learning content, the students would become more observant and curious about the world around them. She believed that until they were curious about the world, science would not be meaningful to them because the purpose of science is to answer questions and explain things in the world. This belief seemed to be based more upon her years of experience teaching science rather than on any specific research or reform movement, although it is consistent with current thinking about the purpose and goals of science as described in the literature review chapter and may have been reinforced through her PDS studies. She felt frustrated that her students were not very curious about anything when they began third grade. She said that she could have all kinds of interesting science materials set out around the room and her students would rarely examine them or ask questions about what they were or why they were there.

Closely connected to these goals for science teaching, Mrs. Runner said that beginning in the fall she works with the students to develop three norms for participation in science. These norms are that 1) they will become more curious about the world around

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them, 2) they will develop science observational skills which in turn will allow them to become curious about the world around them and pursue their curiosity, and 3) they will be able to work productively in small groups, because this is the way in which science proceeds in the "real world".

She said that she wants her students to notice and question everything they see in the world and be able to share these observations and questions with their peers. She believed that curiosity is the foundation of science. If students do not notice the world around them and are not curious about it, they have no use for science. Science is only useful if it is purposeful, and it is only purposeful if it is trying to describe and explain phenomena in the natural world. In addition, science is a social enterprise. Science proceeds by sharing observations and questions about the world with other people.

This goal of helping students become observant and curious, and able to communicate these observations and questions to peers, undergirded all of Mrs. Runner's science content teaching during the school year. It was also reflected in much of her discourse with the students during science.

Atlantis has had a long relationship of research with the university, and Mrs. Runner has been involved in some of these research projects. For example, a Midwestern University professor taught mathematics and studied her practice in Mrs. Runner's room for several years. This professor used a constructivist approach to teaching and learning, emphasized mathematical reasoning, and used classroom discourse as a tool for constructing understanding of mathematical concepts. Her influence is seen in Mrs. Runner's discourse in science. Not a didactic lecturer, Mrs. Runner spent a large portion of her instructional time listening and responding to students' ideas, not only when assessing their prior knowledge at the start of the unit, but also as she taught the unit. Many of the activities and experiments done during the Changes in Matter unit observed for this study were designed to challenge a naive conception or reinforce a scientific conception that had emerged during class discussion the previous day. In this way the students' thinking shaped the science curriculum in her classroom.

Mrs. Runner stressed the value of everyone participating and sharing their thinking during class discussion and all ideas were treated as valuable. This is not to imply, however, that all ideas were accepted as being equally scientifically valid, a problem often associated with inquiry science programs (Roth, 1987). Both Mrs. Runner and Ms. Lawson were very skillful at challenging naive conceptions and drawing out and extending the scientific conception. Although it may have appeared to a casual observer, or even the students themselves, that all ideas were used equally, Mrs. Runner and Ms. Lawson were actually teasing out those ideas which would provide the most productive discussions in terms of leading towards scientific conceptions. Sometimes they deliberately pursued a naive conception if, based on the writing and the talk the students had done, they felt there were many students who were holding a naive conception - this often led to an activity which was designed to challenge the naive conception. However, it should be emphasized that this deliberate eliciting and challenging of a naive conception was not the same as having students share their ideas and accepting all as equally valid in an unchallenging manner.

Building on Students' Thinking and Ideas: A Vignette

An example of the way that Mrs. Runner and Ms. Lawson elicited and pursued the students' ideas was seen very early in the unit. The first activity that the students did in the unit was to work in small groups to observe an ice cube melting, describe it as it melted, and draw some conclusions about why it melted. This was followed by a discussion of their results and ideas on March 3. The teachers' plans for the day included the following,

1. **Review and discuss the ice cube on the tray experiment from last Thursday (2-25-93)**

   Have students share their explanations and conclusions that they recorded on their yellow sheets.

   May be something like: "We believe the ice cube on the tray melted because the warm air came into contact with the ice.

2. Introduce the ice cube in hand experiment.

"Another idea that you had for melting an ice cube was to put it in your hand/body. Why do you think that would melt the ice cube? We're going to try this today. Make a prediction about what you think will happen when you hold an ice cube in your hand. Make a prediction in your science notebook.

The following transcript segments illustrate the way in which the ideas found in the teachers' plans above emerged in the discussion and the way in which the teachers were able to move students gradually to talking about the idea that warm air has something to do with an ice cube melting. The teachers also did not have to introduce the ice cube in the hand experiment but rather were able to elicit the idea from the students and build upon it. By the end of an apparent open discussion and sharing of ideas the teachers had made a great deal of progress and accomplished their objectives for the day by building on the ideas that the students themselves introduced rather than by introducing information directly themselves.

Ms. L. So you were saying that you thought that since your ice cube was bigger it took longer?

P: Yeah

Ms. L. Comments about that or other things people want to share?

Zane: Probably, like, if they were by the window and like, the window was here and they were right here and then the ice was right here. If they were by the window it would get smaller.

(This lead to a brief discussion about where different people were sitting relative to the window. Following this Ms. Smith asked a question)

Ms. S. I have a question. What would sitting by the window have to do with anything? How would that affect it? How would that make a difference?

A: The outside is colder.

Ms S. So what would that do. Why would it change things?

A: If it's by the window.. on the outside it is cold...It makes it, if it is in.. it is going to be hot or warm..but if it's not it's kind of cold..but it still melts but not as fast.

Ms. L: Ajani just said something that I noticed on a lot of peoples' sheets and that was an idea about warm air. An idea about the warm air melting the ice cube. And I am wondering if anybody has comments about that idea? A lot of people talked about it being warm or hot in the room and that is what made the ice melt. Anyone have a comment? Li?

Li: Well I sort of agree with Ajani and sort of disagree with Zane. I agree that if the air is cold it will melt slower but I think that light also helps it melt.

Ms. S: And how would that melt it faster?

Li: I'm not sure but most light.. I mean most light sort of..heat..and.. I'm not sure.

(The discussion about heat and light continued for another minute)

Ms L: So do you think we can kind of say right now that we have two ideas about the ice cube melting...one is the warm air and the other is light....Are there other ideas or comments that people want to make...You could look through your yellow sheets to help you remember what people said.

The discussion then continued as Ajani brought in the idea of warm and cold air. The idea of air was then explicitly included by the teachers as they used the idea of warm and cold. This was followed by an extended discussion by the students about how the warm air melts the ice cube. Ms. Lawson concluded this portion of the discussion by summarizing the ideas that they had discussed so far;

Ms. L: Okay.. if we think about that theory or that idea a little bit more and we think about the hot air that is coming around the ice cube..what is happening to the hot air and what is happening to the ice cube... What do you think...Anyone have any ideas about that..what is happening...Cause a lot of people mentioned ideas like this in your groups...They talked about warm air..they talked about light..they talked about the heat..they talked about heat in general..Henrique what do you think about it?

H: Well..I agree with Casey..but another thing I think why my ice cube melted was because I poked it around for awhile just to see if it would melt faster that way..I touched it.. and then probably the temperature of my body..it melted a lot faster..it melted really fast.

Ms. L: Now that is an idea that we are going to come back to a little bit.

The discussion then shifted to writing a class statement answering the question "We believe the ice cube ____________ because _________________." As students made suggestions the teachers began to push them on the idea of evidence to support their assertions. After several had shared their ideas Ms. Lawson summarized what they had said.

Ms. L: Okay..so that would be a kind of conclusion... we believe the ice cube on the table melted because the heater..air in the room...what did you say..came all around?

Mike: Spread around the whole team area.

Ms. L: Spread around the team area..the team room.

Ms. S: So that would be your evidence for why it happened?

Ms L: So when you write a conclusion you need to have some evidence. A little bit more than just saying "we believe the ice cube on the table melted because ..it was hot" we need to know a little bit more than that... We need to know why...okay here's what we are going to do right now.

(Ms. Lawson introduces the ice cube in the hand activity.)

This early discussion was an important one. Many ideas were introduced by the students which formed the foundation of future discussions. In class discussion over the next several days many of the ideas introduced by the students were revisited to. For example, the teachers continue to return to and build on the idea introduced by Li that the warm or cold air is what causes the ice cube to melt faster. They also revisit Henrique's idea that the ice cube will melt faster if someone is touching it and as evidence for this they had the students measure and discuss their hand temperature -- that hand temperature is warmer than the temperature of the air around them, and so would speed the melting time.

Ms. Lawson: Using Lteracy as a Tool for Learning Science

Ms. Lawson was the lead language arts teacher in this classroom. She was a new teacher, having taught less than five years, and was a graduate of a smaller, thematic, teacher education program at the university in which a small cohort of approximately 30 students worked closely with program faculty. The faculty who taught in this program program were primarily literacy faculty, and, as a result, there was a strong emphasis in this program on literacy and the teaching of language arts. The director of this program developed and taught a science unit as a requirement for her student teaching. Although this unit was on animals in the ocean, when it was enacted it had many similarities to the Changes in Matter Unit. Like the Changes in Matter unit, Ms. Smith emphasized science as discourse. The unit was taught primarily through class discussion in which the students were encouraged to listen to the ideas of their peers and agree or disagree. Also like the Changes in Matter unit there was an emphasis in Ms. Smith's unit on eliciting students naive conceptions and then designing instruction to challenge these naive conceptions.

One of the university faculty on the team, Dr. Nettings, had expertise in language arts and communications and, in addition to participating in the teaching during science time during the month of March, she had provided planning support for the teachers on a limited basis in the fall, and on a more regular basis beginning in January. The other university faculty, Dr. Jones, was a science educator who participated in the initial Friday planning but did not participate in the actual teaching during March because he had primary responsibility for another grade level as well as for coordinating the science teaching building wide. Dr. Jones also played a large role in the planning and organization of the culminating science conference held at the end of the school wide Changes in Matter unit.

Overview of the Changes in Matter Science and Literacy Curriculum

During the summer of 1992 the members of Atlantis Elementary met to determine a curricular focus for their PDS study and planning for the coming school year. The result of this summer planning was the decision to have a building-wide focus on science and literacy with a common topic, changes in matter, to culminate in a school-wide science conference in the spring. Once this decision was made, individual grade groups, and individual teachers within those groups, decided what an emphasis on science and literacy meant to them, how it would look in their classroom, and what sort of planning time and teaching or planning support they would need. It was during this summer planning time that Ms. Lawson and Mrs. Runner decided to collaboratively teach science and language arts (which evolved into collaboratively teaching all subjects except mathematics).

"Changes in Matter" Science Unit

Ms. Lawson and Mrs. Runner were active participants in the school-wide science planning meetings across the year. The focus of these meetings was on developing a science unit broadly on the topic of "changes in matter" in which there was an emphasis on the role of oral and written discourse in learning the science content. This was consistent with the year-long school theme of "Science and Literacy" in which literacy (primarily oral language) was used as a tool for making sense of science content.

Some version of this unit was to be taught concurrently by all the teachers in the school from late February-early April. At the primary grades (K-2) this involved describing the physical differences between ice and water. At the upper grades (4-5) the unit included some activities adapted from Matter and Molecules (Berkheimer et.al., 1990) leading up to the kinetic molecular theory. At this grade level students learned to explain the changes in the states of matter in terms of the motion and arrangement of the molecules.

The third grade was at a midpoint- although they did not discuss states of matter at the molecular level (i.e. the kinetic molecular theory) they went beyond a description of the states to some prediction and explanation of change of state at the observable level. For example, one of the main ideas in the unit was that when two substances of different temperatures come into contact with one another the temperature of both substances may be affected. Related to this was a second main idea that when the temperature of some substances (such as water) changes enough, the form (or state) of the substance also changes. Students were given many opportunities to practice using this new knowledge. One activity they did was to predict what would happen to the temperature of a bowl of soup and an ice cube when the ice cube was added to the soup. They then had to explain their prediction, test the prediction, and explain their results. Because this activity involved an ice cube melting, the idea of change of state was also part of part of this activity although the language "change of state" was never introduced. Other similar activities involved predicting and explaining what would happen to snow when it was at room temperature, predicting and explaining what would happen to hot chocolate if it were left at room temperature, and designing an experiment that would show that two substances of different temperatures change temperature when they come into contact with one another.

According to their intended curriculum developed during the fall and early winter, Ms. Lawson and Mrs. Runner also planned to emphasize the nature of scientific inquiry in their unit through the type of discourse in which they engaged the students. Consistent with Mrs. Runner's philosophy, she explained to me that this discourse would emphasize making observations and being curious and asking questions about those observations. This discourse is similar to the form of the discourse in a scientific community. Also in the scientific community science knowledge is constructed through making observations, being curious, and talking about ideas.

The ongoing emphasis in the class was on providing evidence to support assertions. This was evident in every class discussion during which time the teachers repeatedly asked the students, "And what is your evidence for that?" whenever an assertion was made. Through the activities they had the students do, the teachers provided opportunities for the students to collect evidence which either supported their assertions or caused them to discard or modify certain ideas and assertions. In this way the teachers skillfully led the students to the scientific conception.

Therefore, the third grade unit was planned to have three overlapping components: 1) a science content knowledge component in which the students would learn a specific set of science ideas an concepts, 2) a literacy component with an emphasis on listening to and questioning one another, and 3) a nature of scientific inquiry component in which the students were encouraged to observe and raise questions about everyday phenomena and share these questions and their thinking with their peers. These three components are described below.

Science Content Knowledge Component

The third grade unit was originally designed to include both properties of matter and changes of state of matter. The third grade team developed a concept map that showed the relationships among the various related concepts they wanted to include in their unit (see Figure 4.2). This concept map, which appears to be primarily a brainstorming exercise, was used to organize the early planning of the unit. This map might be called more appropriately a "topic map" because it is very broad and seems to cover many of the major topics related to matter and its changes. At this early stage of the planning, specific concepts were not delineated in the map. For example the concepts of freezing, melting, dissolving, evaporation, and condensation are terminal points on the map. The following large topics were represented on this concept map;

1) Observation and description of the three states of matter.
2) Properties of matter including shape, size, volume, and weight.
3) Change of state of matter including freezing, melting, dissolving, evaporation, and condensation.
4) Temperature, temperature change, and temperature measurement

As the unit was enacted, the focus quickly shifted from teaching all four of these topics to expanding on and teaching only topic number four; temperature, temperature change, and temperature measurement. From early class discussions and writing coupled with pre-test data the 3rd grade team discovered that students had many naive conceptions about the concept of temperature, temperature measurement , and the causes and effect of changing temperature. Students also exhibited confusion regarding the two temperature scales, Fahrenheit and Celsius, and used the two interchangeably. The teachers believed that an understanding of these concepts was necessary before students could understand the concepts of states of matter and changes of state.

For example, on a pre-test one question ased students what they thought the temperature of a glass of water from the drinking fountain was and why they thought it would be this temperature. This is a deceptively simple question, requiring some sophisticated thinking on the part of the students. The student holding a scientific conception would have answered the question by giving a temperature slightly above 32° F or 0° C because that was a cold temperature and drinking fountain water was cold. They would have gone on to explain that the temperature they gave was slightly above the freezing point of water, which was important because if it was at or below the freezing point the water in the drinking fountain would be frozen. The response that the students gave to this question would indicate how meaningful the temperature numbers were to them and also whether they had a sense of the concept of change of state of water at specific temperatures and knew what those temperatures were.

The following responses to that question were given by the two target students and were typical of those given by all the students, "34 degrees because some water fountains are colder than others", "15 because 15 is pretty cold", and "I don't look at temperature much so I can't do this, sorry" . In these examples none of the students who gave actual temperatures used either Fahrenheit or Celsius units so the numbers do not have a lot of meaning to anyone reading their pre-test. However, if these are assumed to be Fahrenheit temperatures, they are both at or below freezing which would make the water in the drinking fountain ice rather than water. If the temperatures are assumed to be Celsius temperatures, 15° would be a borderline reasonable temperature (it is closer to room temperature), however 34° would be much too warm for drinking fountain water.

The students' explanations also gave the teachers some important information. Saying that 34° is a reasonable temperature because some water fountains are colder than others does not appear to address the question of why 34 was selected as the temperature, although it is apparent that the student did have a reason in mind. The other student selected 15 because 15 is "pretty cold". This is a step in the direction of an appropriate explanation. They know that the lower the number the colder the temperature but they do not mention the other piece; that it would need to be above 0° C (assuming they were thinking of the Celsius scale) in order to keep from freezing.

Similar responses were given to other pre-test questions which asked the students to predict the temperature of a snowbank on a sunny day, the temperature of the air in the room, and the temperature of their hand. From this pre-test data it appeared that the students' understanding of change of state and the temperature at which this occurs was fairly general and descriptive -- e.g., ice freezes at a cold temperature and water boils at a hot temperature. It was clear that when considering temperature questions, students did not typically take changes of state into account.

Ms. Lawson, Mrs. Runner, and Dr. Jones decided that if students were to understand change of state at anything more than a descriptive level (i.e. when it gets hot ice melts, when it gets cold water freezes) they would need to know what happened to the temperature of a substance (such as ice) when it came into contact with another substance (such as air) which was either hotter or colder than itself and be able to explain this change at a macromolecular level. In other words, the teachers felt that in order to demonstrate an understanding of the concepts of temperature and temperature change the students needed to be able to explain the phenomenon of temperature change of a familiar substance, such as pop when ice is added, and the sometimes resulting physical change of state (i.e. ice melting). To do this they felt the students needed to explore questions about familiar, everyday phenomena such as, "What causes the temperature of an ice cube to change? Why does ice seemingly spontaneously warm up when left at room temperature? Why doesn't ice stay frozen and the temperature of the room decrease instead? How can ice be melted faster? Why does this melt the ice faster?"

From analyzing the pre-test data and early class discussions, the team also discovered that the students had a lot of naive conceptions about the meaning of the temperature numbers themselves. For example, students knew that zero was probably cold and that 100 was probably hot on any scale. However they were not able to use this knowledge to make sense of real world phenomena. For example, on the pre-test, some students did give the information that 0°C (or 32°F) was the freezing point of water and

100°C (or 212°F) was the boiling point of water. However, when asked to make a prediction about the temperature of water that was very cold but not frozen, they were not able to use the information about freezing and boiling points to predict a possible temperature of the water - which would indicate that the numbers themselves had some meaning to the students. In other words, the knowledge of the freezing and boiling temperatures was in all likelihood information that they had memorized at some point, or had heard in an out-of-school context such as listening to a weather report, but it was not knowledge that was useful to them in making sense of the world. In this sense temperature readings appeared to be disconnected numbers that for them had limited meaning.

Finally, students were confused about how to read a thermometer and so this also became part of the unit. Possibly because many of them went to school initially in a country where Celsius rather than Fahrenheit was the unit of temperature measurement , there was also confusion between Fahrenheit and Celsius scales. Keeping in mind that many of the students would be returning to their native countries, the unit was consistently taught examining both Fahrenheit and Celsius temperatures and noting the difference between temperature reported in Fahrenheit and temperature reported in Celsius.

Therefore, following some preliminary activities and discussions in the unit, the teachers decided to focus on the topic of temperature and temperature change for their Changes in Matter unit. They felt that their students did not have the prior knowledge necessary for understanding the concept change of state of matter. Their first goal conception for the evolving unit was that the temperature readings have some meaning and that students could estimate the temperature of unknown substances based upon certain "benchmark" temperatures. Their second goal conception was that the students be able to use the knowledge that when two substances of different temperatures come into contact with one another, one or both of the substances will change temperature, to make predications and generate explanations of various everyday phenomenon.

Usually Mrs. Runner and Ms. Lawson collaboratively developed the science plans either after school immediately following the science and literacy teaching time or during their morning planning times on the day of the lesson. In either case they based their instructional decisions upon what had occurred during the previous lesson's discussion. For example, during the discussion on March 4, Mrs. Runner and Ms. Lawson discovered that they had made too many assumptions - although students knew what temperature was in a general sense, and knew that room temperature and body temperature were probably different, they did not have background knowledge to predict what these temperatures might be or to use these temperatures in any way. Therefore, in order to make sense of the activity they had done on March 3, two additional days were spent discussing and measuring room temperature and body temperature.

These concepts, developed on March 8 and March 10, were then used in the March 15 lesson where teachers and students developed what were to become "benchmark" temperatures based on the temperature of familiar substances. These benchmarks were used through the remainder of the unit as a basis for predicting the temperature of other substances so that the predictions were informed by scientific knowledge and reasoning rather than just being guesses. The benchmark temperatures also provided evidence that could be used to support assertions about the temperature of unknown substances.

An examination of the teachers' plans for the unit shows the shift in focus that took place across the unit as the teachers listened, and responded to, the students. The question raised on February 25, "Why does an ice cube melt?" became the central organizing question for the unit although it was not clear whether this was originally the intention or whether this simply became a productive organizing question as the unit unfolded and was shaped by the interactions among all the participants. March 3 began the shift in focus from change of state to temperature and how it affects the melting of an ice cube, although at this point the teachers anticipated that this was going to be a short detour. By March 10 the emphasis has completely shifted away from change of state and focused on temperature measurement and developing benchmark temperatures to use to predict the temperature of a substance. By March 18 the students were using these benchmark temperatures to make predictions. This continued through the "doctor for a day" planning, which is the way in which Mrs. Runner decided they would present their learning about temperature at the science conference.

Listed below is an outline of the intended curriculum taken from Ms. Lawson's and Mrs. Runner's daily plans over the course of the unit.

2/25 What does it mean to melt? Why does an ice cube melt?

3/3 Ice cubes melt because warm air comes into contact with ice. An ice cube will melt faster if it is held due to contact with body temperature.

3/4 The ice cube on the table melted because of contact with warm air.
The ice cube in the hand melted because of contact with a warm hand.
Body temperature is around 98.6F, room temperature is around 70 F.
Therefore, ice in hand melts faster than ice on table.

3/8 Temperature is the amount of hot or cold an object has. Body temperature is 98.6 F and room temperature is 70 F.

3/10 Room temperature is going to vary but it is around 70 F.

3/15 The temperature of snow is around freezing, the temperature of oatmeal is around room temperature, the temperature of hot soup is around body temp. (These will serve as "benchmark" temperatures for making predictions.
Procedure for reading a thermometer.

3/16 Same as 3/15

3/18 Can use benchmark temperatures to predict the temperature of other, similar things.
Procedure for reading F and C temperature on a thermometer.

3/25 Science conference planning - Doctor for a day. What is hand and body temperature? Are they the same or different? Why?

3/29 Science conference planning - Doctor for a day.
Review of what they have learned about taking temperatures, benchmark temperatures, and predicting temperature using benchmark temperatures.

3/30 Science conference planning - Doctor for a day. Measuring hand and body temperature. Reporting temperature in degrees Fahrenheit and Celsius.

4/2 Science conference.

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Although the teachers in this classroom were trying to establish new norms for school science, it was a difficult task given the existing structure and limitations of the school day. First, helping students construct their understanding of science through oral and written discourse takes considerable more time than the more traditional lecture method. This means that more than the traditional 20-45 minutes per day needs to be allocated to science. This short period is simply not enough time to explore a science question or issue in talk or writing in any substantive sort of way. The discussion has barely begun when it is time to end. Additionally, if any experiment or hands-on activity is done it takes the entire class period and any discussion or writing must take place on another day. This segmentation tends to emphasize rather than bridge the gap between "doing" science (process) and talking and writing about science in order to "understand" science (content). This content/process dichotomy is something the teachers were expressly trying to avoid.

The teachers also believed that if their students were to understand the unit concepts, considerably less content could be covered on any given day than is typical because it is being covered in much more depth than is typically done. For example, an entire week (March 3-March 10) was spent experimenting and discussing the difference between room and body temperature and how this difference might affect the ice cube melting. This same topic, in a traditional lecture-based classroom, might be covered in 5 minutes by the teacher giving the students the information that room temperature is about 70°F and body temperature is about 98°F. Therefore, ice held in a person's hand will melt faster than ice sitting out in the room on a tray. The problem with this information-giving approach is that, as was illustrated by students' responses on the pre-test, the temperature numbers have little meaning and are not useful to the students when they are simply presented to, and memorized by, the students in this manner. By contrast, the teachers in the Atlantis third grade classroom believed in taking the time necessary to make sure the stud

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students understood the concepts well. They also believed that this understanding took repeated opportunities to "play around" with the ideas orally and in writing.

Because of this need to spend more time on science, and to cover the content at a much slower pace than is traditional, it seemed as if a balancing act was always going on in this classroom. Originally the team intended for science and literacy to last 1-3 hours at least four afternoons a week. However, in order to teach science in larger blocks of time like this, something else was going to receive less time. On some days the teachers felt they could not justify so much time spent on science and literacy as they were falling behind on other things. For example, on at least two occasions science time was partially or totally replaced by mathematics because too much time had been consistently "borrowed" from mathematics time. Other times science provided an authentic context for mathematics instruction and so some of the science and literacy time was also spent on mathematics. An example of this was a discussion of the temperature data the students had collected. The data was compiled into a class list, and the children used this data to work with the statistical concepts of mean and mode, discussing which was the more mathematically accurate way to treat the data. Thus, science was taught in larger blocks of time but it was not taught every day.

In addition to students learning specific science content, there was another ongoing goal the teachers were working on which is not readily apparent from the their written plans. Both Ms. Lawson and Mrs. Runner were committed to helping the students become curious about a phenomenon- temperature change- that they had encountered every day of their lives and had unquestioningly taken for granted. Just as the anthropologist studying his or her own culture has to first "make the familiar strange" in order to notice patterns (Bogdan and Biklen, 1982), so too an everyday phenomenon has to be made problematic for the students in order for them to become curious about the underlying scientific explanation. Unfortunately, as Mrs. Runner discovered during her years of teaching, schools do not actively seek to elicit children's curiosity. As a result, curiosity -

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which is the cornerstone of science- is typically not a norm for elementary school science. To begin to change this "lack of curiosity" norm, teachers needed arouse the students' curiousity about why an ice cube melted and what there was about holding an ice cube in your hand that made it melt faster.

During the first half of the unit all 42 students participated in class discussions together. Then there was a shift in pedagogical strategy approximately half-way through the unit. On March 15-March 30 students did not meet as a whole group during science. Rather they broke into four smaller groups. Each of these groups was led by a teacher; Ms. Lawson, Mrs. Runner, Dr. Nettings, or Ms. Smith. Initially the intended curriculum for each of these four groups was the same. However, once they started planning for the science conference on March 25, each group did something different because each group was responsible for a different conference presentation. I followed the group headed by Mrs. Runner because my target students were placed in this group.

Although the reason given for breaking into the four smaller groups was that it would facilitate planning for the science conference, I believe that it was also done for purposes of classroom management. It is difficult to have a discussion with 42 students; it takes a long time and many voices are not heard. Breaking into smaller groups facilitated the participation of more students in the discussion, while at the same time did not take as much time as a discussion with 42 participants.

Literacy Component

An important aspect of the science and literacy unit was that teachers were attempting to change the classroom norms for participation in the science learning community. Adding a literacy component to the science content knowledge piece was one way in which these new norms were explicitly taught to the students.

As part of the literacy component, students were taught to listen to their peers' ideas and to build on, question, or challenge these ideas. The teacher was not viewed as the only source of knowledge. Rather, the students were taught that there is a great deal of know

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knowledge residing within their discourse community if they were able to listen to and build upon, or debate, each others' ideas. The goal of the literacy curriculum was to teach them how to do this.

Reflecting these literacy goals, the class discussions during the "Changes in Matter" unit followed a different pattern than the traditional norm in which the teacher is the center of attention who asks the questions which the students answer while the teacher evaluates the "correctness" of their answer. This teacher-dominated initiation-response-evaluation (I-R-E) format is found in most science discussions (Mehan,1979; Cazden, 1988; Lemke, 1990). One reason the I-R-E format is so popular is that it appears to be time efficient, allowing for a lot of content to be covered in short time period. In contrast, a discussion in which students are supported in making sense of the scientific phenomenon does not appear to be time efficient in the short term. However, in the long term, research on conceptual change teaching and learning (e.g. Driver, Asoko, Leach, Mortimer, Scott, 1994; Roth, 1992) has shown that a pattern in which the students are supported in making sense of scientific phenomena is more efficient because it results in personal knowledge or understanding that students have constructed for themselves, and they have ownership over that knowledge.

The intended literacy curriculum, with an emphasis on listening and consensus building, was adapted by the third grade teaching team from the National Council of Teachers of Mathematics (NCTM) Standards. This document, which emphasizes the importance of student thinking and ideas, outlines both the teacher's and the students' role in the classroom discourse. They may have selected to use this document rather than a document specific to science because the recommendations in this document were more detailed and specific than in any science education documents at that time. The recommendations of the NCTM are, however, consistent with those found in Science For All Americans (AAAS, 1989). For example, in Chapter 12 of Science for All Americans, "Habits of Mind", there is a segment on communication skills. The following are excerpts from this segment:

> Discourse in science, mathematics, and technology calls for the ability to communicate ideas and share information with clarity, and to read and listen with understanding....Everyone should have the skills that will enable him or her to do the following:
>
> •Express orally and in writing the basic ideas covered by the recommendations in the report. This requires, above all, that students acquire some understanding of those ideas, build them into their own conceptual structures, and be able to illustrate them with examples and rational argument.
>
> •Participate in group discussions on scientific topics by being able to restate or summarize what others have said, ask for clarification or elaboration, and make alternative responses.

In addition there is a segment entitled "Critical-Response Skills" which further elaborates on the ways in which students need to be able to apply critical response skills to "their own observations, arguments, and conclusions...and should learn to notice and be put on guard by the following signs of weak arguments:"

- The premises of the argument are not made explicit.
- The conclusions do not follow logically from the evidence given.
- Fact and opinion are intermingled

Although the third grade teachers did not refer specifically to this particular document, many of these same ideas are present and further delineated with respect to teacher and student roles in the NCTM standards --which <u>was</u> used by the teachers to support their science and literacy planning. According to the version of the NCTM standards adapted by the third grade team, the teacher's role in the discourse is to elicit ideas and then listen carefully to student thinking. Once they have done this they need to decide which ideas to pursue during a discussion as some ideas will be more productive than others. The teacher also needs to make decisions about what type of problem will lead the students into constructing a particular mathematical concept, if and when to provide a particular problem, concept or proof, when to clarify an issue, when to model scientific thinking and when to lead in a more didactic fashion. Finally, the teacher must monitor stude

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students' participation in discussions and decide when and how to encourage students to participate and engage with their peers in constructing understanding. It may have been in response to this complex discussion pattern that the teachers decided to break down the group of 42 into four smaller discussion groups, thus allowing for more student participation and easier monitoring individual student participation. The role of the teacher as stated in the NCTM document is as follows:

1. Pose questions and tasks that elicit, engage, and challenge student thinking.
2. Listen carefully to student thinking.
3. Ask students to clarify and justify their ideas orally and in writing.
4. Decide what to pursue in depth from among the ideas that students bring up during a discussion.
5. Decide when and how to attach scientific notation and language to student's ideas.
6. Decide when to provide information, to clarify an issue, when to model and when to lead.

In addition to these NCTM-defined teacher roles, there was another teacher role that appeared in the discourse in the science discussions in this third grade classroom. This teacher role was to provide opportunities which would challenge the students' non-scientific thinking and draw on ideas in the discussion which led toward understanding the scientific conception.

According to the NCTM standards, the student's role during discussion is to participate and help construct successful mathematical (or scientific) discourse through making conjectures (or assertions), providing evidence, and asking questions. They are also encouraged to listen not only to the teacher but also to the ideas of their peers. They are expected to challenge their peers' ideas by asking for clarification or justification. Finally, students have the responsibility for keeping track of the flow of ideas in the discourse. The following list summarizes the student's role during scientific discourse as stated in the NCTM document:

1. Make contributions including: stating conjectures, posing questions, providing information and clarifying, elaborating, and justifying ideas.
2. Encouraging and challenging others by seeking their input or opinion, reminding them that their contributions are valued, and asking for clarification,

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elaboration or justification.
3. Listen carefully and valuing the contributions of everyone.
4. Keep track of the flow of the discourse (how arguments are developing and being supported).

When enacted in the Changes in Matter unit there was an additional responsibility for the students which paralleled the additional one for the teacher. The teachers, both explicitly and through the questions they asked, communicated to the students that they needed to use the evidence collected through experiments and discussion to consider their personal thinking and ideas and to make modification in their ideas to be more consistent with the scientific conception. This is an important addition because it was this responsibility which led students toward an understanding of the science content.

The two specific literacy concepts that were part of the "Changes in Matter" unit were ***listening*** and ***reaching agreement*** (consensus). Literacy in this context was not treated as a subject matter, nor as an isolated process. Rather, the goal of the literacy instruction was to teach students how to use literacy skills such as listening, debating, and writing to support their science learning, much the same way a scientist might rely on literacy in his or her work. In this way science was to provide the authentic context for literacy learning. The teachers planned to emphasize that in the real world listening is an important skill. Scientists must listen to, and read, what other scientists write in order to be able to agree, or disagree, about scientific knowledge. And just as scientists must listen to one another in a scientific discourse community, students in a science learning community must listen to one another so they can decide as a class what description or explanation is the most plausible. A major emphasis in the literacy curriculum was to teach students how to question, challenge, or build upon someone else's ideas and how to use other peoples' ideas and thinking to revise their own ideas.

The way in which the teachers planned to promote this was through questions that asked for students to make assertions and conclusions supported by evidence as called for in the NCTE standards. The following are questions excerpted from the teachers plans:

•What conclusions can be drawn? (have students share ideas)
•How can we be sure of our conclusions? (have students suggest ways)
•What evidence do we have? (summarize experimental and thought evidence)
•What is our group's conclusion? (reaching consensus)
•Do you agree or disagree with the conclusion? With XXX's ideas?
•What part do you agree with? What part do you disagree with?

These questions were asked repeatedly as the teachers helped the students construct whole class versions of their conclusions which were consistent with the scientific conception. Additionally, some of the science classes began with the teachers talking about the discussion that had taken place in the previous lesson. If it had been a particularly fruitful discussion in terms of making progress towards consensus about a scientific idea, the teachers would describe to the students the types of things they had heard the students saying that were particularly helpful to the discussion. For example they would note that students had stated that they agreed or disagreed with an idea (rather than a person) and that they gave evidence to support that assertion. So in addition to modeling the desired discourse pattern by asking the questions described by the NCTM document, the teachers also created opportunities to discuss and reflect upon the discourse strategies that had been used in a particularly fruitful discussion.

Often an entire class period of 1-2 hours would be spent reaching consensus about what conclusions could be drawn from an experiment. As described earlier, the teachers were careful and skillful about drawing on those ideas that led to a final version of the conclusion that was consistent with the scientific conception. Because many of the ideas came from the students, and because they had debated over the ideas and the wording that should be in the conclusion, the final group conclusion was something over which all students who had participated verbally or through listening would hopefully feel ownership.

The two main literacy concepts in the Changes in Matter unit were listening skills and consensus building skills. The two of these are closely related -- it is impossible to reach consensus if people are not listening to one another -- and thus were intertwined throughout the unit. As they were listening to their peers' ideas, the students were encouraged to decide whether they agreed or disagreed with the other person's idea. They would be asked to respond to the idea on the table. It was stressed to the students that they were agreeing or disagreeing with the idea rather than the person.

As with listening, consensus building during class discussion was an integral part of the science discourse rather than a decontextualized instructional topic. For example, early in the unit the teacher asked many questions such as, "Do you agree or disagree with what Avesta just said?" which was a way of modeling or scaffolding students in using the discourse pattern that was to be adopted in science class. In addition, the students were always asked to tell why they agreed or disagreed. It was not sufficient to simply announce that they agreed or disagreed with someone's statement; they needed to provide additional evidence or reasoning for why they were doing so. They were continually challenged by the teacher to provide this evidence. For example, if a student said "I agree", the teacher's response was "Why do you agree?" or "Do you have an additional reason for why you agree?"

In addition to the oral discourse there was some emphasis on written discourse. Students had science notebooks which they had been using for a variety of purposes all year. During the "Changes in Matter" unit they were to write their predictions, data, and conclusions from the activities in their notebook. Additionally, during the second half of the unit they were encouraged to use their science notebook to jot down anything that emerged from the discussion that they found interesting or that they wanted to remember. However, these notebooks did not work as well as had been anticipated as will be discussed in the next chapter. In practice the teacher told the students what to write in their notebooks, and the students dutifully recorded the data they were told to record. Unlike the pattern in the oral discussions, they were not encouraged to puzzle through their ideas in writing.

Nature of Scientific Inquiry Component

This component linked the science content knowledge component and the literacy component. As part of the unit students were to do many science experiments. The science experiments were to be closely connected to the discourse and were intended to both teach both science concepts and scientific processes such as debating ideas and building consensus; this combination represents the essence of the nature of scientific inquiry. Each experiment was designed to test a class hypothesis which had emerged either from the students' writing or from class discussion and/or to provide further data or evidence for an ongoing discussion. For example, the teachers pursued the student-proposed theory that "an ice cube will melt faster if you are holding it than if it is on a tray" by designing an experiment which provided data to support this theory. Another experiment required students to measure and compare hand and body temperature. These two temperatures, hand and body, were then used as "benchmark" or reference temperatures for comparison to other data collected later in the unit.

The activities were also designed so that the purpose of the activity was not just to collect data or answer questions, the purpose was to make sense of the data collected. This allowed the students to make sense of a real-world phenomenon such as why ice melts faster when held then when left in a tray. What made the literacy component so critical was that because of the many naive conceptions held by the students, there were many times when there were multiple ways in which the experimental data could be interpreted. This meant that different groups of students could conceivably arrive at different explanations for their data. There were often multiple interpretations for any data set although one explanation was generally more plausible and scientifically acceptable.

Because of this polysemic nature of the experimental data, the literacy and science reasoning skills were critical. Without these literacy and reasoning skills, each student might have the tendency to believe that their own interpretation of the data was correct unless told otherwise by the teacher. The students needed to listen to the conclusions that different groups reached, compare them to their own conclusions, debate those conclusions they disagreed with, and modify their conclusions if needed. Once consensus about the meaning of the results was achieved, the activities provided evidence that students could agree upon and use in their discussions with one another.

The activities also served the purpose of teaching students that science knowledge is constructed through inquiry which is guided by authentic questions. In science class, authentic questions are ones which emerge from the students' own thinking and questions rather than questions which are posed by teacher and text. Examples of questions which were student-generated and became part of the science curriculum are described in detail in Chapter 5. Authentic questions in science do not call for memorized definitions, a statistic, or a formula. Rather authentic questions in science are questions about a real world phenomenon, such as "why does soup cool when an ice cube is put in it?".

Summary of Tasks in "Changes in Matter" Unit

Table 4.1 shows an outline of the three different types of tasks in which the students engaged during science and literacy time during the first half of the unit. Table 4.2 shows the task outline for the second half of the unit. During the first half of the unit the students were all in one group of 42 for the discussions and all did the same activities in groups of three. During the second half of the unit the shift in focus from changes in matter to temperature was complete, and the students were divided into four groups of approximately 10 students each. Each of these groups had a teacher who led the discussion. All science activities at this point were teacher led and were typically done as a group, although there were several that were done in groups of two. In addition, the groups did not each do exactly the same activity near the end when each group was responsible for a different presentation for the science conference. Table 4.2 summarizes the enacted curriculum that occurred Mrs. Runner's group.

An important thing to notice is that there was never a science task (or activity) that stands as an independent entity. With only two exceptions there was always both a discussion and a writing task to accompany the activity. The two exceptions were on March 4, when the discussion went on for so long there was not time for the intended writing task, and on April 2 which was a student-led science conference presentation for a cross age group of their peers. There was no teacher present in this group on that day.

Table 4.3 at the end of this chapter represents the main ideas in the three curriculum strands - science content, nature of scientific inquiry, and literacy -- as they are decribed in the teachers' daily plans. One aspect of the science and literacy component that is clear from the table is the natural way in which science and the oral and written literacy tasks were integrated. In informal discussions before the daily science lesson the teachers described to me the writing task and the discussion topic for the day and how they hoped the task or discussion would help the students better understand the science concept. The teachers intended that the discussion and writing tasks would add to and support the students' understanding of the experimental activities that they had done in small groups. The curriculum avoids becoming mindlessly activity-based through the use of discourse as a tool for writing, thinking through, and frequently debating the data collected and the conclusions that could be drawn from that data.

TABLE 4.1
Description Of The Science Activity, Discussion Task, And Writing Tasks For The First Half Of The Unit.

Date	Science Task	Discussion Task	Writing Task
2/25	(Done in groups of 3) Predict what will happen to an ice cube on their desk. Watch changes in the ice cube over time. Describe and explain what happened.	(Whole class discussion) What will happen to an ice cube when it is left out on the desk? What causes the changes in the ice cube when it is left out?	(Group product) Write prediction and explanation. Draw the ice over time. Describe observations. State a conclusion. Science terms worksheet to be done between ice cube observations
3/3	(Done in groups of 3) Predict what will happen to an ice cube when held in your hand. Describe and explain what happens to the ice cube and the hand holding it over time.	(Whole class discussion) Sharing conclusions, observations, and explanations for ice cube on tray melting. Description of ice cube in hand experiment.	(Group product) Write prediction and explanation. Describe and draw ice cube over time. Draw ice cube over time. Explain findings. State a conclusion.
3/4	Class discussion - review previous day's activity. Whole group measurement of selected student's hand and body temperature.	(Whole class discussion) Sharing of anything interesting from the ice cube in hand experiment. Reporting hand and body temperature data.	None
3/8	(Small groups) Measuring the temperature of the room at 8 stations in the two rooms. Groups rotated from station to station.	(Whole class discussion) What is the approximate temperature of our hands? What is the approximate temperature of our body?	Individual writing (science notebooks): Why do you think body temperature is higher than hand temperature? Completed table: Location, temperature, and comments.
3/10	(Small groups) Discuss data collected yesterday. Come up with one room temperature. Decide why that is room temperature (justify).	(Whole class discussion) What did we measure on Monday (hand and body temperature)? What does it mean when we say we measured something?	Individual writing (science notebooks): Write what you noticed about the temperatures around the room yesterday. Complete the phrase "We believe that room temperature is_____ because _______________.
3/15	Measuring and recording the temperature of soup, oatmeal, snow. Predicting and comparing the difference in temperature between oatmeal and snow.	(Teacher led small group discussion). How do you read a thermometer? What happens to the temperature of snow and soup if they are left out at room temperature?	Data (as given by the teacher) is recorded individually in science notebooks. Teacher directs them on how to set up a data chart in their notebooks. Write predicted and actual temperature of the oatmeal, soup, and snow.

TABLE 4.2
Description Of The Science Activity, Discussion Task, And Writing Tasks For The Second Half Of The Unit

	Science task	Discussion task	Writing task
3/16	(Small group, teacher led, discussion.) Using benchmark temps of soup, oatmeal and snow to predict temp of hot chocolate.	How do you read a thermometer? Is the temperature of snow outside the same as the temperature of snow inside? Why or why not? What factors affect the temperature of snow?	Data collected from temperature measurement recorded individually in science notebook. Told to record their observations in words, not just numbers. Wrote a list of other things they would like to know the temperature of.
3/18	(Small group, teacher led, discussion.) Make chart of known temps. Use this to predict the temp of soda with and without ice. Need to use the chart to justify prediction.	Brainstormed a list of items that were about the same temperature as snow, the room, and hot soup.	Individually write predictions for temperature of soda with and without ice in science notebook. Given math homework worksheet, "temperatures we know".
3/25	Small group, teacher led, discussion. Plan how they can organize their science conference "presentation".	Teacher asks students for their ideas about what sorts of things she might have been thinking about when she selected the "doctor for a day" topic. Remainder of discussion is procedural; what supplies they will need, how they will organize themselves, etc.	No explicit directions given however students are taking notes about supplies needed, procedure, etc. in their science notebooks.
3/29	Small group, teacher led, discussion. Continued planning for science conference. Review of content learned during unit - deciding which were the important things they wanted to share with other students.	Students volunteer concepts that they have learned about temperature which they might want to teach about during their session.	Occasional notes in science notebooks - up to students. No teacher directions re: doing this.
3/30	Small group, teacher led discussion. Final planning for science conference. Discussion on the need for precise language in science - i.e. water vapor vs. gas.	What is the temperature of boiling water? Are air and water temperature necessarily the same?	Occasional notes in science notebooks. No explicit teacher directions given however teacher praises kids for taking notes.
4/2	Cross age group led by students from "doctor for a day group". No teacher present. Topic is taking and comparing hand and body temperature.	None	None.

TABLE 4.3
Main Ideas In The Science Content, Nature Of Scientific Inquiry, and Literacy In Science Components

Science Content Knowledge*	Nature of Scientific Inquiry	Literacy in Science
Describe temperatures of objects or differences in temperatures. -reading a thermometer	Observation is an important part of science. *(informal conversation with Mrs. Runner)*	In order to reach consensus and decide which scientific description or explanation is most appropriate people need to **listen** to each other. *(teachers' plans)*
Estimate the temperature of objects by comparison to reference temperatures of freezing, room temperature, body temperature, boiling.	Science proceeds by being curious and asking questions about the world. *(informal conversation with Mrs. Runner)*	Writing can help support your thinking during class discussions or discussions with peers. *(observation of Mrs. Runner, Ms. Lawson, Ms. Smith)*
Predict changes in temperature or state of an object taking into account the temperature of the matter surrounding the object.	Experiments provide data to support assertions. *(observation of Mrs. Runner, Ms. Lawson, Ms. Smith)*	Data/ideas need to be written down so that it can be used at a later time (*teachers' plans*)
Explain changes in temperature in terms of contact or proximity of matter of a different temperature	Science proceeds by debate and **consensus** building . *(teachers' plans)*	Being a good listener means listening to ideas to build on someone else's idea and to get new information to revise your thinking. *(teachers' plans)*
		It is important to listen and decide whether you agree or disagree with a persons idea and thenrespond to the idea. (*teachers' plans*)

*Determined after the unit through discussion with Dr. Jones and Dr. Nettings and based upon participant observation of the enacted unit.

Chapter Summary

This chapter gave a snapshot of the school setting, the teachers in that setting, and the "Changes in Matter" curriculum. This was not a traditional setting. The classroom was a double classroom in which there were 42 students, two classroom teachers, a university collaborator, and a student teacher. The students formed a widely diverse group with respect to race, class, and country of origin. In addition while some of the students were the children of foreign graduate students in which one parent was a full-time parent, some of the students were the children of single parents working on a degree as a non-traditional undergraduate student.

The school, Atlantis Elementary, was a professional development school in which the professional development project for the school year was creating a school-wide unit on the topic of "Changes in Matter". There was a focus on both literacy and scientific understanding in this unit and the culminating school-wide science conference reflected this focus.

When the unit was enacted in this classroom the teachers employed a different discourse pattern than the traditional I-R-E pattern. The emphasis in this new pattern, which will be described in detail in Chapter Six, was on eliciting student thinking and ideas and encouraging students to listen to and agree or disagree with the assertion presented based upon evidence.

A small segment of a lesson was described to illustrate the way in which the teachers used is this new discourse pattern to probe student thinking and support them in moving towards a scientific conception. A more detailed description of a whole class discussion is found in Chapter Five while two students' perceptions of and learning through such discussions is described in detail in Chapter Six.

Chapter 5

THE SOCIAL CONSTRUCTION OF UNDERSTANDING: TEACHERS AND STUDENTS TAKE ON NEW ROLES DURING DISCUSSION

Overview and Purpose of the Chapter

The whole-class discussion described in this chapter took place approximately two weeks into the "Changes in Matter" unit and is typical of the whole-class discussions that were held during the unit. I elected to describe this particular lesson because it illustrates the unique student and teacher roles during discussion. It will be used to examine more clearly these roles and the pattern of discourse in the class.

This chapter also provides the context for the stories of Casey and Padma, whose learning and participation in the discourse community are examined in Chapter 6. For the stories of Casey and Padma to be meaningful, it is necessary to understand what a typical whole group discussion looks like and the implicit and explicit teacher and student roles and responsibilities during class discussion.

Teacher and Student Roles and Responsibilities During Discussion

The norms for participating in the discourse in this class during the "Changes in Matter" unit differed from the traditional in some important ways. Therefore, this chapter will begin with a brief discussion of the discourse pattern, view of the learner, and teacher and student roles and responsibilities in a traditional science class discussion and in a social constructivist science class discussion.

A Traditional Science Class

In a "traditional" science class the Initiation-Response-Evaluation (I-R-E) mode of discourse is prevalent (Cazden, 1988; Lemke, 1990; Mehan, 1979). In this mode the teacher asks a question (initiation) which generally requires a one-word response or a short answer. A student is then nominated by the teacher and gives an answer (response) which the teacher typically evaluates (evaluation) without necessarily considering why the student responded the way that he/she did (Cazden, 1988; Lemke, 1990; Mehan, 1979). Answers given by the student are deemed either right or wrong by the teacher and are not typically challenged or questioned by the teacher or by the other students. If a wrong answer is given, the teacher simply evaluates it as such (either subtly or not so subtly) and moves on to another student until someone gives the scientifically correct answer. Once this correct answer is given, it is accepted and the lesson continues.

This discourse pattern reflects a traditional perspective on the learner. From this perspective a teacher assumes that all students are at a single place, point "A", prior to the lesson. Through the presentation of the lesson the teacher moves the students from this point "A" (no knowledge of the topic) to a new place, point "B" (a knowledge of the topic) in a fairly lockstep fashion with all students assumed to be moving at approximately the same pace and in the same ways. This view of teaching and learning implies a fairly linear progression on the part of the students in which they progress from "absence of knowledge" to "presence of knowledge" in a relatively unproblematic; if the teacher presents the information in a clear and understandable fashion, its assumed the students will learn. Figure 5.1 below illustrates how this path from point "A" to point "B" looks in an traditional science class.

Figure 5.1

Traditional view of elementary science learning

Point A ------>------>------->----->----->----->----->----->-----> Point B

"Tabula Rasa"	"Scientific fact" "Scientific information"
Absence of knowledge (all students begin here)	Presence of knowledge (all students end here)

From this perspective the role of the teacher is that of "presenter of information", and the role of the student is that of "receiver of information." The responsibilities of the teacher in a traditional classroom are straightforward:

*Present the information in an clear, understandable, and interesting manner.

*Question students orally and in writing to ensure they are "getting" (receiving) the information.

Similarly the responsibilities of the student in a traditional classroom are straightforward:

*Listen to the information presented by the teacher.

*Learn the information so that when questioned, orally or in writing, an appropriate response can be given.

A Social Constructivist Science Class

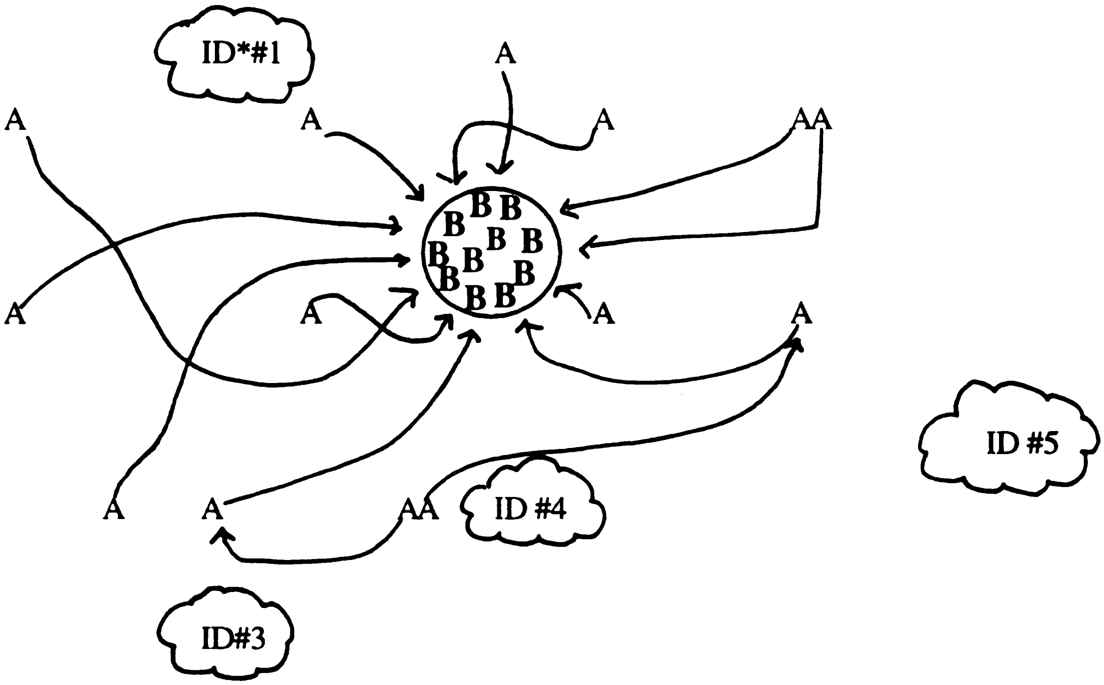
The discourse pattern in a social constructivist class does not consist of the traditional I-R-E pattern, although the teacher does ask some questions (initiation) and the students do respond to the questions (response). The differences between a traditional I-R-E pattern and a social constructivist discussion pattern are described and illustrated in detail later in this chapter. Generally, however, there is a richer set of possible moves by both the students and the teacher. Some of the differences are seen in the nature of the questions the teacher asks, in the near absence of teacher evaluation except in one specific type of situation, and in the presence of discourse moves not present in the I-R-E.

In addition to "Initiation" (I), "Response" (R), and limited "Evaluation" (EV), four other moves were present in the social constructivist discussions in this classroom: "Probe" (P), "Redirect" (RD), "Reasoning" (RE) and "Revoice" (RV). As with both initiation -- which may include teacher modeling or clarification of something a student has said previously -- and response, these four new discourse moves may be made by either a teacher or a student in a social constructivist discussion, although typically only the teacher revoices or redirects as he or she facilitates the discussion. Furthermore, although a social constructivist discussion typically begins with some form of a teacher initiation and a student response, the pattern that follows varies depending on the context of the discussion and the content of what is said in the previous move. Thus, although there is a pattern, it is not as easy to characterize as the I-R-E because each move is so context- and content-dependent.

This discourse pattern reflects a social constructivist view of the learner. From this perspective, the progression from point "A" to point "B" is not a nice neat linear progression, nor are "A" and "B" clearly defined points. Rather than being at a single point "A" prior to the discussion, the students could be considered to comprise a constellation of points. Some students will be fairly near, or even at, the scientific conception, others will hold a variety of different, non-scientific, conceptions. The teacher must somehow, and with the help of the students, shift this constellation of points (or conceptions) toward a new, agreed upon, constellation -- the scientific conception. The scientific conception is described as a constellation of points rather than a single "right answer" because there may be more than one way of representing or describing the scientific conception. Not every student in the class will represent their knowledge and understanding in the same way.

This process is not a linear one because everyone in the class is at a different starting point and will not reach the scientific conception constellation at the same time and in the same way. In addition, each student may follow a different path at a different speed in reaching the scientific conception. Furthermore, as these different students share their ideas in the discussion, all kinds of unplanned "side excursions" occur which, although important, are not part of the main trajectory from "constellation A" to "constellation B". At times the teacher may also see a need to enter into the discussion and take students off the main path onto a side path that the teacher determines will be a helpful detour for many of the students. These times are referred to as instructional detours when describing the lesson. Figure 5.2 on the next page illustrates visually this set of relationships.

Figure 5.2
Social Constructivist View of Elementary Science Learning



*ID=Instructional Detour

Rather than assuming a single starting point, the teacher who holds this second perspective on teaching and learning realizes that there may be as many different conceptions, and ways of representing those conceptions, at the beginning of the lesson as there are children in the class. A goal for this teacher would be to create a common discourse for teacher and students which includes not only common ways of agreeing, disagreeing, and sharing thinking but also a common understanding of the "scientific" terms that are being used in the discussion. Establishing a common discourse is one purpose of the discussion described in this chapter.

Creating this common discourse requires the following teacher roles and responsibilities:

*Valuing and probing students thinking and ideas and drawing on these rather than presenting her own perspective.

*Working hard at understanding the students' arguments and logic.

*Listening to student's thinking and "teasing out" the ideas that will lead them collectively towards a deeper understanding.

*Treating students' questions seriously and using them as "teachable moments".

*Helping students articulate their thinking and give evidence or reasoning to support their assertions.

*Keeping the discussion going in a productive direction by revoicing a student's response, redirect a response by calling for agreement or disagreement, and periodically summarizing the ideas on the speaking floor.

Associated with these common roles and responsibilities are a set of discourse moves that the teacher makes. These moves are;

*Initiating the discussion by asking a question.

*Probing a student's response for reasoning.

*Revoicing a student's response.

*Redirecting a student's response by calling for agreement or disagreement.

*Evaluating a student's response during an instructional detour.

The student's role in a traditional I-R-E discussion is to pay attention to the teacher and repeat the appropriate scientific "facts" at the appropriate time -- as determined by the teacher. The student's role in a social constructivist discussion is considerably more complicated and cognitively demanding. The students have the responsibility to listen to both their teacher and their peers and to compare their personal ideas with the ideas on the floor. They must then decide whether they agree or disagree with the idea proposed by the speaker. In order to participate in the discussion, they must state their position and provide evidence which either supports or challenges the assertion on the floor. Because the teacher does not necessarily dominate the speaking floor, the rules for getting and maintaining the speaking floor are also more complicated than in an I-R-E discussion.

Participating in a social constructivist learning community requires the following student roles and responsibilities:

*Listening to, and valuing, the thinking and ideas of the other students in the class.

*Sharing thinking and ideas during discussion.

*Working hard at understanding the other students' (and the teacher's) logic and arguments.

*Considering the ways in which the idea on the floor connects with, or does not not connect with, their personal theory.

*Agreeing or disagreeing with the ideas of their peers and providing evidence or reasoning to support that.

*Understanding that science is about puzzling through ideas and reaching consensus rather than about getting the answer.

Associated with these common roles and responsibilities are a set of discourse moves that the students make. These moves are;

*Response to a teacher's initiation

*Reasoning in response to a probe.

*Evaluation of another student's ideas by agreeing or disagreeing.

*Summarizing at the end of the day's discussion or as a segue to the day's activity.

The remainder of this chapter focuses on describing the lesson and the interactions between the students in the class and Ms. Lawson as they struggled together to understand each other's thinking and reasoning and gradually work toward reaching consensus -- an agreement about what the average hand and body temperature are. The purpose of this is to illustrate a social constructivist discussion in action and to describe the discourse pattern in such a discussion. Chapter Six will then look closely at the participation and science content learning of two students in the constellation of the class.

<u>Background on the March 8 Lesson</u>

Pre-test data indicated that students maintained a number of naive conceptions about the concept of temperature. They recognized small numbers as representing cold temperatures and larger numbers as representing hot temperatures but were confused about the relationship of the numbers to the change of state of matter. For example, they did not realize that at 0°C (32°F) water would be a solid. Because of this, the teachers decided to help the students develop a series of "benchmark" temperatures they could use as reference points. Boiling point, body temperature, room temperature, and freezing point were chosen as the benchmark temperatures. Therefore, it was important that students had a good understanding of what body temperature was and what the number 98°F meant. Additionally, in order to understand why their hypothesis that an ice cube in the hand melted faster was correct, they needed to have some concept of "hand temperature".

Because these temperature values were important for the students to understand if they were to understand other targeted unit concepts such as temperature change, the teachers made the decision to spend a substantial amount of time across several class discussions talking about these numbers. The March 8 class discussion described in this chapter is one of these discussions. The focus of this particular discussion was on understanding what body temperature and hand temperature are. Once thing that is unique about this discussion is that it is about something that most people would consider to be a scientific "fact"; body temperature is 98.6°F. In many traditional elementary science classrooms this topic would not be something that would be a topic of discussion; rather, it would be a piece of information the students would be expected to hear, remember, and use. It would be considered information to "know" rather than a concept to be "understood".

In the two lessons prior to this discussion, the students worked in teacher-assigned groups of three to observe and describe an ice cube melting. (Unfortunately, this is the first time, and the last time, the groups had this particular configuration. The teachers regularly changed the group assignments.) As a group they formulated a hypothesis about what was happening when the ice cube melted and explained their hypothesis during class discussion. One group hypothesized that their ice cube melted faster than all the other groups' ice cubes because they kept touching their ice cube with their warm hand. This led the class to formulate the hypothesis that an ice cube held in the hand would melt faster than one left on the table.

In order to gather empirical evidence for the "ice cube in the hand" hypothesis, students working in groups of three[1] held an ice cube in their hand and measured the time it took to melt compared to an ice cube left sitting on the table. They also measured the temperature of their hand to see if it was warmer than room temperature, which would account for why an ice cube held in the hand melted faster. During class discussion the teachers also had several people measure their body temperature as a reference point. Figure 5.3 gives a timeline of the March 8 discussion.

Science Class, Monday, March 8, 2:45 p.m.

It is 2:45 p.m. Monday afternoon, and the students are coming in from afternoon recess. There is one hour left before they go home for the day. As the students finish hanging up their coats in the coat room and enter the classroom, the teachers tell them to sit in the team area. All whole-class discussions during science and literacy time are held in this area which is a carpeted open floor space between the two classrooms. There is a blackboard, an overhead projector, and several "adult" chairs at the front of this area. Generally during a class discussion the teacher leading the discussion will sit on one of these chairs rather than stand so the students do not have to look up quite so far from their positions on the floor when talking with the teacher.

Talking quietly, the students hang up their coats and sit cross-legged on the floor in the team area. This area is small and it is cramped for all 42 students to sit in the area. However, they manage to do so without any altercations. Ms. Smith, Mrs. Runner, and Dr. N sit at student desks off to one side of the team area. Casey is sitting on the outer periphery of the group as usual. And, as is typical, he is sitting near the front, but to Ms. Lawson's left and out of her direct line of sight. By contrast, Padma is sitting in the center of the group approximately four students back from the front and directly in Ms. Lawson's line of vision. She is sitting next to Yaza and diagonally in front of Sarina, both of whom

[1]These groups, which were teacher assigned, were not the same groups they had worked in when observing the ice cube melting on the table.

Figure 5.3

March 8 Discussion Timeline

Lesson Introduction

↓

Body Temperature Discussion
-Review of body temperature data

↓

Instructional Detour #1 & #2
-definition of "approximately"

↓

Conclude discussion of approximate body temperature

↓

Discussion of approximate hand temperature

↓

Sarina's question re:approx.
Instructional Detour
-definition of "approximately"

↓

Continued discussion of hand temperature
-Derek's disagreement

↓

Instructional Detour
-Thermometer structure

↓

Continued debate about hand temperature
-Most students disagree with Derek
-Derek continues to argue his position

↓

Discussion of what scientists would do if they
disagreed with their experimental data

↓

Ms. Lawson's cojecture

↓

Transition to writing time

are friends of Padma's and appear to compete with her for the mantle of "smart student." Yaza and Sarina are both active participants later in the day's discussion. The result of this seating arrangement is that Padma appears to be an active participant in the discussion, even through she contributes little verbally.

Once they were all seated Ms. Lawson, seated on a stool at the front of the room, began the lesson by reorienting the students to the activity they had done the previous week. She spoke in a low, even tone and maintained a consistent pace throughout the lesson, never speeding up or slowing down and never raising her voice even later in the lesson when she reprimanded a student for not listening;

> Ms Lawson: Okay...you need to have your eyes up here and think back to last week when we were taking the temperatures of our hands...and I quickly recorded some of the different hand temperatures in our classroom...do you think looking up here...today we could talk about kind of an approximate hand temperature...what does that mean.. approximate.. if you were gonna say well approximately..my hand temperature is..what do you think that means... (Transcript, March 8, 1993)

As soon as she said "okay" the students stopped talking and faced her. This was their signal that the lesson was beginning. Once she had their attention Ms. Lawson reoriented them to the data they collected the previous week by reminding them that they took the temperature of their hands, and she recorded some of their temperatures on the overhead projector. Not everyone had the same hand temperature she noted; rather there was a range from 89° to 98° F. Hand and body temperature are not fixed values that are always the same - for example, body temperature will elevate with exercise or illness.

<u>Rationale for Establishing Hand and Body Temperature</u>

Although "normal" hand and body temperature could be defined as a range of temperatures such as this, this is not the convention and Ms. Lawson had decided to have students select a single number as an approximate hand temperature. Having a single number as the approximate hand temperature would allow the class to have another "benchmark" temperature they could use for future reference. A single number is also easier to manage and conceptualize for the third-grade students than would be a range of numbers. Developing an approximate temperature also provided an opportunity to review a concept learned in mathematics - determining an approximate value.

Review approximation was not in the daily lesson plans and appears to be an integration opportunity that Ms. Lawson took advantage of as it emerged from the conversation. I observed this sort of natural integration of mathematics and science a number of times during the Changes in Matter unit. The teachers in this classroom seem to take advantage of any opportunity to integrate knowledge across the curriculum. So, although this was officially a time when science and literacy were being explicitly integrated, mathematics was often integrated whenever there was a natural place to use mathematical concepts or reasoning.

An Instructional Detour

If students were to determine an approximate body temperature it was important that everyone in the class understood what Ms. Lawson meant by the term "approximately." This knowledge was necessary in order to understand the lesson, the focus of which was on using the data collected the previous week to calculate an approximate hand and body temperature and then to use this approximate temperature to decide the effect that different temperatures have on an ice cube. Thus Ms. Lawson took what I have termed an "instructional detour" to discuss the meaning of the term "approximately." Instructional detours such as these where the meaning of a word or term is clarified and discussed are common in this classroom. These instructional detours seem to be the way that the teachers slip out of their role of discussion facilitator and take on the role of information provider and clarifier. There are times when this is necessary; if students do not all have a common understanding of the term "approximately," for example, they will be interpreting the lesson in different ways based upon their understanding of the word. Instructional detours allow the teachers to make sure that everyone has a common starting point for the discussion. This is important in any class and may be even more important in a class where there are so many language minority students.

Ms. Lawson began the instructional detour with the question, "What does that mean...'approximate'?" This opening question was marked as being different from much of the discourse that was to come because there was clearly a specific answer that Ms. Lawson was quickly seeking (as opposed to opinions, agreement or disagreement, or ideas which needed to be justified with evidence). In response to this question Casey immediately raised his hand. As Ms. Lawson finished speaking, Tito and Mike also raised their hands. Although, or perhaps because, Casey was sitting in the front directly to Ms. Lawson's left, Ms. Lawson appeared not to see his raised hand and called instead on Tito who responded by saying "about." Casey turned toward Tito as he answered and then immediately faced Ms. Lawson again and raised his hand. Ms. Lawson evaluated Tito's response by repeating "about" and then saying "okay." This evaluation move is unusual in this class and is typically only present during an instructional detour such as this. Once Ms. Lawson evaluated Tito's response she continued the lesson despite the fact that Casey still had his hand raised. Casey kept his hand up for another moment then slowly lowered it.

What is Our Approximate Body Temperature?

Apparently satisfied that "approximately" was a familiar term to the students, perhaps based upon Tito's accurate synonym, Ms. Lawson turned on the overhead projector which showed the hand temperature data table constructed during the previous lesson;

Hand Temperature

Temp	# of people
98	1
95	1
92	1
91	1111
90	1111 1111
89	111

As she did this Ms. Lawson began initially to ask about determining hand temperature but quickly shifted to talking about body temperature more generally. In this, and all remaining transcript segments in this chapter, each move has been coded and labeled as initiation, response, evaluation, probe, reasoning, revoice, or redirect;

Initiation	Ms. L:	(Adjusting overhead projector as she talked) Could we come up with a ...hand temperature that we could say well hand temperatures are about..this..what are our body temperatures about..does anyone remember when we took the temperature of our bodies". (Pause as many students, including Casey raise their hands. Padma is sitting politely with her hands folded and is looking down at her hands)
Initiation	Ms. L:	What was our approximate body temperature we came up with? Shakira do you remember?
Response	Shakira:	(somewhat tentatively) Ninety six
Initiation	Ms. L:	Okay I think you're close, maybe it would help to remember what we had. I think we had, um...

(Transcript, March 8, 1993)

At this point Ms. Lawson may have realized that the students in the class did not necessarily know that body temperature is 98.6°F. However, rather than explicitly evaluating Shakira's response and saying that 96 was not correct and/or calling on another student , Ms. Lawson took another approach. With the students' help she reconstructed the data they had collected the previous lesson by reviewing what different people's body temperature was found to be.

Initiation	Ms. L:	Okay I think you're close. Maybe it would help to remember what we had. I think we had..um
Response	Chorus:	Ninety nine
Elaboration	Ms. L:	One person was ninety seven.
		(overlapping calling out of temperatures)
Revoice	Ms. L:	Ninety nine, Mrs. Runner and..
Response	Chorus:	Titi

Revoice	Ms. L:	were Ninety eight
Response	Yaza:	Ninety nine
Revoice	Ms. L:	Yaza was ninety nine and then um Miss Smith and I, our thermometers weren't working very well. So, hmm...
Initiation	Ms. Smith	What about Dana?
	Ms. L:	Hmmm?
Initiation	Ms. Smith	Dana?
Response	Ms. L:	Dana was ninety seven right.
Initiation	Ms. L:	(to Dana) You were ninety seven, right?
Response	Dana:	Yeah.

(Transcript, March 8, 1993)

The segment began much like an I-R-E discussion with a teacher initiation and student response. However, rather than evaluating the student's response and moving on to another question there was a sequence in which the teacher merely revoiced what a student had said and another student responded. The segment then ended with the second teacher asking a question to which the first teacher responded. There was no evaluation move present as there would typically be in an I-R-E sequence. Thus, if you were to "map" the moves in this segment the pattern would be; I(T1)-R-RE-RV-R-RV-R-RV-I(T2)-R(T1)-R with (T1) and (T2) representing the two teachers, Ms. Lawson and Ms. Smith, who participated in the discussion.

As the students were collectively reconstructing the list of temperatures, Ms. Lawson was writing them on the overhead:

Body Temperature

Temperature	# of people
97	1
98	11
99	1

The students then had a visual representation of the data they had collected the previous week. They could use this data to decide what they thought was an approximate body temperature. Ms. Lawson began by asking what the approximate body temperature was and Micah, raised his hand, and, when called on, responded that he thought body temperature was 98 degrees.

So far the discussion has followed the traditional I-R-E pattern --the teacher asked a question to which a student responded. However, at this point, Ms. Lawson departs from that pattern. Rather than immediately evaluating Micah's answer and giving him feedback as to whether it was correct, Ms. Lawson questioned him about how he came up with this number. After Micah had given his reasoning Ms. Lawson did not judge the correctness of his answer or his reasoning in the traditional sense seen with an Initiation-Response-Evaluation (I-R-E) discourse pattern. Instead she turned this responsibility over to the students by repeating what he said and asking for comments. These two discourse moves -- questioning Micah's thinking and calling for comments -- directed the students' attention to the way in which Micah determined the number rather than the number itself. It was this emphasis on the thinking rather than on the specific answer that marked this portion of the discussion (as with much of the discussions in this class) as being different from a traditional science discussion. This interaction between Ms. Lawson and Micah is shown below:

Initiation	Ms. L: So what was our, what's an approximate body temperature based on our results?
Response	Micah: (calls out) Ninety eight
Probe	Ms. L: And why do you say ninety eight?
	(Micah raises his hand to "rebid" for the floor)
	Ms. L: Okay. Micah?
Reasoning	Micah: Because ninety eight is between ninety nine and ninety seven.
Revoice	Ms. L: Ninety eight is between.
Redirect	Ms. L: Comments about that?

When this exchange is mapped out, the pattern is seen as I-R-P-RE-RV-RD. Ms. Lawson initiates with a question which Micah responds to. However, rather than evaluating his response Ms. Lawson probes his thinking and then gives Micah an opportunity to give his reasoning for his response. Ms. Lawson still does not evaluate but rather revoices what Micah has said and redirects the response back to the rest of the class by calling for comments.

By probing Micah in this way and allowing him to share his reasoning for his original response, Micah's thinking was made visible to everyone in the class and became part of the shared knowledge of the class. Therefore, Micah's peers had the opportunity to know not only what he believed body temperature to be based upon the available data but they also had the opportunity to know how he had determined it. As a class and individually they could now decide if they agreed or disagreed with Micah based upon his reasoning. In this way the emphasis in the ensuing conversation is on the underlying thinking that led to the answer rather than on the "answer" only.

Giving Answers vs. Exploring Thinking

In elementary school there are a multitude of different subjects and many concepts within each subject area that the district or state requires taught. This creates a situation in which the teacher is nearly continuously in the position of having to weigh the advantages and disadvantages of pursuing a particular line of thinking or a particular strategy against the need to continue on with the lesson so that it is completed in a timely fashion. It is this pressure to cover a certain amount of content by the end of the year that leads many teachers to approach science in a more traditional, less time consuming, I-R-E manner.

The exchange between Micah and Ms. Lawson described above is an example of an interaction that could have been considerably shorter if the teacher had chosen to make it so. After Micah responded that 98°F is body temperature, Ms. Lawson could have made the decision to verify the accuracy of this and to tell students that they needed to remember this number as they would be referring to body temperature in the future and they would need to know a numeric value for it. This would place the emphasis on science content knowledge, and the student would have the responsibility for remembering this content.

Instead, by asking him why he thought ninety eight was body temperature, Ms. Lawson tried to communicate to Micah, and the rest of the class, that they have the responsibility for supporting their assertions with evidence. The potential message is that their thinking, and how they determined the answer they gave, is equally as important as reaching an answer. The questioning of how Micah decided that ninety eight was body temperature shifted the responsibility for meaning making back to the students. In this discussion the teacher did not claim full responsibility for evaluating whether the answer was correct or incorrect. Each member of the learning community had the responsibility of listening to Micah's reasoning and deciding if they thought it made sense. They then had the responsibility for agreeing or disagreeing with Micah based upon his reasoning and had to give reasons of their own for this agreement/disagreement. In this manner class consensus was built.

Sharing Their Thinking

Ms. Lawson implicitly communicated to the students their responsibility for participating in the class consensus building by not commenting herself upon Micah's reasoning. Rather, she asked the students to comment about what Micah had just said;

Initiation	Ms L.:	Comments about that? Yaza what do you think?
Response	Yaza:	Yes.
Probe/ Revoice	Ms. L:	You agree.
Elaboration	Yaza:	I have another reason why. Because two people were ninety eight.
Revoice	Ms. L:	Two people were ninety eight.
Redirect	Ms. L:	What do you think about that? Mike, what do you think about that?

(Transcript, March 8, 1993)

In this exchange with Yaza, the discourse pattern is exactly the same as in the interaction with Micah. The two patterns are mapped out below:

Micah I-R-P-RE-RV-RD

Yaza I-R-P-RE-RV-RD

Both Micah and Yaza have now provided different, and valid, statistical arguments for why body temperature should be considered to be 98°F based upon their data. Micah argued for the statistical median saying that he thinks ninety eight is the approximate body temperature because it is in the middle of the three numbers recorded for body temperature. Yaza said that she agreed but had another reason for agreeing. Her argument was that 98° represented the statistical mode -- two people were 98°. Although the students did not use the terms "median" and "mode" they were effectively using these ideas in context-- ideas which many might consider too sophisticated for third grade students to understand and use.

The discussion about body temperature continued with Ms. Lawson revoicing the pieces of evidence provided by Micah and Yaza. Zane and Mike (who is a special education student) joined the discussion at this point. This is a fairly "safe" time intellectually to join the discussion. There were several assertions with supporting evidence on the floor. Although a new idea could be added, students could also join the conversation at this point by saying that they agree with one or both assertions and evidence. However, even during this time when students could participate in ways which were less intellectually risky, some students, such as Padma, chose to sit silently. During this time these students appeared to be listening attentively, but never made a bid for the speaking floor.

By the end of this brief interaction, it appeared that the class had reached the consensus that 98° is the approximate body temperature.

Initiation	Ms. Lawson:	Mike, what do you think about that? Micah and Yaza think that ninety eight is the approximate body temperature because two people were ninety eight and it is also in the middle of ninety seven and ninety nine.

Response	Mike:	I agree with that.
Probe	Ms. Lawson:	You agree with that.
Response	Mike:	Yes.
Initiation	Ms. Lawson:	Zane?
Response	Zane:	I agree also.
Probe	Ms. Lawson:	Why?
Reasoning	Zane:	Because ninety seven and ninety nine have just one person but ninety eight has two people.
Probe	Ms. Lawson:	Do you feel comfortable saying that ninety eight is approximately body temperature?
Response	Zane:	Yeah.

(Transcript, March 8, 1993)

Ms. Lawson interacted with Zane and Mike differently than she did with Micah and Yaza. When Mike said that he agreed, Ms. Lawson revoiced what he said with falling vocal intonation. She wasn't confirming that he was agreeing, rather she was revoicing what he had said. However, unlike Micah and Yaza, Mike did not pick up on the subtle hint to give a reason why he agreed and did not share his reasoning the way that Micah and Yaza had done before him. Ms. Lawson chose to go on to another student rather than to probe him.

By contrast Ms. Lawson quickly probed "why?" when Zane said that he agreed. In response to this, Zane elaborated by repeating the reason given by Yaza that two people were ninety eight. Additionally, he added further clarification of, and support for, Yaza's reason saying that ninety seven and ninety nine have just one person each. No one else in the room raised their hand at this point to say that they are not comfortable saying that ninety eight is body temperature. This seemed to be at least some indication of consensus.

The pattern of the interaction with Mike and Zane is shown below along with the pattern seen with Yaza and Micah:

Mike I-R-P-R

Zane	I-R-P-RE-P-R
Yaza and Micah	I-R-P-RE-RV-RD

In Mike's case once he did not respond to Ms. Lawson's probe she initiated the question again. By contrast Zane, Yaza, and Micah all responded to Ms. Lawson's probe with reasoning which led Ms. Lawson to either probe further or to revoice their reasoning and redirect. The pattern that emerges is that Ms. Lawson will probe a response and in order for the student to keep the speaking floor, and/or for their idea to remain on the floor and part of the discussion, they must elaborate and/or give their reasoning in response to the probe.

An Instructional Detour - What Does Approximate Mean?

Following the discussion of body temperature, Ms. Lawson began a second, longer, "instructional detour" about the concept of approximation. This was done by having the students volunteer synonyms for the word "approximately". As described earlier, these instructional detours were much closer to a traditional I-R-E sequence. During this exchange Ms. Lawson used a great deal of repetition, possibly for the managerial purposes of allowing everyone to hear the responses. She also evaluated responses both implicitly or explicitly. There is also no teacher probing, and as a consequence, no reasoning is given. This contributes to the rapid exchange--no single person or idea maintains the speaking floor for more than one turn:

Initiation	Ms. Lawson:	Approximately. Does that mean exactly?
Response	Chorus:	No.
Initiation	Ms. Lawson:	What does approximately mean?
Response	Sarina:	About
Revoice	Ms. L:	About. ?
Redirect	Ms L:	Another way you could define approximately? Padma?
Response	Padma:	Maybe
Revoice	Ms. L:	Maybe.

Evaluation	Ms. L:	Okay.
Response	???:	Almost.
Revoice	Ms. L:	Almost.
Redirect	Ms. L:	Pritik?
Response	Pritik:	Kind of.
Revoice	Ms. L:	Kind of.
Evaluation	Ms. L:	Good.
Redirect	Ms. L:	Rachel?
Response	Rachel	Close to.
Revoice	Ms. L:	Close to. So approximately we could say body temperature is ninety eight.

(Transcript, March 8, 1993)

This segment is marked as being different from the rest of the conversation. The pattern maps out as:

I-R-I-R-RV-(EV)*-RD-R-RV-EV-R-RV-(EV)-RD-R-RV-EV-RD-R-RV

*(EV) represents an implied evaluation in which Ms. Lawson indicated that the answer was correct by going on to another person for another synonym.

This instructional detour was very rapid, and Ms. Lawson's talk was limited primarily to revoicing what one student had said and nominating the next student. Instructional detours like this also included teacher evaluation which was rarely seen during discussions other than instructional detours. Defining a term or reaching agreement about the meaning of a word such as this is different than making and evaluating claims about a phenomenon. This may account for the difference in the structure and pace of these instructional detours -- which were not about making claims.

Ms. Lawson made this instructional detour concerning the concept of "approximately" for the second time presumably because of the importance of understanding this concept . If students do not understand this, they will not have access to the ideas in the discussion. She may have been generating a range of synonyms for the word approximately so that it is more likely that one will be used which will have meaning to the students.

What is Our Approximate Hand Temperature?

Now that students were reoriented to the previous week's activity, had established an approximate body temperature, and had demonstrated that they understood the term "approximately" and knew how to determine an approximate temperature from a data set, Ms. Lawson was ready move into the next segment of the lesson which dealt with determining an approximate hand temperature. This was a more difficult task for the students than determining body temperature because there were twenty data points spread over six temperatures compared to the four data points over three temperatures for body temperature. This is probably the reason why, when first introducing the idea of an approximate temperature, Ms. Lawson had abruptly shifted from asking about hand temperature to asking about body temperature. Students had now had some practice determining an approximate number from a data set that was a little less intimidating because it was smaller. The data chart was still on the overhead, recorded in the table with a green marker;

Hand Temperature

Temp	# of people
98	1
95	1
92	1
91	1111
90	1111 1111
89	111

Ms. Lawson began the discussion of the data;

Initiation	Ms. L:	What do you think approximately hand temperature is based on the green results you had last week. What would you say? What would you say Mike?
Response	Mike:	Ninety.
Probe	Ms. L:	Okay, why.

Reasoning	Mike:	Because it has ten and the others have one or three or four or two.

(Transcript, March 8, 1993)

At this point the pattern of the conversation was identical to the earlier one about body temperature, I-R-P-RE. Although an answer had been given which is a reasonable one based upon the data, Ms. Lawson did not immediately accept the response, give feedback that it was correct, and continue on. Rather, she patiently asked Mike why he believed that 90 is hand temperature.

At this point in the discussion the students were still remarkably engaged and attentive. There were forty two 8-10 year old children on the floor in a very small area looking up at the teacher who is sitting on a stool. They were not wiggling around as you often see young children doing, nor are they talking or otherwise interacting in some way with their peers sitting around them. Generally they were sitting cross-legged facing the teacher, although some of them shifted to look at each speaker as they take a turn. These factors indicated a high level of engagement with the discussion.

In response to Ms. Lawson's request for evidence that the approximate hand temperature is ninety, Mike gave the same reasoning that Yaza gave for body temperature; that there were more people who measured 90 than any other temperature (statistical mode). Mike's explanation represented one way in which he was potentially learning from one of his peers in this learning community, specifically Yaza. Mike gave an appropriate statistical explanation which he may have learned from listening to Yaza. However, it can be argued that he did not simply memorize Yaza's explanation and parrot it back without understanding it, because he did not use the exact same language as Yaza. In addition, Mike had added to his explanation additional information about how many people were at the other temperatures to his explanation. This is the same thing that Zane did earlier when he supported Yaza's initial assertion about body temperature.

To further illustrate the assertion that Mike learned both how to calculate the approximate temperature and how to give evidence for that from listening to his peers the following transcript segments show Yaza's original reason for why 98°F should be the approximate body temperature. Zane's support and further clarification are shown below along with Mike's reason for why 90°F should be body temperature. Note the similarity of the ideas even though the language used is slightly different. Note also the line numbers which illustrate that these three statement occurred over time, not one after another:

Elaboration	31	Yaza:	I have another reason why. Because two people were ninety eight.
Reasoning	41	Zane:	**Because ninety seven and ninety nine have just one person** but ninety eight has two people.
Reasoning	60	Mike:	Because it [90°F] has ten and **the others have one or three or four or two**.

(Transcript, March 8, 1993)

The underlined portion of Mike's explanation shows the reasoning process that he may have learned from listening to Yaza and Zane while, the bolded text shows the additional supporting evidence he may have learned from listening to Zane.

Following Mike's statement, Mrs. Runner entered the discussion for the first time during this lesson, probing Mike about how he knew that there were ten students who had 90°F so quickly. Mike explained to her that he understood the tallying method that was used. During this discussion Mrs. Runner asked Mike what the tally marks stood for, and Mike communicated some lack of clarity about this. This was followed by an interaction with Josie explaining to Mike what the tally marks stood for. The interaction is interesting, because Ms. Lawson gives Josie explicit instructions to talk directly to Mike rather than to a teacher. By doing so Ms. Lawson is indicated that she was not the only authority for knowledge in the classroom and that the students needed to talk to, and listen to, one another.

Initiation	Ms. Lawson:	(to Mike) Okay, and what do the tally marks stand for?
Response	Mike:	For how many people or numbers there are.
Redirect	Ms. Lawson:	Okay, could someone expand on that a little bit. Ten what were ninety?

Revoice	Ms. Lawson:	Mike said ninety because there were ten.
Redirect	Ms. Lawson:	Josie?
Response	Josie:	I think that ten students for ninety.
Elicit St. evaluation	Ms. Lawson:	What do you think about that Mike? Did you hear what she said?
Request	Ms. Lawson	Could you tell him again?
Response	Josie:	I think that...
Request	Ms. Lawson:	Why don't you tell him.
Response	Josie:	...that ten students are ninety degrees

(Transcript, March 8, 1993)

This exchange is slightly different than the interactions earlier in the lesson, although it has the same moves with one addition. In one instance, however, the order of the moves was switched and Ms. Lawson redirected without revoicing. However, when there was no response to her redirect she "backpedaled" and revoiced at which time her redirect garnered a response. A new move in this segment was to ask Josie to respond directly to Mike. Again, this served to illustrate that the students in this learning community had the responsibility to listen to one another and to help each other understand the material under study.

Following the discourse pattern that she established in this lesson, Ms. Lawson continued the discussion by asking the class if they agreed with Mike that 90° is the approximate body temperature. Naomi raised her hand and, when called on, agreed with Mike saying, "I think so because there are ten people and not more than ten or like ten people in the other one". Naomi was the first student during this discussion to agree and then give her reasons for agreement without explicitly being asked to do so. As with Mike, Naomi was using the argument for the statistical mode begun by Yaza, that there were ten people who measured their body temperature to be 90°F, and further clarifying that there was not another temperature in which there were ten or more people. And, as with Mike, Naomi was not merely parroting the statements made by Yaza, Zane, and Mike, but was explaining her thinking in her own words.

A Third Instructional Detour about "Approximately"

Following Naomi's comment, Sarina raised her hand and asked what the word "approximately" meant. This was followed by a third instructional detour concerning the word "approximately". Again, this segment of the discourse is marked as being different from the rest of the lesson. The conversational tone was dropped, and Ms. Lawson again initiated a rapid exchange with no probing or reasoning in which the students provided synonyms for the word approximately which Ms. Lawson evaluated:

Initiation	Ms. Lawson:	Approximately. What does approximately mean. Mioka?
Response	Mioka:	Like about or..
Initiation	Ms. Lawson:	About what were some other, do you remember some other words we used? Could someone help us with our definition? What does approximately mean Bethany?
Response	Bethany:	Almost.
Revoice	Ms. Lawson:	Almost.
Elaborate	Ms. Lawson:	Close
Response	???:	Near.
Revoice	Ms. Lawson:	Near.
Redirect	Ms. Lawson:	Hosea?
Response	Hosea:	Kind of.
Revoice	Ms. Lawson:	Kind of. Understand now Sarina?
Sarina:	Umhmm.	

(Transcript, March 8, 1993)

Once again Ms. Lawson showed a great deal of patience in a situation where many of us would be tempted to point out that the word had been defined twice before and therefore another explanation should not be necessary! Ms. Lawson did not, however, tell

Sarina that they had already discussed the meaning of "approximately" twice or otherwise appear irritated with Sarina for asking the question. Rather, she took the question seriously and used it as another opportunity to review the term which was central to the day's lesson.

Sarina had appeared visibly engaged in the lesson up to this point. She was sitting on her knees leaning slightly forward, frequently raising her hand when a question was asked. This apparent engagement in the lesson followed by Sarina's question about a term that had been defined twice previously shows that a teacher cannot presume that students understand a term or concept simply because it has been presented once before. It also illustrates again how difficult the idea of "approximately" is for third grade students and the importance of the patient repetition done by Ms. Lawson. If Ms. Lawson had only had students calculate an approximate temperature for one of the data sets, hand temperature, as she originally began to do, it is possible that Sarina would not have asked her question and would have left the lesson understanding little. It is only because Ms. Lawson provided multiple opportunities for the students to calculate an approximate temperature and because they discussed the meaning of the term "approximate" twice that Sarina realized that she really didn't understand what the word meant and that she might be missing something important.

The way in which Ms. Lawson handled Sarina's question was also consistent with the discourse pattern established in the lesson. Ms. Lawson did not simply invoke her authority and tell Sarina the definition of the term so that they could continue with the lesson. Rather, she asked the students to once again come up with their own definition of, or synonym for, the term. The students were able to do so based partially based upon the context in which the term was used in discussion and partly based upon knowledge gleaned through the first two instructional detours. This gave all students more ownership over the concept of "approximately" than if Ms. Lawson had told them all what the word meant. It also provided another opportunity for Ms. Lawson to assess their understanding of the term.

Casey Disagrees

The preliminary work was now done, the students had been reoriented to the data they collected the previous week, body temperature had been discussed and an approximate body temperature agreed upon, and the concept of approximation had been reviewed several times. The students appeared engaged in the lesson at this point -- they were facing the teacher, raising their hands to participate, making comments that related directly to the lesson.

Immediately before the instructional detour about the meaning of "approximately" Mike had said that he thought hand temperature is 90°F and gave reasons to support this assertion. Following this instructional detour Ms. Lawson returned to this assertion by calling for comments. Casey, who had been sitting quietly on the periphery of the group raising and lowering his hand but never being called on, finally gained the speaking floor when Ms. Lawson nominated him. He entered the conversation for the first time with a new theory which led him to disagree with some of the other evidence that had been provided:

Initiation	Ms. Lawson:	Are there any comments about, we are trying to decide which temperature we think is approximately the temperature of our hand.Mike says he thinks ninety. Comments about that? Daniel?
Response	Daniel:	I agree with, all the other ones are like one, two, and three, or four and ninety has ten.
Redirect	Ms. Lawson:	Casey
Evaluation/ Elaboration	Casey:	I disagree with Mike's idea because ninety degrees has ten people out of the whole classroom and there weren't even ten people to get their temperature taken for the one over there [points to body temperature table]. So I think that it is ninety eight.
Redirect	Ms. Lawson:	Okay. What do you think about that? Saul?
Evaluation	Saul:	I kind of agree except that I don't agree that it is ninety eight. I still disagree. I still agree that it is ninety but there were thirty five people that took their temperature.

(Transcript, March 8, 1993)

Although this interaction began with the typical teacher initiation - student response, Casey changed the pattern by evaluating Mike's idea. Ms. Lawson may have been somewhat surprised by this change in the pattern and so did not probe and have Casey give his reasoning as had been the pattern in the lesson. Rather she "skipped" these two moves and went to the move that normally follows probing and reasoning -- she redirected. Saul responds, but, taking Casey's lead he also evaluates Casey's response.

Further complicating this interaction was Casey's disagreement at this point in the discussion. It had appeared that everyone was in agreement that 90°F represented hand temperature. Ms. Lawson may have been assuming that a few people would support this assertion, she could announce that consensus had been reached, and the lesson could continue. The focus of the lesson was intended to be on establishing a numeric value for hand and body temperature to use as "benchmark" temperatures in the future. A lengthy discussion of what these temperatures were was not necessarily anticipated and planned for (teachers' plans, March 8, 1992). And, in a more traditional class, a continued discussion with someone disagreeing probably would not have happened. In a more traditional class once someone had given the approximate temperature of 90°F and someone had supported that assertion, the teacher would have rhetorically asked if everyone understood why 90° was the approximate temperature and continued. A student like Casey might not have gotten this opportunity to disagree out loud.

Although Ms Lawson did not follow her pattern and probe Casey further, Casey was persistent and would not allow the teacher to "gloss over" his disagreement. The argument that Casey introduced is that you cannot compare hand and body temperature in this instance because the sample sizes are different. He also argued that hand temperature should be 98°F - the same as body temperature although he didn't give a reason for this belief. Saul, who was working hard at listening and understanding his peer's ideas, immediately picked up on this argument saying that he agreed that the sample sizes are different and therefore might be problematic, but he still believed that hand temperature is

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90. It took careful listening on Saul's part to understand Casey's point. I am not sure that Ms. Lawson was clear about what Casey was saying, since she had not yet probed and/or revoiced his idea, a move she generally made in response to assertions and/or evidence given by a student. Given this, Saul's contribution is fairly remarkable. Not only did he understand Casey's concern, but he formulated a response to him.

Following Saul, Yaza said that she didn't understand what Casey was saying. Rather than summarizing or revoicing Casey's idea for him, Ms. Lawson asked Casey to explain what he meant. This implicitly communicated to the class that they needed to talk and listen to each other and removed Ms. Lawson from being the sole authority in the classroom. This also gave Ms. Lawson the opportunity to listen to Casey's ideas a second time and try to make sense of his argument.

Casey says:

> What I mean is Ms. Lawson, Miss Smith, Diana, Chao, and Nino, they went up to get their body temperatures and I don't think, that's not ten. And the people said that it's ninety degrees Fahrenheit. There was ten people, there were ten. And we have more than ten people in our class. So, they got ninety for it but over here in the red, ninety eight. I think, it couldn't be ten for it cause there's many people got their temperatures taken.
> (Transcript, March 8, 1993)

Even though Ms. Lawson asked him to explain his thinking to Yaza, Casey faced Ms. Lawson as he gave this explanation, evidence that he continued to see the teacher as the primary audience for his talk. However it is also possible that his body position was due to the fact that although Yaza said that she didn't understand, Ms. Lawson was the last speaker and the one who made their request that Casey repeat his ideas.

Following Casey's speech Ms. Lawson attempted to clarify Casey's argument saying, "So you think there needs to be ten people", which is the phrase that Casey repeated most frequently. Casey responded to this question with a third fairly long speech:

> Yeah. If we had, well maybe not ten, but if there were, the thing is, I just think that it's not ninety because I think that Naomi said that ninety degrees Fahrenheit was because it had ten, or Daniel, and I think it [hand temperature] would be ninety eight even though it just had two because...
> (Transcript, March 8, 1993)

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With this speech Casey continued to argue that there was not a large enough sample size to determine if 90°F is hand temperature. This is a sophisticated idea for a third grade student to hold, and Casey was having difficulty finding the language to articulate his thinking clearly. Words for concepts such as "sample size" and "comparison of groups" and even "fair test" would have helped him make his point but may not have been part of his vocabulary. At this point, perhaps out of frustration with his lack of suitable language, his voice trailed off and he gave up on his argument.

Another Instructional Detour

Ms. Lawson shifted the focus following the disagreement with Casey by taking another instructional detour explaining why everyone didn't take their body temperature. This instructional detour was different than the ones for the discussion of the concept of approximation. This time she did not have a "drill and recitation" format but rather took on the role of an "expert" as she described the expense of the thermometers used to measure body temperature and that they contain the chemical mercury which isn't particularly safe to touch if the thermometers were broken and this spilled out. This information partially addressed Casey's issue of sample size - it explained why they were different. However, it didn't speak to his concern that you cannot compare the two samples because they are different sizes.

Casey's Argument Revisited

Following this detour Ms. Lawson returned again to Casey's idea; "So Casey you think that the hand temperature should also be 98". At this point Casey has had a few minutes to think, and he has come up with a third argument for his position:

> Yeah, because it is part of your body and if your hand temperature **is 98**, the hand is part of the body so that should **be 98** too. Because it's part of your body and it **is 98**.
> (Transcript, March 8, 1993)

Casey's argument this time was that the hand is part of the body and so its temperature should be the same as body temperature, which is 98. He made this point three times during his speaking turn, each time repeating the idea that the hand is part of the body and body temperature is 98 (the repetition is bolded and/or underlined). This repetition is significant and is discussed in greater detail in chapter six.

For the first time since Saul commented earlier on Casey's original statement regarding sample size, there was some uptake of Casey's idea by other students. Kareem responded to Casey, and Sarina commented back to Kareem in the following exchange:

Response	Kareem	It doesn't always have to be that way.
Probe	Ms. Lawson	Why?
Elaboration	Kareem	Cause you know if you don't have any gloves outside right now, if you have hats on and you have a coat and no gloves on your body on the inside its gonna be very hot and your hand is gonna be cold.
Redirect	Ms. Lawson	Comments. Sarina?
Response	Sarina	Um..I have something to say to Kareem.
Directions	Ms. Lawson	Nice and loud.
Evaluation	Sarina	You know how when people go outside. Like if you think your hand is cold and your body is hot. I think sometimes your body gives heat to the whole thing. Maybe your hand is cold. Maybe a little hot air causes, sometimes your body might give heat to your hand.

(Transcript, March 8,1993)

The pattern in this segment was similar to the pattern seen earlier in the discussion with the addition of Sarina evaluating Kareem's idea: R-P-RE-RD-E(S2). Kareem began by responding to an idea on the floor, Ms. Lawson probed him, he elaborated, and although she did not revoice the idea she did redirect it back to the students at which point Sarina gave her evaluation of the idea.

This segment further illustrated some of the discourse norms which were at work in this learning community. First is the way in which Sarina raised her hand to get the speaking floor. Once she had been nominated she told the teacher she had something to say to Kareem. It can be inferred from this that even if they are making a comment to another student, who in this case was sitting on the floor behind Sarina, they have the

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responsibility for raising their hand in order to get the conversational floor. Then, even though Sarina said that she was saying this to Kareem, she faced Ms. Lawson as she talked. Therefore Ms. Lawson was still the audience for her talk, perhaps because she nominated her to speak. This same pattern was seen with Casey earlier.

Ms. Lawson chose not to pursue the line of reasoning presented by Kareem and Sarina; instead, she returned to Casey. This may be because she had some time while Kareem and Sarina were talking to consider how to address the issue Casey raised:

Revoice	The most people were 90.
Probe	Now Casey if you're a scientist and you do an experiment and you get results that you don't agree with that you think "well that doesn't seem right to me", what do you think scientists do? What do they do if they get results that they aren't so sure about? Daniel?

(Transcript, March 8, 1993)

Several students described their ideas on what scientists would do. Eventually Casey again entered the conversation with his idea. He elaborates on the other students' ideas saying:

> I kind of think that they would use other people. They would try other people for it. Put those results down and then, and then, try some other people. About the same amount that you used on the other test. And then you find out if they got the same results. Try it three or four times and see. Cause there might be more people that got eighty nine or something. (Transcript, March 8, 1993)

Casey described replicating the experiment with a second sample of the same size but with different people, a fairly sophisticated idea. Again, he used a great deal of repetition (which is underlined), this time centering around the idea of "other people". This is a clue that he is thinking about using a different sample - one that would consist of other people. This is the final speech of the day and Ms. Lawson responded to this by ending the discussion with a summary of the discussion;

> Umhmm okay. I'd kind of like to make a conjecture...there are some other things that we wanted to do today, another experiment that we wanted to do..so would people feel comfortable if we said according to the results we have right now it looks like 90 is our approximate hand temperature..but maybe in the future we could have a time that we could recheck our results to find out for sure..because there may be other people in our class like Casey who think "that doesn't really

> make sense to me"..and we can talk about this some more but for right now, according to these results we can say it is ninety, would you be comfortable with that?
> (Transcript, March 8, 1993)

The question "would you be comfortable with that?" appeared to be a rhetorical question. Mrs. Runner did not give the students an opportunity to respond to this question before moving on to begin the procedural explanation for the day's activity, although several students nodded their heads or murmured assent. Casey did not respond one way or another to this statement.

Thus this speech marked the closing of the discussion. Ms. Lawson was apparently feeling the need to move on. Based on the lesson plans for the day, this discussion-- which lasted about 20 minutes-- was intended to be a quick introduction to the day's lesson. It was intended that the students would quickly reach the consensus that hand temperature was lower than body temperature and puzzle about why that was so. That this was not quite so simple and straightforward as anticipated is important to consider. First, students are going to have ideas of their own which may not coincide with the scientific conception. Second, any time a discussion is opened up for comments and sharing of ideas it takes considerably longer than anticipated. The result is that even the simplest concept may take a very long time to teach. For example, the idea of approximately was reviewed three times (with students requesting the third time) before students seemed to understand the idea.

Chapter Summary

This chapter was intended to give a glimpse of a typical science class discussion and discourse pattern in Ms. Lawson and Ms. Runner's room. As described in the literature review, although there exist many descriptions of what a social constructivist discussion does not look like and what the teacher and students do not do, there are few descriptions of the pattern of discourse and the roles and responsibilities of the teacher and e

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the students in a social constructivist discussion. This chapter provides one such description.

A social constructivist discussion does not have a neat and tidy I-R-E pattern in which the teacher asks a question, a single student responds, and the teacher evaluates the response. In addition to the moves of initiation, response, and evaluation there are four discourse moves present in the discussion described in this chapter which are not typically seen in a traditional discussion: probe, reasoning, revoice, and redirect. At the end of a discussion or as a segue to a new activity the teacher also occasionally summarizes the discussion. Furthermore, the moves of initiation, response, probe, reasoning, and evaluation are done by both teacher and student -- something not seen in the traditional I-R-E. Revoice and redirect were only done by the teacher in this discussion --primarily as a discussion management tool.

The most frequently seen pattern in the discussion described in this chapter was a I-R-P-RE-RV-RD in which the teacher initiated with a question which was frequently an open-ended question, a student responded, the teacher probed the student's response, the student elaborated on his or her response, the teacher revoiced the response for all students to hear and then redirected the response back to the students by asking them to comment on the response. This pattern was very context- and content- dependent, however.

Context affected the pattern when the teacher's purpose was to review quickly a piece of knowledge as in an instructional detour, for example. In these instances the teacher did not probe, and students did not give their reasoning. The result was a discourse pattern that was marked by very quick and consisted of short responses.

Content also affected the pattern. For example, Casey gave responses in which the content of his talk may have been difficult to follow or were evaluative. In this case Ms. Lawson responded by immediately redirecting rather than probing or revoicing the response. Other times the content of the talk was "off topic" or did not contribute to the ideas under discussion. In these instances Ms. Lawson also immediately redirected.

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The change in the discourse pattern from the traditional I-R-E pattern reflects a change in the view of the learner and in the roles and responsibilities of the teacher and the students. In a traditional discussion, all students are thought to be at the same point in their thinking and the teacher assumes that when a "right answer" is given it is being given for the right reasons, i.e. the student understands the content and has used that understanding to respond to the teacher's question. However in a social constructivist class discussion, students are recognized as having many different entering conceptions and developing understanding at a pace that is appropriate for them and fits with where they were in their thinking at the start of the discussion. This means that three students could give the same answer but have three different reasons for doing so. Thus, the teacher needs to probe student thinking rather than accepting answers giving at "face value". This belief in the personal, individual nature of learning in the social setting of the classroom demands that students be allowed to give their reasoning for their explanations and react to the ideas of their teachers and peers. The result is the unique discourse pattern seen in this classroom.

In this classroom the science was the discourse and the student role was one of an active participant in the discourse as they learned to control and use the discourse of science. Each student had the responsibility to listen and respond to the ideas of their peers in the form of agreeing or disagreeing with their assertions, and to use the discourse -- either through listening or through oral participation -- to make sense of the ideas for themselves. This discussion description provides the context for the stories of Casey and Padma told in Chapter Six.

Chapter 6

A SINGLE LEARNING COMMUNITY FOR ALL? THE STORIES OF CASEY AND PADMA

Introduction and Overview of the Chapter

Up to this point I have described the ways in which Mrs. Runner and Ms. Lawson created a discourse pattern in which the students played an active role in constructing and evaluating ideas. I have described what such a learning community looked like in action, highlighting the ways in which the discourse in this learning community was different from the discourse in a traditional science classroom. In this chapter I turn my attention to two students: Casey and Padma. I explore the ways in which each of them participates in the discourse, and the extent to which the discourse supports or fails to support their science content learning.

Casey and Padma's experiences in this learning community help us think about the advantages and disadvantages of a learning community in which a social constructivist discourse pattern is used. The story of Casey represents a picture of hope for students who do not do well in a traditional science classroom, while the story of Padma represents the conflict experienced by a student who is successful in a traditional science classroom and encounters difficulties when the norms for participation in the discourse in science are changed. I begin the chapter with a picture of hope.

Casey's Story: Refusing to be Invisible

I didn't originally plan to tell the story of Casey. In fact I really didn't even notice Casey during my initial observations of the Changes in Matter unit. Although he had been present every day I had observed, Casey first captured my attention during my third week of observations. And even then, I didn't realize that he was a boy. His long hair, slight build, and delicate features convinced me he was a girl.

I believe that every class has a Casey -- a student who doesn't receive as much of the teacher's attention as do many of the other students. Because this student is well behaved, appears to be engaged in the learning tasks presented, and performs at grade level academically, he or she simply doesn't demand the teacher's attention the ways many other students do. There are so many demands on a teacher's time and attention over the course of the day that a student like Casey, while not deliberately neglected or unkindly ignored, doesn't receive as much teacher attention as some of the other, more demanding, students in the class. This case, which illustrates that it is possible to construct a learning community in which all students learn - even those who might "slip through the cracks" in a traditional classroom, paints a picture of hope for students like Casey.

There were a number of possible explanations for why Casey did not immediately catch my attention during my initial observations of the third grade classroom. It may have been his dress -- he was shabbily dressed wearing the same, or similar, black T-shirt and jeans every day. It may have been his unkempt appearance - although always clean, his hair was long and shaggy, brushing his shoulders. It may have been his unassuming presence in the classroom or his lack of social interaction with the other students -- he always sat alone on the periphery of the group during class discussion. It may simply have been that he held back while many other students were clamoring for the attention of myself, the "newcomer," in the classroom.

However, what finally captured my attention was that seemingly against the odds Casey refused to be invisible. Although it was a struggle for him to participate in class discussion, he continued to bid for the speaking floor and to talk through his ideas when he finally received the speaking floor. He never gave up, no matter how difficult it was to get the speaking floor nor how minimal the feedback he received from teachers and his peers. Equally intriguing was that in spite of what initially appeared to be factors which would prevent him from being a successful, participating member of the classroom learning community --his seeming invisibility and his difficulty in getting the speaking floor during class discussion, comparison of pre- and post-test data revealed that Casey was very successful in learning the science concepts in the unit. His written post-test contained detailed explanations of scientific phenomena, many of the unit goal scientific conceptions, and few naive conceptions. Additionally, he showed considerable change between his pre- and post-test responses indicating that he had learned and understood the unit concepts.

Why was this seemingly invisible child so successful in learning the science? What was it about the learning community that enabled him to learn successfully despite the apparent odds against him? The answers to these questions can be found by looking closely at the discourse patterns in the learning community and the ways in which Casey modified these discourse patterns to fit with his learning needs. Thus, this case illustrates the value of creating a supportive learning community in which children such as Casey are able to find a discourse style that works to support their learning rather than being forced "lockstep" into a rigid discourse pattern dictated by the teacher as is often seen in a traditional classroom.

Casey's Social Status in the Third Grade Classroom

Although a white male, Casey was an outsider in this particular classroom. Many of the students in his third grade class were children of color (primarily Asian, Middle Eastern, and Hispanic). Although he represented the majority culture in this country, he was the minority in the classroom. Many of these children from other countries had also traveled extensively around both the United States and the European or Asian continents. Thus, they had many life experiences which Casey had not had. Additionally, most of the students in the classroom were from two-parent homes in which at least one of the parents was in graduate school. Often the other parent was a full-time parent. Casey was the child of a single mother who was working on an undergraduate degree.

On the Edge: Sitting Outside the Group

When considering Casey's participation in class discussion one pattern that became visible was his physical placement in the classroom during discussion. This pattern was probably closely related to his social status in the classroom. During science time the students sat on the floor in a cluster in front of the lead-teacher, who sat on a chair. Casey always sat at the front of the cluster but on the outer periphery. The only change from day to day is that sometimes he sat on the right- hand side of the room and sometimes the left.

Although many of the students sat together whispering with friends, Casey did not appear to have a friend that he sat with. He sat near different students every lesson during my afternoon visits and did not interact socially with any of the students sitting around him. During class discussion his body always faced the teacher although he often turned his head to look at whomever had the speaking floor.

Casey's physical placement during class discussion seemed to be a metaphor for his relationship with the other students in the classroom. It was not only during class discussion that he was on the periphery. He didn't appear to talk to any of the students in the class and during recess he walked around by himself on the outside edge of the other students' play. He was always respectful of the teachers; they rarely had to ask him to turn around, or be quiet, or pay attention. His proximity to the teacher (at the front edge of the discussion) may represent this respect of the teacher.

There Are Rules and Then There Are Rules: Figuring Out the Implicit Rules for Classroom Communication

Casey clearly understood the explicit norms for participation during science class discussions -- which included traditional classroom rules such as "raise your hand and wait to be called on by the teacher before speaking". He always politely and patiently raised his hand and waited for the teacher to call on him. I never observed him wave his hand in the teacher's face or make noises to get the teacher's attention. Neither did he make loud noises of disappointment when not called on. He simply waited for another opportunity and raised his hand again in a bid for the floor.

However, Casey didn't seemed to "catch on" to the more implicit norms of participation in the third grade learning community during the course of the "Changes in

Matter" unit. For example, although the explicit rule was "raise your hand and quietly wait to be called on", the implicit rules were that in addition to raising your hand you should be sitting at or near the center of the room in order to catch the teacher's eye and you should be waving your hand in the air to further ensure catching the teacher's eye.

Additionally, there were times when it was okay to forego the hand raising rule and call out ideas. One example of this was when the teacher requested a specific piece of information. In one instance the teacher said, "I can't remember, who were the people who measured their body temperature" (Transcript, March 8). The students then called out the names of the people who measured their hand temperature while the teacher recorded those names on the overhead. Self-nomination also occurred during a discussion when a student was agreeing or disagreeing with an idea that was on the floor. For example, if a child responded to a statement made by another student by self nominating and saying directly to the student, "I disagree because I think..." the teacher would revoice that student's idea rather than reprimanding the student for failure to comply with the hand-raising rule. One important, and complicating, aspect to this rule was that the self-nomination could apparently only be made when responding to an idea on the floor and currently under discussion. If a student wished to put a new idea on the floor and wanted to do so without directly referencing the idea currently under discussion, he or she had to raise his or her hand and bid for a turn.

Furthermore, rules of "conversational courtesy" had to be adhered to when self nominating. For example, students could not interrupt one another or the teacher, and overlapping talk (i.e. two students talking at once) was also not acceptable. When this occurred, the teacher would make a statement that she couldn't listen to more than one person at a time or would point out that she, or another student, already had the floor.

In addition, the speaker needed to follow the classroom discourse pattern in order to keep the speaking floor, or for their idea to be "picked up on" on carried on in discussion. As described in the previous chapter, a teacher initiation was almost always followed by a student response which was then typically probed by the teacher. Ways that the pattern was changed at different times included responding to a teacher initiation with an evaluation such as agreeing or disagreeing with a previous response, or by failing to give their reasoning in response to a probe. When this happened the speaker lost the speaking floor and the content of their response did not become part of the conversation.

Casey did not seem to figure out these quite complex and implicit rules, and he had difficulty getting and holding the speaking floor. In one memorable incident he was the only student with his hand raised to answer a question and the teacher appeared to be looking directly at him. However, she kept repeating the question saying that "someone must know" until Sarina , who was sitting front and center, said "oooh" and raised her hand. The teacher then promptly called on Sarina.

Figuring Out How to Get the Floor: A Vignette

As described above, Casey did not follow the unstated rule about calling out and waving his arm in order to get the speaking floor during whole class discussion. I wrote the following vignette after a whole class discussion (field notes 3/4/95). This vignette illustrates the difficulty Casey had getting the speaking floor but also attests to his persistence and unwillingness to just "give up" and become invisible. This particular lesson was being conducted by Ms. Smith (the student teacher) and Ms. Lawson:

Casey is sitting on the floor in his usual spot at the outer edge of the group. He is in the exact same position as during the previous day's discussion except that he has changed sides of the room. The teachers instructed the students to sit with members of their science group from the previous day. If Casey is doing so, it is not obvious to me. He is not talking or otherwise interacting with any of the students around him. As usual Casey is wearing his "uniform" of jeans and an oversized black t-shirt which hangs part way to his knees. Today he has a skinny braid in his hair with several beads in it falling from his crown the length of his hair.

Ms. Smith begins the discussion by asking the assembled class to look over the worksheet they had done the previous day and think about some things they wanted to share. The worksheet was a group-written product which the students completed as they did the day's experiment. On it the group was asked to predict what would happen to an ice cube if it were held in their hand and to explain their prediction. They were also asked to illustrate the experimental results on the worksheet. They were then asked to explain what they thought happened to the hand holding the ice cube and what happened to the ice cube. The final activity on the worksheet was a conclusion statement that the group was to write together. This statement was to say "We believe ________ because ____________".

As soon as Ms. Smith asks if they have anything they want to share, Casey raises his hand. One other student, Jack raises his hand. Ms. Smith calls on Jack. This results in an extended discussion with Jack, the teachers, and several other students. During this discussion about whether sitting by the window influenced the speed with which the ice cube melted, Casey raises and lowers his hand twice after he did not get the speaking floor. He does not attempt to participate in the discussion again for several minutes.

Several more students share their observations about the ice cube melting and their hand getting cold. Ms. Smith than makes the observation that many students were bringing in the idea that there is heat in their bodies and raises the question, "What does body heat have to do with melting?" Casey immediately raises his hand to answer this direct question; however, 5-6 other students also raise their hands and Ms. Smith calls on another student. The discussion continues with several other students sharing their ideas about body temperature and how that could cause an ice cube to melt. Sarina makes the statement that she knows her body is hot because when she has a temperature she can feel her forehead and it is hot. In response to this Ms. Smith asks, "How many people have had that happen to you?" Casey raises his hand to signal that he has had that experience but then keeps his hand in the air probably signaling that he has a comment that he wants to *make in response to Ms. Smith's question. Ms. Smith either does not see or chooses not to respond to Casey's raised hand.*

Ms. Lawson joins the conversation at this point asking, "Are there other ways you know if your body temperature is higher?" Casey raises his hand higher and keeps it up even after another student is nominated and responds to Ms. Lawson's question. Following this student's response Ms Lawson asks if anyone in the class has ever used a thermometer before. Casey already had his hand up and keeps it up in response to this question. Once again Ms. Lawson calls on another student. As this student talks Casey keeps his hand in the air for a while then slowly lowers it.

This continues for 53 minutes. Every few minutes Casey raises his hand but does not get nominated for the speaking floor. Approximately one hour into the lesson Ms. Lawson asks if anyone has ever taken their body temperature and Casey raises his hand along with many others in the class. This is evidence that he continues to be engaged in the discussion although he does not get the speaking floor when he would like it.

Ms. Lawson asks for volunteers to have their temperature taken. There is much excitement among the students and Casey, along with many others. raises his hand to volunteer. He is not one of the three selected.

During and after the temperature taking there is a lot of movement as students stand and walk to the front of the room to see the results on the thermometers. During this time Casey stands and walks around the back of the group of students trying to see the front. However, he never moves into the crowd of students but remains on the periphery. Over an hour elapsed during this lesson and, although Casey raised his hand and attempted to get the speaking floor numerous times he never got a chance to talk.

Casey's experience was not unique. We probably all remember times in our life as students that we had an idea that we wanted to share yet we could not seem to get the speaking floor to share the idea. What made Casey unique is that this happened frequently and yet he never gave up. Additionally, although he was not getting the speaking floor there was something about the learning community that helped him to make sense of the content even though he was not getting the benefit of talking through his ideas with his peers.

Rambling and Repeating: A Different Discourse Pattern

On March 3 and March 4 Casey tried hard to be part of the discussion but was never able to gain the speaking floor as is illustrated in the preceding vignette. However, persistence paid off for Casey, and on March 8 he was nominated for the speaking floor.

Not surprisingly, however, this was not the end of Casey's communication problems in the classroom. Further compounding Casey's difficulties in participating in the classroom discourse was that when he finally did get the speaking floor, his talk did not follow the established discourse pattern for sharing thinking and/or ideas in science. Often, in response to a student comment, Casey would respond with an evaluation -- agreeing or disagreeing with the student comment -- before the teacher had probed, the student elaborated, and the teacher revoiced and redirected. This interrupted the usual flow of the discourse. Instead of I-R-P-RE-RV-RD-EV, the pattern became the much briefer I-R-EV.

Additionally, in contrast to the contributions of many of the other students in the class, Casey's thinking was difficult to follow because his speech appeared disconnected and rambling. And yet, when careful attention is paid to Casey's talk it provides a window into his thinking in a way that the more structured "presentational" talk (Barnes and Todd, 1995) of other students does not.

The rambling nature of Casey's talk is illustrated in the transcript segment below in which Casey is disagreeing with an assertion made by a classmate that hand temperature is 90° F arguing that you cannot compare the hand temperatures taken by *ten* students in the class and the body temperatures taken by *five* teachers and students in the class because the sample sizes are different:

Evaluation Casey: What I mean is...Ms. Lawson...Miss Smith...Laura.. . Keung..and Takeo...they went up to get their body temperatures..and I don't think...that's not ten...and the people that said it's ninety degrees Fahrenheit...there were ten people..there were ten..we have more than ten

		people in our class..so they got ninety for it...but over here in the red [on the data table on the overhead] ninety eight I think ...cause..couldn't be ten for it..cause there's not that many people got their temperature taken.
Probe	Ms. L:	So you think there needs to be ten people.
Reasoning	Casey:	Yeah..if we had..well maybe not ten but..there were..the thing is..I just think that..that..that..it's not ninety because I think that Ajani said that ninety degrees Fahrenheit was because it had ten or David and I think it would be ninety eight even though it just has two because..um..

(Transcript, March 8)

Following this lengthy speech by Casey, Ms. Lawson appeared to make a decision to give an explanation in response to Casey's ideas. She shifted to what I have termed in other places an "instructional detour" in which she talked about the mercury indicator in the body temperature thermometers and the dangers of mercury:

Information	Ms. L:	The reason that we had only a few people take their body temperature is because...the thermometers that Ms. Smith and Mrs. Runner and I use..have a certain kind of...
Initiation	Ms. L:	What's that [looking at Mrs. Runner]..an element..you don't call it a chemical do you...?
Response	Mrs. R:	Indicator I guess we'll call it
Probe	Ms L:	You kind of...
Elaboration	Mrs. R:	It's a metal
Elaboration	Ms L:	Inside of the thermometer
Elaboration	Ms R:	In a liquid form
Initiation	Ms L:	If it breaks and you swallow it, it can kill you or just make you real sick?
Response	Ms R:	I'm not sure
Information	Ms L:	I know it's very bad for you..we didn't want to take the chance in school of having kids put those in their mouths even though probably at home that's the kind of thermometer you use..because your parent can watch you and make that choice for you so we decided that for the kids for the three kids we had take their temperature that's why we used those kind from the office.. those are very expensive and we didn't want to ask Mrs. F (school secretary) for forty of

those thermometers to throw out..um..so that's why Casey we didn't have everybody take their body temperature..but I can kind of see what you're saying..you're thinking you wish there were more people that took their body temperature is that what you're saying?

Response Casey: Umhmm

(Transcript, March 8)

This detour seemed to be a teacher explanation of why only five people (three students and two teachers) took their body temperature. This explanation, although related to Casey's statement, did not directly address Casey's concerns about sample size. However, Casey's reaction to this information is different than I would have anticipated. I believe that although the information did not directly address the stated concerns, most students would have taken the teacher's explanation as an implicit evaluation that their idea that hand and body temperature were the same to be incorrect. Casey was more tenacious, however. He did not assume that the teacher was telling him that his assertion was wrong. Rather he seemed to have assumed that it was his explanation that was problematic and he needed to create a better argument and/or better evidence for his argument. Thus, when Ms. L asked him if he still thought hand temperature was 98°, Casey took advantage of the opportunity to verbally think through another possible argument. This time his argument was a little shorter and more focused, but there was a clear pattern of repetition of ideas in his talk. During this short statement he repeats the phrases "part of the body" and "ninety eight" three times each.

Probe Ms L: So Casey you think that the hand temperature should also be ninety eight

Reasoning Casey: Yeah because it's part of the body and if your body temperature is ninety eight .um.. the hand is part of the body so..that should be ninety eight too because..um.. it's part of the body and it is ninety eight.

(Transcript, March 8)

A number of sociolinguists have examined the use of unconscious repetition in dialogue and conversation (Tanen, 1989; Hymes, 1981; Becker, 1984) and argue that repetition is the way in which discourse is created (Tanen, 1989). Tanen (1989) puts forth the idea that repetition serves as a tool for thinking on one's feet. In conversation a person might repeat something that another person has stated as they are considering how to respond to the statement, while at the same time maintaining control of the conversational floor.

Although the research on repetition refers to repetition in dialogue with one interlocutor repeating another's statement, the idea of repetition can also be applied to monologue where one speaker repeats himself. Casey appeared to be unconsciously using repetition as a floor-holding device in his monologue. Because he had difficulty getting the speaking floor, he may have tried to keep it through repetition of his ideas. Thus he might have used the strategy of repetition to hold the floor while thinking through what he wanted to say. Alternatively, he may have been repeating himself in an attempt to clarify his meaning further so that the teacher would not misunderstand the point he is trying to make.

Repetition may also have served another, more conscious, purpose for Casey. As he elaborated on his original idea he may have continually returned to a specific phrase as an "organizing phrase." When elaborating he may have been aware of the ease with which he could become confused or lose his train of thought so he used repetition as a way to keep reminding himself of the idea that he was thinking through. In the example below the word "ten" or phrase "ten people" appears to be the "organizing phrase". The use of such an organizing phrase may also be an unconscious strategy used by Casey whenever he talks thorough his ideas:

> Casey: What I mean is...Ms. Lawson...Miss Smith...Laura..Keung..and Takeo...they went up to get their body temperatures..and I don't think...that's not ten...and the people that said its ninety degrees Fahrenheit...there were ten people..there were ten..we have more than ten people in our class..so they got ninety for it...but over here in the red [on the data table on the overhead] ninety eight think.. cause..couldn't be ten for it..cause there's not that many people got their temperature taken.
>
> (Transcript, March 8)

For whatever reason, the use of repetition is a common, although perhaps unconscious, strategy for Casey. This repetition marks his responses as being different because there was not repetition seen in the responses the other students in the class gave.

Casey's Exploratory Speech

Speaking turns of the length of Casey's were not the norm in this classroom. Although most students had moved away from the "right answer" approach of giving the teacher the answer she was looking for, most of the students' responses were "neater" than Casey's longer "exploratory"[1] speech. In general most students' responses followed a pattern of making an assertion and then giving a single piece of evidence to support that assertion. Casey on the other hand would often make several assertions and give several pieces of evidence when he got the speaking floor. The different assertion-evidence patterns, and the contrast between Casey's exploratory talk, and the "neater" briefer talk of his classmates can be seen in the transcript segment below:

Response	Henri: *The air needs to be hot or warm for it to melt the ice cube.* (ASSERTION)
Nomination	Ms. L: Casey?
Response	Casey: *I think to make it melt faster the water, it becomes the ice when it gets, well when it freezes, and it , and there has to be air in it.* (ASSERTION)
	Because there is air in everything. (EVIDENCE)
	And, the cold air turns the water, the ice cube cold so then it, so then the hot air rises and the cold air goes down. (ASSERTION)
	I was reading in a book that hot air is [inaudible word] than the cold air so the hot air will push the cold air up and then go out of the ice cube and then there would be a clear path for the hot air to go up to the ice cube to melt it. (EVIDENCE)
Nomination	Ms. L: Zane?
Evaluation	Zane: *I disagree with Casey .* (ASSERTION)

[1]Barnes and Todd (1994) used the term "exploratory talk" to designate talk which is for the purpose of exploring and reconstructing ideas. Thus, exploratory talk used by students as a tool for making sense of ideas. Exploratory talk, according to Barnes and Todd is more common in small group discussions where there is not a teacher than in teacher- led class discussions.

Because it [air] can go in any direction. (EVIDENCE)

I still agree with him that hot air can go up but it can go in other directions also. (EVIDENCE)

(Transcript 3/3)

Thus, possibly due to the length and the unfamiliar pattern of his talk, teachers and students alike often did not respond to Casey's ideas using the established discourse patterns in the class.

To the casual observer it may have appeared that during class discussion there was an open sharing of ideas in which the teacher was merely facilitating turn taking. However, on closer inspection, this was not the case. Although not the traditional drill and recitation format frequently seen in elementary science, there was a pattern which was being followed. As part of this pattern the teacher was working very hard to draw out and expand upon student ideas which would reveal some aspects of their thinking about the concepts under discussion or would lead in an interesting and productive direction for student learning of the science concepts.

Casey and the Social Constructivist Learning Community

The most common discourse pattern in this class was not the traditional I-R-E sequence (Mehan, 1979; Cazden, 1988). In a traditional I-R-E sequence the teacher initiates by asking a question to which there is a scientifically accepted "right" answer, the student responds to the question, and the teacher evaluates the accuracy of this response. For example, the teacher might ask "What is our body temperature?" to which a student would respond "ninety eight degrees Fahrenheit." The teacher would acknowledge the accuracy of this response by saying something like "good," and would move on to the next question.

There were multiple differences in the discourse pattern in this classroom compared to the traditional I-R-E sequence. The result of these differences was a classroom learning community which had the characteristics of a social constructivist learning community. In contrast to the traditional I-R-E pattern, the teacher initiation in this classroom was frequently an open-ended question such as "Would someone like to share something interesting they noticed when measuring their hand temperature?" Students would then raise their hands and bid for an opportunity to share their thinking and ideas. Once a student had responded the teacher then frequently probed the student, the student gave their reasoning for their idea, the teacher revoiced this reasoning, and then redirected it back to the class for their comments saying, "What do other people think? Do you agree or disagree?" To which other students would make an evaluation (either agreeing or disagreeing) and provide evidence for the evaluation. Thus the pattern in this class was frequently teacher initiation-student response-teacher probing-student reasoning-teacher revoicing and/or re-initiation.

The transcript segment below illustrates a typical teacher-student interaction following the initiation-response-probe-reasoning-revoicing/redirect pattern frequently followed during class discussion. In this particular segment the teacher probed by revoicing with rising intonation indicating the revoicing was a question. The student in this interaction chose not to give their reasoning:

Initiation	Ms. L:	And if you find something you want to share, raise your hand and Ms. Smith is going to record it on the overhead. Okay.. Reiko?
Response	Reiko:	We believe the ice cube on the table takes longer because our ice cube was bigger.
Probe	Ms. L:	So you are saying that since your ice cube was bigger it took longer?
Response	Reiko:	Yeah
Redirect	Ms. L:	Anybody have any thoughts about that? What do you think about that?
Revoice	Ms. L:	They thought their ice cube was bigger so that would mean it would take longer.

(Transcript, March 3)

This exchange in which Reiko reads her answer directly off her paper is very different than Casey's lengthy musings. The majority of class discussion fit into the mode above. Although some student responses were more concise and some were longer, rarely were they as lengthy as Casey's. What marked Casey's talk as being different than the norm was that while the responses most students gave to a teacher initiation were not a single word response, they were typically a single assertion supported by a single piece of evidence. These responses were much more concise and clear than Casey's responses. In this way most students did not appear to be talking through their ideas out loud to the same extent that Casey did and thus they did not have the exploratory quality seen in Casey's talk.

Perhaps as a result of the differences between Casey's talk and that of his peers, the teacher often did not follow the pattern of revoicing and reinitiation when talking with Casey, and the exchange didn't "fit" with the flow of the rest of the class. The transcript excerpts below shows the teacher's response to Casey's statements the two times he got the speaking floor during a discussion on March 3. In this discussion students are sharing ideas about what makes an ice cube melt and how to make it melt faster. Neither of Casey's statements fits the discourse pattern in that they are long and exploratory:

Response/ Reasoning	78 C:	I think to make it melt fast the water, it becomes ice when it gets..well when it freezes, and it, and there has to be air in it because there is air in everything. And, in the cold air turns the water,the ice cube cold so um, then it , so then the hot air rises and the cold air goes down. I was reading in a book that hot air is lighter than cold air so the hot air will push the cold air up and then go out of the ice cube and then there would be a clear path for the hot air to go up to the ice cube to melt it.
	79 T:	Jack?

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Evaluation	91 C:	I kind of disagree because I think the hot air is only on the bottom. It doesn't go on the top. But the hot air is on this side, it is going this way [gestures with hands]. And the cold air, I think the cold air won't be going that way. They are always, the hot an cold air are always connected...So, I don't know..maybe it will work..if the hot air was up here and the cold air was here [illustrates with hands] than the hot air wouldn't be rising, it would be going in the cold air.
	94: T:	Carlos?

It was also difficult to always follow Casey's argument and grasp his meaning when listening to him talk. This may have influenced the teacher's responses to Casey. Perhaps because Casey's responses are long and rambling, Ms. Lawson (represented as "T" in the transcript segment) does not follow the pattern of probing, revoicing and reinitiation but rather listens quietly to Casey and then calls on another student without responding to Casey in any way.

Unrehearsed speech: The Language of Casey's Learning

One possible interpretation of Casey's exploratory, repetitious speech is that he was just talking to hold the speaking floor because it was such a novelty to have it. However, based upon the connections among ideas that Casey made by the end of the unit, I believe that the talk is representative of much deeper, and more complex, thinking on Casey's part than might first be assumed.

The repetition, the disconnectedness, and the exploratory nature of Casey's speeches resulted in speaking turns that were much longer than the turns taken by other students in the class. All of these are indications that Casey's talk is what I call "unrehearsed talk." Casey did not seem to have mentally thought through exactly what he was going to say. He did not respond with the neat, coherent answers more commonly heard in classrooms, including this one. Instead, Casey appeared to know that he has some ideas about the topic under discussion and bids for the speaking floor as an opportunity to "think through" his ideas out loud. Although the ideas appear disconnected from Casey's perspective they may be very connected. He may just not yet have reached the point where he can articulate the relationship among the different ideas that come "spilling out" when he has the opportunity to "think aloud."

The repetition in Casey's speech is another indicator of this exploratory talk. If Casey had thought through, or "rehearsed," his ideas prior to getting the speaking floor he may not have needed to use the linguistic tool of repetition. Rather he appeared to use repetition unconsciously to hold the speaking floor while figuring out what word or idea to say next.

Following Casey's speaking turns, perhaps due to the exploratory, unrehearsed nature of his talk, there was generally limited uptake of his ideas in the form of repetition or reviocing by the teacher or agreeing/disagreeing by his classmates, thus his ideas rarely became part of the class discussion. But, surprisingly, this did not stop him from continuing to argue the position he was taking or from further clarifying his ideas verbally. When he could get the speaking floor he would often return to the original idea that he had voiced, even though there was no, or limited, uptake. Often as Casey talked through his idea for a second or third time he would alter it slightly, perhaps based on further reflection or as an attempt to clarify his thinking for himself and/or his classmates.

The way in which Casey verbally revisited and modified his ideas is illustrated in the three statements below which were all made at different times on the same day. Each statement is an argument that hand and body temperature should be the same temperatures (rather than hand temperature being 90°C), yet each has been modified slightly as Casey has listened to, considered, and responded to, the comments made by his classmates.

Evaluation	104	I disagree with Nick's idea [that hand temperature is 90°F] because.. um..ninety degrees has ten people out of the whole classroom and *here weren't ten people to get their temperature taken for the one over there* [body temperature] so I think that it is ninety eight. (Transcript, March 8)

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Evaluation	112	Ms. Lawson, Ms. Smith, Laura, Keung, and Takeo went up to get their body temperatures and I don't think...that's not ten and the people said that its ninety degrees Fahrenheit there was ten people...there were um ten..*we have more than ten people in our class* so they got ninety for it but over here in the red ninety eight I think....cause...it couldn't be ten for it cause there's *not that many people got their temperature taken.* (Transcript, March 8)

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Probe	140	Ms. Lawson: So you think that the hand temperature should also be 98.

Reasoning 141 Casey: Yeah because *its part of the body* so...that should be ninety eight too because um...*its part of your body* and it is ninety eight.

(Transcript March 8)

In line 104 Casey stated his argument that hand and body temperature are probably both 98°F, and he argued that you can't compare hand and body temperature because the sample sizes are different ("there weren't ten people to get their temperature taken for the one over there"). In line 112 he restated his argument that the sample sizes are different and cannot be compared. He clarifies this further by listing the names of the students who took their body temperature and pointed out that there weren't ten people. He expanded his argument further arguing that the sample size for hand temperature is too small: "We have more than ten people in our class". He again entered the conversation several minutes later after having had the opportunity to listen to his classmates and possibly to consider his position further. At this point he offered another argument, that the hand is part of the body and if body temperature is 98°F then so too is hand temperature. He reinforced this idea by repeating it twice.

Again, this clarification, modification, and addition of ideas is evidence of the unrehearsed nature of Casey's talk and indicates that he is using the discourse as a tool in his learning rather than as a way to display his knowledge. Even though he did not receive teacher support in the form of revoicing, clarification, and/or uptake of his ideas, he still apparently used the classroom discourse as an opportunity to play with ideas and make some sense of the science content. This may account for the progress in the sophistication of his ideas during this unit.

At the beginning of the unit, students were given a written pre-test composed of constructed response questions to determine their understanding of the content prior to instruction and to identify any naive conceptions. At the completion of the unit a similar post-test was given. The same content was assessed, however, in some instances, the situation the students were asked to explain was slightly different. Detailed information on the content of the tests and the scoring rubrics can be found in Chapter Seven. Once a student had taken both the pre- and the post-test, gain scores could be calculated to determine the extent of an individual student's learning.

A comparison of Casey's pre- and post-unit written assessment provides evidence for the claim that the opportunities to talk through his ideas in class deepened his understanding of the science content. Casey's pre-test score was 48% and his post test score was 71%, a gain of 23% from pre-test to post-test.

The Beauty of Social Constructivism: Allowing the Non-Conformist to Thrive

The discourse pattern described in Chapter five and Casey's frequent failure to conform to this pattern illustrate the beauty of a learning community undergirded by a social constructivist perspective. At the start of this chapter I raised the question, "What was it about the learning community that enabled a student like Casey to succeed in science class?" I believe there are two key features of the learning community which supported Casey and enabled him to engage in and learn the science concepts.

The first was that the teachers encouraged students to puzzle through their thinking and ideas --although at this point in the year most students were using what Barnes and Todd, 1994) refer to as "presentation talk" for the teacher-audience rather than the "exploratory talk" (Barnes & Todd, 1994) that was being encouraged. In this class thinking was valued over a single right answer. Because of this, even though Casey had difficulty figuring out how to get the speaking floor, he was still engaged in thinking about the concepts in a way which promoted his understanding. This sort of thinking and the resultant understanding is not promoted in a classroom in which the student is focusing on a single right answer which they rarely get the opportunity to share. Even while Casey had his hand in the air waiting to share an idea (which he may or may not get an opportunity to do) he was thinking about his idea, listening to other students' ideas, and perhaps modifying his own thinking. Although clearly it was an advantage for him to be able to think through his ideas verbally, he appeared to be actively engaged in thinking even while not always given the opportunity to think aloud.

Evidence to support this claim of apparent engagement in the content comes from Casey's post-test data in which he uses some of the same language that emerged in the class discussion. For example, one concept that was discussed repeatedly throughout the unit was the idea that the change in temperature of matter, i.e. snow, is caused by contact with a substance, such as air, that is a different temperature. Although not in his pre-test responses, the idea of air causing a temperature change was present in four of Casey's five post-test explanations for the temperature change of some piece of matter. For example, when asked why hot chocolate in a cup cools off over time Casey responded, "The air cools it off". This contrasts with a pre-test response, "Because you would let it sit so long it would get cold". Similarly, when asked why the snow on a pair of boots melted when brought inside Casey responded, "It (snow) is a form of water that is cold and warm air melted it".

Another concept that was stressed throughout the class discussion was that temperature could be measured in degrees Fahrenheit or Celsius and therefore it was important to always include units when giving the temperature of an object. Casey included Fahrenheit units on his pre-test responses and continued to do so on his post-test responses. It appears that he understood the importance of units prior to the unit and this was reinforced throughout the unit. It is also interested that he did not appear to be confused by the option of using degrees Celsius but continued to consistently refer to the temperature in degrees Fahrenheit.

The second key feature of this learning community was the established discourse pattern which, while clearly structured, was flexible enough to accommodate Casey's different discourse style. His exploratory style of talk, while challenging for students and teachers to follow, was not ridiculed or cut off. In this way students in the class were allowed to work through their thinking and ideas in a way that was most productive for them rather than in the way that is most productive for the teacher. This is a unique approach to class discussion and certainly complicates the discussion for both the teacher and the students as they learn the new discourse norms.

The Story of Padma: A Quiet Enigma

I noticed Padma almost immediately during my first visit to Atlantis Elementary. She was intrigued by my presence in the classroom. During that first visit she asked me what I was doing there, and when I told her, asked if she could be one of the students I was studying. When I consulted with Mrs. Runner about selecting Padma as a target student, she recommended her because she considered Padma to be bright and articulate. She felt that I would be able to get good information about Padma's thinking if I were to interview her. According to Mrs. Runner, Padma enjoyed writing and talking about her ideas in science. Combined with her eagerness to be part of the study, this enjoyment of writing and talking about science convinced me that she would be an interesting target student.

Beginning at the End: Padma's Science Learning During the Unit

What emerged over the course of the two months I was in the classroom was a surprisingly different picture of Padma than I had anticipated based upon my early observations and interactions with her. The unit pre- and post-test revealed that Padma had made only limited progress along the continuum towards scientific understanding. Her post-test score of 48% was only 10% higher than her pre-test score of 38%. This contrasts with a mean gain score of 25% for her classmates.

In addition to the quantitative data, qualitative analysis showed that although Padma's answers to the constructed response items on the post-test were longer than her pre-test responses, they were primarily descriptive rather than explanatory and involved a lot of repetition of information. She said what she wanted to say and then repeated it in a different way which made the response appear initially to be very detailed. However, further analysis revealed a heavy reliance on repetition rather than on developing an explanation.

For example, one question which appeared on both the pre- and post assessment read:

> "It is a cold day in winter. The temperature outside is below freezing. You take a thermometer outside and stick it in a snow bank. After a couple minutes, you take the thermometer out and read the temperature. What would the temperature probably be? Why would the snow be this temperature?"

A student holding the goal conception would respond to this question by giving a reasonable temperature below 32° F. The accompanying explanation would be that this temperature is below freezing which is necessary because snow is solid (frozen) water. On the pre-test Padma responded to the question by giving a temperature of 0° (no units were given) . Her explanation for predicting that snow was this temperature was brief -- "Because it is very cold outside". On the post-test Padma gave a temperature of 13° (no units) with the explanation, "Because it is very cold day and if it is a very cold day then the snow would probably be cold so 13° would be a good temperature I think". In this response Padma relied on the information in the question, "it is a very cold day", rather than drawing on the knowledge learned in the unit. She repeated "cold" or "very cold day" three times in the same sentence. However, although she repeated the information in the question, Padma did not pick up on a critical piece of information in the question that it is below freezing. Thus, although she did give a temperature that is below freezing she only justified it by saying it was a cold temperature and did not further justify it by stating that it was below freezing.

Science as Discourse: Not for Padma

As Mrs. Runner predicted, Padma proved to be delightful to interview and was quite articulate about her learning and about the role of talk in her learning. However, there were some puzzling contradictions between her talk in the interviews and her actions during class discussion. For example, in the first interview she said that during class discussion, "I don't care if I have the best answer. All I really think about is if I really get it" (Interview #1). And yet, during class discussions, she typically only responded to calls for "known answers" or data. She did not take advantage of the opportunities to puzzle through her thinking out loud the way that Casey did, although I expected her to do so based upon in her talk in that first interview.

In all but the last interview -- which was a group interview involving Padma and two of her classmates -- Padma was articulate and thoughtful as she described how she talked with her peers to help her make sense of the science content. For example, when asked how talking with her classmates helped her make sense of the science content she responded, "If I have a different idea and they have a different idea we can kind of get together and see what's the best idea. And then you come up with the best idea together". (Transcript, Interview #1). It is possible that she did have these kinds of conversations with her friends at some time outside of science class. However, during science class there was no evidence of her combining her ideas -- at least orally -- with her classmates' ideas in order to reach a conclusion based upon those ideas. Again, her oral participation during science class discussions was very different than Casey's and very different from the way in which she described her participation.

The disappointing growth seen in Padma's science content understanding combined with the discrepancy between her talk in interviews and her actions in class contributes to a picture of a student who knows the role that the classroom discourse should play in her learning, but has not yet learned to control and use the discourse in support of her learning. Although Padma was making progress towards a vision of science as Discourse, she is not yet to that point. Thus, the science learning community which was so engaging and successful in supporting the science concept development of many children in the class, including Casey, did not appear to support Padma's science learning.

This case raises some new questions about the learning community in this classroom. Why was Padma, who was perceived by her teacher as a successful student, apparently so unsuccessful in learning the science in this unit? What was it about the learning community that hindered Padma from learning despite the perceptions of her teacher and peers that she was a "smart student"? Does Padma's participation in the discourse give us any clue about why her learning did not show the remarkable growth that Casey's did? What hindered Padma from learning to control and use the discourse to the extent that Casey did? Possible insights into these questions can be found by looking closely at the classroom discourse patterns and the ways in which Padma used the discourse, possibly unconsciously, to allow her to appear successful to her teacher and peers -- and possibly herself-- while avoiding engaging in the science content in a way that promoted her learning.

Things Are Not Always What They Appear

Most classes have a Padma -- a student who is perceived by teachers and classmates as smart. Sometimes such students are especially "smart" about learning how to play the game of school. They have learned how to be pleasant to have in the classroom and to always appear eager to learn and willing to "do the work". This good student behavior may conceal, however, learning struggles. I believe this was the case with Padma. Padma was very good at appearing to be a good student. She always came eagerly to the team area for science, she completed all her seat work neatly and in a timely fashion, and she was always eager to help the teacher in small ways such as running messages to the office or washing chalkboards at recess time.

As a result of these activities, Padma was a student that Mrs. Runner noticed favorably. However, most of the activities where Padma captured Mrs. Runner's attention in such a positive manner were non-instructional activities. Surprisingly, during instructional time Padma seemed to disappear. Occasionally she would emerge temporarily; for example, if she had data to contribute to a data list or if a known-answer question were asked she would raise her hand to talk. But during the intellectually engaging discussions where the students were encouraged to construct their understanding of the science concepts, Padma rarely raised her hand to participate and thus seemed invisible. She found many opportunities during the day to attract the teacher's attention in a positive manner but she apparently "shut down" when the more conceptually challenging discussions were taking place without drawing the teacher's attention to her lack of participation.

When Actions Don't Match Words: The Silent Enigma

As described earlier in this chapter, the discourse pattern in this class during a whole class discussion was considerably more involved than the traditional I-R-E pattern frequently found in science classrooms. While this pattern did include the moves of initiation, response, and evaluation, these moves could be made by either the teacher or the student. This contrasts with the I-R-E pattern in which the only move the student makes is "response". In a social constructivist classroom, there were also the moves of probing, elaborating, revoicing and redirecting. These moves are not present in a traditional I-R-E discussion and thus can be used as one way to characterize a social constructivist discussion.

Further characterizing this discussion as unique was the way in which Ms. Lawson or Mrs. Runner redirected a student's response or reasoning. This redirection frequently involved what I call the agree/disagree pattern. The teacher would redirect the question by calling specifically for the students to evaluate an idea on the floor by agreeing or disagreeing with the idea. For example, once a student had put on idea on the floor, such as, "We believe our ice cube melted faster than the others because it was smaller," the teacher would turn the response back to the students and say, "What do other people think? Do you agree or disagree and why?". Other students would then make an evaluation (either agreeing or disagreeing) and provide evidence or reasoning for the evaluation. This agree/disagree pattern was part of the literacy curriculum and was a strategy which students were implicitly taught through repeated calls for agreement or disagreement. This agree/disagree was a discourse strategy that was being taught school wide across the year (Smith, 1995).

In an interview midway through the unit Padma described her participation in class discussion and had some surprising things to say about the agree/disagree strategy when asked about it:

KP: You said that you talk to your friends a lot and that sometimes they help you when you don't understand something. How about when you are in the team area talking? Does it sometimes help you to think of new things to hear other people's ideas?

P: Yeah, because when I listen to them talk people might say things about it and I think, "yeah, that would be a good idea so..." [voice trails off]

KP: So even though there are forty kids sitting there on the floor you can still kind of listen and figure out what people are saying and get ideas from them?

P: Umhmm, right.

KP: Can you think of something that you might learn from talking to somebody that you wouldn't learn as well if you were just working by yourself? Is there anything in science class that it really helps to work with other people?

P: Well, yeah. Like if I have a different idea and they have a different idea we can kind of get together and see what's the best idea. And then you come up with the best idea together.

KP: Okay. How, do you ever disagree on what is the best idea?

P: No, we never disagree. We just kind of, well we kind of talk about it, and then, I don't care if I have the best answer or not. But lots of my friends don't care about that either. So we just....[voice trails off]

KP: You don't care if you get the best answer. So what is important to you? What do you care about?

P: I don't care if I have the best answer. All I think about is if I really get it.

(Interview, March 18)

I was surprised by many of Padma's statements about the value of discourse. My perceptions of her participation were quite different than her own. First, she described herself as very much an active listener, listening to other people's ideas and using those ideas to help her make sense of her own ideas. This was not apparent to me when observing her. Although she appeared polite and one might assume she was listening, her lack of verbal participation communicated disengagement to me.

I was also surprised when I asked her whether there was ever any disagreement about the best idea and she said that there was not. This contrasts sharply with the lesson transcripts which show that frequently students began their statement by saying "I disagree with..." or "I agree with..." And, as noted above, this was a discourse pattern which was stressed as being productive and encouraged by the teachers through questions such as "Do you agree with that statement?"

There are several possible explanations for this discrepancy. One is that in reflecting back on the class discussions, Padma is remembering tone rather than exact words. She may associate the word "disagree" with an argumentative tone which was not typically present. Therefore, even though the words "disagree" are used, she may not associate them with her definition of disagreement. This explanation casts a favorable light on the learning community. Although students are continually disagreeing with one another's ideas, and are encouraged by the teacher to do so, there is not an argumentative tone to the class nor is there an atmosphere of animosity or hostility among the students as they disagree with one another. If there were such an atmosphere, Padma might be more likely to remember that there was a great deal of disagreement taking place.

An alternative explanation for the discrepancy between the level of disagreement in the class and Padma's perceptions of the amount of disagreement is that Padma is not as engaged in the discussion as she appeared and thus was unaware of the level of productive disagreement that was taking place. Her scores on the unit post-test suggest to me that this is a likely explanation.

During the short interview segment above Padma said twice, "I don't care if I have the best answer." This was an idea that the teachers stressed to the students throughout the unit discussions. They were frequently told that the purpose of the discussion was to share ideas and to figure things out and that there were not right and wrong answers to many of the questions. This was reinforced by the discourse pattern in which there was little teacher evaluation of a statement but rather the teacher reinitiating through calling for agreement/ disagreement from the students. Padma had heard the statement that it wasn't important to get a right answer enough to repeat it in the interview. However, her unwillingness to participate in the class discussion and her volunteering to answer only familiar questions and questions with specific "right" answers would seem to contradict this statement. Perhaps intellectually she knew that it didn't matter if she gave a wrong answer. However, she may still not have felt "safe" enough in the learning community to risk giving a wrong answer. Again, this gives support to the assertion that although Padma knows that discourse is to play a role in her learning, she has not yet learned to control and use the discourse to support that learning.

Although I believe the teachers in this classroom think "smart students" are the ones who engage in sharing their thinking and ideas with peers and who puzzle through their thinking out loud, this is not the traditional definition. A traditional definition of a smart student is one who regularly responds with the correct answer when called upon by the teacher. I believe that Padma is having a difficult time overcoming her belief - gained through three years of full time schooling- that a smart student is one who always knows the right answer. She may unconsciously be in conflict between what the teachers are saying, "that it doesn't matter if you have a right or wrong answer as long as you share your ideas" and what she believes to be true -- it matters very much that you have the right answer -- based upon her previous experiences as a student. Additionally there are not negative consequences for her using the discourse to share "right answers" rather than to puzzle through her ideas. She is not reprimanded in any way for giving "right answers" and in many ways is reinforced for doing so -- she is considered by Mrs. Runner to be a smart student. The first day I observed the class Mrs. Runner pointed her out to me as a

Response	Yazwa:	Um..um...
Probe	Mrs. R:	Would you tell us..what do we put before the number?
Response	Yazwa:	We put..um.. [Padma raises her hand]
Redirect	Mrs. R:	Padma?
Response	Padma	A minus sign
Revoice	Yazwa	A minus sign
Revoice	Mrs. R:	We put a minus sign

(Transcript, March 16)

In this interaction Mrs. Runner was looking for a specific piece of information -- a "known answer" -- which Padma provided. Once she provided this both Mrs. Runner and her friend Yazwa revoiced her answer.

A few minutes later in the discussion Padma again participated in a slightly different way. This second time she participated she provided data collected by she and her partner. In this example, students had just returned inside from measuring the temperature of the snow outside. While discussing the results of the temperature of the snow in the cup, Mike had argued that the snow that was indoors in the warm room air would be warmer than the snow that was outdoors in the cold air. To test this hypothesis the students worked with a partner to measure the outside temperature of the snow. In the transcript segment below Mrs. Runner was having the students share their data:

Initiation	Mrs. R:	Let's share the temperatures that we found. What did you find, Yazwa?
Response	Yazwa	I found thirty degrees Fahrenheit and zero degrees Celsius.
Evaluation	Mrs. R:	Okay..I'm going to write these up on the board
		(several other students bid for the floor, are called upon, and share their data)
Initiation	Mrs. R:	Okay...somebody...all right...Padma?
Response	Padma:	Forty degrees Fahrenheit.

good potential target student because she was "bright" and "articulate" and a "good student" (Fieldnotes, February 25).

A question that the reader might have at this point is why Mrs. Runner didn't challenge Padma more. Why is Padma allowed to sit quietly and participate only when there is a called for "known answers" or data. One possible explanation is that because Mrs. Runner perceives of Padma as bright and articulate, she may have simply assumed Padma understood the concepts under discussion even when she was not participating verbally.

Safety in Numbers? Not for Padma!

About mid-way through the unit on "Changes in Matter" the class was divided into four smaller, teacher-led working groups. Padma was with her two good friends, Sarina and Yazwa, in this small group. The smaller group size -- there were about ten students in the group --coupled with being with her friends may have been less intimidating for Padma than the large group. Evidence to support this claim is that on the first day she was present in the smaller group (she had been ill the first day of small group discussion), Padma began to participate a little more than she had during large group discussion. For example, during a single twenty minute discussion on March 16 she provided the way to indicate in writing that a given temperature was below zero, she provided a piece of evidence for the argument that the temperature of snow is not always the same, and she shared a data point she had collected with her partner .

In the first example described above -- providing a way to indicate in writing that a given temperature was below zero, Mrs. Runner had asked the students in the group to tell her the temperature of snow in a cup according to their data table:

Initiation	Mrs. R:	Who has a number for the snow? Yazwa?
Response	Yazwa:	For Celsius I have...for Celsius the snow was..below zero..
Probe	Mrs. R:	So how do we write that according to what Casey told us?

Response	Yazwa:	Um..um...
Probe	Mrs. R:	Would you tell us..what do we put before the number?
Response	Yazwa:	We put..um.. [Padma raises her hand]
Redirect	Mrs. R:	Padma?
Response	Padma	A minus sign
Revoice	Yazwa	A minus sign
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		(several other students bid for the floor, are called upon, and share their data)
Initiation	Mrs. R:	Okay...somebody...all right...Padma?
Response	Padma:	Forty degrees Fahrenheit.

Revoice	Mrs. R:	Forty degrees Fahrenheit.
Revoice	Padma:	Forty

(Transcript, March 16)

In this conversation Mrs. Runner was collecting data without passing judgment on the correctness of that data. And, prior to Padma's sharing her data, several other students had also shared their data. Padma was able to check her numbers against those of the others and see that her data was nearly the same as theirs before sharing her data. Thus Padma's contribution was reasonably non-threatening -- all numbers were being accepted and hers compared similarly to ones already given.

Although her participation still tended to be limited to brief data sharing or responses to known answers, during small group time Padma also attempted to participate in the agree-disagree discourse for the first time in this unit. The topic under discussion at this point in the conversation was whether the temperature of snow is always the same or whether snow is different temperatures as determined by the temperature of the air around them. Evidence to support the students in making their assertions could be found in the two data tables they had completed in their science notebook; one table of the temperature of snow in the cup in the warm room air and the other the temperature of the snow in the cold outdoor air.

Redirect	Mrs. R:	How many of you would like Jake to repeat his idea...so that you could think about it...okay...Jake could you say that again so that we can all think about it?
Response	Jake:	I think that from two minutes and like um if another guy like if you put it in for two minutes and another guy put it in for three minutes there is no difference because the snow isn't changing only the weather gets colder.
		(Kent raises his hand)
Redirect	Mrs. R:	Kent?
Evaluation	Kent:	I agree.

Redirect	Mrs. R:	Let's go to Padma now I think she had her hand up a minute ago.
Response	Padma	I was gonna say..when you said..um.. that the weather...my mom says that in Michigan the weather changes every minute.
Revoice	Mrs. R:	I see.. then you agree with the idea that the weather changes because in Michigan your mom says it changes every minute.
Response	Padma	Umhmm

(Transcript, March 16)

This is the first time since the beginning of the unit observations in late February that Padma has agreed or disagreed with a classmate. She not only agreed with Jake, but she provided evidence to support her agreement. Therefore, on the first day of the small group discussions Padma participated three times during one discussion. This is more than triple her typical daily participation. Furthermore, although two of her three discourse moves are ones which could be considered "low risk" interactions, this third move represents a considerably higher risk move. Considering Padma's verbal participation up to this point, this is a fairly remarkable change.

Padma's Continuing Participation: Progress or Only An Illusion?

Padma continued to participate in the small group on the following days although after her one "breakthrough" in which she agreed with a group member and provided evidence to support her assertion, she fell back into her pattern of sharing responses only to "known- answer questions". For example, in the discussion below a student has just read the definition of boiling from the encyclopedia:

Revoicing	151	Mrs. R.	The boiling point is the temperature at which the liquid evaporates.
Response	152	Timothy	Vapor
Revoicing	152	Mrs. R.	Timothy is saying vapor.
Redirect		Mrs. R.	Have you heard that word before? Vapor? Have you heard the word vapor?

Response	153	Padma	Evaporate
Revoice	154	Mrs. R	Evaporate

(Transcript, March 30)

Again, Padma participated when she could give a short response to which there is a "right answer". When there were opportunities for Padma to expand on her ideas or puzzle over them orally, she either withdrew from the conversation or turned the question into a known-answer response. Puzzling through her ideas orally appeared to be risky for Padma. One example of her withdrawing from a potentially intellectually risky conversation is seen in line 74 in the transcript segment below:

Initiation	69	Mrs. R:	We have measured some temperatures within this room. The temperature of the air. What do we call the temperature of the air that's in this room?
Response	70	Padma:	Room temperature.
Revoice	71	Mrs. R.	Room temperature.
Initiation	72	Mrs. R.	What did we find the room temperature to be? What does that mean then? How would you define the temperature that is in this room?
Response	73	Padma	Seventy two degrees.
Probe	74	Mrs. R.	Suppose someone said to you, "What do you mean Padma, when you say the room temperature of the air is seventy two degrees."? Suppose someone asks you, "What do you mean about room temperature? I don't know what room temperature is" What would you say to them? How would you answer that?
Response	75	Padma	[eyes downcast] shakes her head no.

(Transcript, March 30)

Padma's response to Mrs. Runner's probing effectively ended the discussion. Any further probing by Mrs. Runner would probably have felt to both Padma and Mr. Runner as if she were badgering Padma. It is doubtful Padma was willing to say anything more, regardless of how many questions Mrs. Runner asked, or how kindly they were asked.

Another example of Padma's reluctance to puzzle through her ideas even when explicitly encouraged to do so by Mrs. Runner occurred in another small group discussion. The class was discussing ways that you could make a hot liquid like soup cool enough to eat as well as ways that you could make a room temperature drink cold. Mrs. Runner had posed the following problem to the class:

> All right, supposing you went to somebody's house for a birthday party say, and they had lots of glass sitting out like we sometimes do in here. You didn't feel like you wanted something real cold to drink that day but your only choice was red pop. Now some of them had four or five ice cubes in them and some of them had one or two ice cubes in them and some of the glasses had no ice cubes in them. If you didn't want something real cold to drink that day which one would you choose? (Transcript, 3/29)

Mrs. Runner was developing the concept that if two objects of different temperature come into contact with one another, both will change temperature. She hoped that the students would respond to her questioning selecting the glass with no ice, because if there was ice in the glass the liquid touching the ice would become colder; therefore, the pop would be cold. Padma immediately raised her hand in response to Mrs. Runner's question;

Response	Padma:	The one with no ice.
Probe	Mrs. R:	Why?
Reasoning	Padma:	Because..ice is cold..and you would expect the red pop to get cold and the red pop with no ice just stays red pop.
Probe	Mrs. R:	Okay...
Reasoning	Padma:	It wouldn't get cold.

(Transcript, 3/29)

In response to Mrs. Runner's query of "why", Padma offered a <u>description</u> (the pop would get cold) but did not offer an <u>explanation</u> other than to stay that if there is ice in the pop you would expect it to get cold. Mrs. Runner responded to this description of the phenomenon by saying "okay" with her voice trailing off. This was a subtle cue to Padma that she needed to give a further explanation or reasoning. Padma picked up on this cue; however, she still did not respond with an explanation of why the ice would make the pop cold. Rather she clarified and extended her description, saying that pop with no ice "wouldn't get cold". Although Ms. Runner gave Padma an opportunity to puzzle through her ideas orally, Padma did not take this opportunity. She wasn't encouraged to do so nor were there any negative consequences when she did not.

I asked Padma a similar question to the one above in an interview approximately two months after this conversation. She repeated the same information she had given in class; however in this private conversation away from the audience of her peers, she said considerably more than she did the day in class. However, she still continued to give a description rather than an explanation:

> KP: Why would a cup of red pop with ice in it be colder than a cup of red pop without ice?
>
> P: Because an ice cube is cold and you have red pop and you have another cup of red pop, plain old red pop. And then you take the ice cube and put it in one of the cups and the other cup is without an ice cube. And you leave it and then if you taste them, the one with the ice cube will probably be cold because the ice cube is cold.
>
> (Interview Transcript, 6/3)

Reliance on Familiar Words and Phrases: Yet Another Barrier To Learning Science

Once the class had been divided into the four small groups and Padma began to participate more in the discussion, a third pattern emerged in her discourse. A common pattern seen in science in general is for students to rely on terms and definitions rather than on trying to develop a conceptual understanding (Roth, 1987)[2]. A variation of this pattern was seen in Padma's discourse.

On the second day of the teacher-led small group discussion, for example, the group was discussing an experiment they had done measuring the temperature of snow.

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[2]For a more detailed description of this pattern and the reasons kids rely on terms and definitions see Chapter 2.

They were debating whether a thermometer left in a snow bank would "level off" at a certain temperature or would continue to get colder and colder. Many of the students were arguing that it would continue to get colder. However, Jake argued that it wasn't the snow that was changing temperature; it was the weather that was changing. Therefore it didn't matter how long a thermometer was left in the snow, it would always be the same temperature.

Padma appeared to have been engaged in this discussion because following the statement about the weather changing, she entered the conversation:

Padma: I was gonna say...when you said...um..that the weather isn't changing...my mom said that in Michigan the weather changes every minute.

(Transcript 3/16)

The statement that the weather was changing may have caught Padma's attention, because this was a familiar phrase she had heard her mother say. Because of this familiarity she was able to momentarily enter the conversation and comment upon this statement. Although this provided an opportunity for Padma to enter the conversation, and may have represented one way in which she was making sense of the ideas in the discussion, her response probably didn't fit with the content of the larger discussion from Mrs. Runner's perspective. As a result Mrs. Runner did not probe, revoice, or redirect Padma's statement but rather called on another student. Possibly because Mrs. Runner did not follow the pattern of probing, revoicing, or redirecting, this one statement about the weather changing represented the end of Padma's verbal participation at this point in the lesson. Following the interaction about the Michigan weather, Padma remained silent in her small group for nearly two weeks. It seemed that when her idea wasn't given support by the teacher or her classmates, she essentially retreated from the discourse.

By March 29 much of the discussion in the teacher-led small groups for the previous two weeks had centered around reading a thermometer and understanding the distinction between the Fahrenheit and Celsius scales. A question asked repeatedly during this time was, "What is a different way of saying 212°F (or whichever temperature had just been named)?" to which the student responded by naming the corresponding Celsius temperature.

On March 29 Padma finally entered the conversation in a move very similar to the one made surrounding the issue of the "weather changing" as described above. During the course of this discussion, Padma was asked a direct question by Mrs. Runner. The question contained the familiar phrase "different temperature", which resulted in a patterned response from Padma which again did not appear to answer Mrs. Runner's question. The group has been talking about how each time the red indicator moves up in the thermometer it is a different temperature reading:

Probe	Mrs. R:	Okay..you mean every time that you jump a little..the red moves up..it's going to be a different temperature.
Reasoning	Padma:	Well..yeah..because it..um..moving it has different temperatures on each side like..for our hand temperature we had ninety Fahrenheit and fifty seven Celsius and they are different so...
Probe	Mrs. R:	How do you know which one is Fahrenheit and which one is Celsius?
Reasoning	Padma:	Because you have an f on one side of a thermometer and c on the other side
Probe	Mrs. R:	And the f stands for..
Response	Padma:	Fahrenheit

(Transcript, 3/29)

In this example even though the question was not a familiar one, Padma picked up on the key word "different" in the context of a temperature discussion and turned the question into a familiar one about Fahrenheit and Celsius to which she knew the answer. In response to Mrs. Runner's clarification question "...the red goes up..it's going to be a different temperature?" Padma elected herself group spokesperson and agreed that yes, that is what they, the class, were saying. However, she then went on to clarify further, and the explanation she gave is in the familiar pattern of giving the Fahrenheit and Celsius temperatures, "Like for our hand temperature we had ninety Fahrenheit and fifty seven Celsius.." This information, while correct and accurate, is out of place in the context of the current discussion.

Perhaps because Mrs. Runner perceived of Padma as a smart student, she did not appear to pick up on the difference between her question and Padma's response. Rather, Mrs. Runner followed Padma's lead and shifted to discussing Fahrenheit and Celsius asking the "known answer" question: "And the F stands for..." Padma easily replied, "Fahrenheit". In this way Padma, perhaps not consciously, shifted the discussion to one in which she could provide a response to a known answer question.

The final interview in June provided further evidence that Padma relied on familiar information to answer questions. During a class discussion in March Ms. Lawson had talked with the students about what would happen to hot soup if an ice cube was added to it. In an interview at the end of the school year, more than two months after the discussion, Padma repeated a portion of that earlier class conversation. However, she said that the situation had happened to <u>her</u>, rather than saying it was something that had been discussed in science class. In this case it was the word "steam" which triggered this response. The first transcript segment below shows the original science class discussion; the second is from Padma's end-of-the-year interview:

> Mrs. R: Okay, supposing you go to a restaurant and you order a bowl of chicken soup ... and you wanted to check whether that soup was awfully hot, what could you do?
>
> Sam: You could put ice in it...when you put the ice cube in it steam comes off it so that is how you would know it is hot
>
> (Transcript, 3/29)
> *******************
>
> Sam: When we mix cold, freezing, and boiling together, steam comes.
>
> Padma: Yes, cause one time I went to a restaurant and I had a bowl of hot soup and he put the ice cube in the soup and the steam came off.
>
> (Interview transcript, 6/3)

One explanation for this is that Padma picked up on the key word "steam" similar to the way she did with the words "weather" and "different temperature" and repeated the same thing that Sammy had said two months earlier, except that she has taken "ownership" of the idea and said that it happened to her. This interpretation supports the assertion that Padma is picking up on key words or phrases and participating in the discourse based upon those ideas.

An alternative explanation is that Padma had experienced a similar situation and when she heard Sammy describe putting an ice cube in soup during class discussion she immediately connected it with a personal experience. Perhaps because of her reluctance to speak in a public setting, she refrained from agreeing with Sammy and describing her own experience as evidence. However, two months later in an interview setting in which there were only three students present, the reference to "steam" may have again reminded her of her experience which she then shared in that setting. This interpretation supports the assertion that key words triggered responses and also the assertion that Padma was not comfortable talking about her thinking, ideas, or experiences in the whole group and possibly, although perhaps to a lesser extent, even in the small group setting.

The Potential Problems with Social Constructivism: Allowing the Conformist to Hide

When teaching there are always "tradeoffs" -- what works for one student may not work for other students. Such was the case with this learning community. Although the discourse style allowed a student like Casey to thrive in learning the science concepts, Padma showed little change from pre- to post-test as described earlier in this chapter. Unlike Casey, who was a non-conformist in his discourse style, Padma conformed to traditional classroom discourse styles. She appeared to have a strong image of herself as a good student when considered from a traditional perspective on teaching and learning. She did not engage in the discourse in ways that would threaten that image in any way. Thus, she did not engage in the discourse in ways that promoted her conceptual understanding of the material under study. She did not put her thinking and ideas out in public for inspection by her teachers and classmates.

Although a learning community such as the one described in this dissertation provides opportunities for students who are not traditionally successful in science to thrive, such a learning community may still allow for the perpetuation of less successful discourse strategies. Some students, like Padma, are able to continue using the strategies which have allowed them success in the past. To a certain extent these strategies work in getting favorable attention from the teacher. However, they do not work when considering the science content learned.

Chapter Summary

The stories of Casey and Padma represent the rewards as well as the struggles with creating a learning community in which understanding is socially constructed through the discourse. Ms. Lawson and Mrs. Runner were working to create a learning community in which the students became scientifically literate through the use of discourse. From this perspective, a student who is successfully using the discourse would be successful in science. This successful student would be listening to the assertions and evidence made by their peers and agreeing or disagreeing and providing evidence to support their position.

Casey did listen closely to his peers as is evidenced in the responses that he made to them. He also learned to make assertions and give evidence to support his assertions when agreeing and disagreeing with his peers. Perhaps because of his ability to engage in the discourse in this way, he developed a conceptual understanding of the science concepts in the unit as evidenced by the depth of his explanations on the post-assessment.

However, change is difficult for everyone. Although Casey was agreeing and disagreeing-- which was a discourse strategy recognized by his teachers as successful-- the way in which he made his assertions and provided evidence for these assertions did not seem to "fit" with the traditional image of a "good student". He frequently used "unrehearsed" exploratory talk which was much longer and included more repetition of key words and phrases than the "presentational" talk of his peers. He never figured out the implicit norms for participation in the discourse and, when he did get the speaking floor, he often disrupted the flow of the discourse by making an unexpected move -- such as disagreeing with an idea before a teacher had revoiced an redirected the idea.

At the same time, Mrs. Runner had a long history of thinking about good students in a more traditional way -- a good student is one who is polite, eager to learn, gives the right answer using presentational talk, and knows the implicit rules for participating in the discourse. This "preconception" of a good student may have sometimes unconsciously played into the way in which she viewed the discourse in her classroom. Thus, although Casey was agreeing and disagreeing with his peers, Mrs. Runner may not have initially recognized it as such because of the rambling nature of his exploratory talk. Casey's talk did not have the "neatness" of the presentational talk Mrs. Runner was accustomed to hearing from her "good students". Thus, Casey did not appear articulate and, initially, Mrs. Runner may not have realized the power of Casey's discourse and the extent of his learning.

Furthermore, Casey's physical placement in the classroom compounded his difficulties. He tended to sit quietly on the periphery of the science class during discussion and did not wave his hand or make other noise to catch the teacher's attention when he wanted to answer a question Thus his bid for the speaking floor often went unnoticed, and he did not participate in the learning community as frequently as the students who were perceived of by teachers and peers as good in science.

Thus, Casey did not match the traditional image of a good science student -- an image that is so deeply entrenched it is difficult to ignore. And yet Casey was successful in learning the science concepts. One explanation for his success is that the very structure of the learning community enabled and encouraged him to use discourse strategies which promoted his understanding of the science content even when he was sometimes neglected by the teacher. Thus, for Casey, the discourse allowed him access to the science concepts even though he was not engaging in the discourse in a more traditional "smart student" way.

In contrast to Casey, Padma engaged in the discourse in ways that were consistent with the traditional image of a good science student. For example, Padma used presentational speech in which she gave clear, concise answers in response to the teacher's questions. One reason she may have been able to do this successfully was that she generally responded only to questions which called for information, rather than an explanation. Because of these clear, easy to follow, responses, she was perceived by her teachers as articulate - which is a traditional characteristic of a good science student.

In addition to being polite and well behaved during class discussions, Padma had figured out how to get the speaking floor with minimal difficulty. Unlike Casey who sat on the periphery, Padma sat in the center, directly in the teacher's sight line. When a question was asked, Padma raised her hand and waved it in the air. If this didn't catch the teacher's attention she would also make quiet noises which caught the teacher's attention. Padma also volunteered to do many extra things - such as run notes to the office or stay in from recess to wash the blackboards. All these behaviors contributed to an image of Padma as a good student.

Thus, at the same time that the structure of the learning community allowed Casey to learn the science concepts, it allowed Padma, perhaps unconsciously, to avoid risky discourse moves, such as exploratory talk, which would have helped her make sense of the content. However, because there were enough opportunities for Padma to participate in ways which did not challenge her thinking or push her intellectually (e.g. known answer questions and calls for data), her lack of engagement with learning the concepts was not readily apparent and she fit the teacher's image of a successful student.

This does not mean, however, that Padma cannot learn science concepts in a social constructivist learning community. I believe that Padma, and many students like her, can thrive in such a classroom. However, Padma needs time and support in changing her long-held view of what it means to be a good student. To use the language of conceptual change, Padma needs to have her conceptions of what it means to be a good student in science challenged. Interview data provided evidence that this had taken place. Padma clearly understood that the discourse was to play an important role in her learning -- however she hadn't had enough time and practice controlling and using the new discourse for it to be "plausible and fruitful" for her. Thus, she continued to rely on her old strategies of giving known answers, providing data, and using presentational talk. With time and continued explicit teacher support in learning to control and use the discourse of science, Padma could change her image of what it means to be successful in science and would learn to use the discourse as a sense-making tool.

Chapter 7

THE SCIENCE CONTENT KNOWLEDGE THAT WAS CONSTRUCTED THROUGH THE TALK: A GLIMPSE OF STUDENT LEARNING

Introduction and Chapter Overview

I have made the assertion that the classroom discourse in the third grade team room at Atlantis Elementary provided a powerful tool for Casey to construct his understanding of the science content. Making the discourse a part of the science curriculum during science and literacy time enabled Casey to engage in "exploratory" talk (Barnes and Todd, 1995) in which he thought through the concepts aloud. As he did so, Casey learned to control and use the discourse of science. In this way Casey developed a conceptual understanding of the science concepts in the unit such that he was able to use them in describing and explaining real world phenomenon on the Changes in Matter unit post-assessment. Thus, for Casey, science was Discourse.

Unlike Casey, who engaged in exploratory talk as he learned to control and use the discourse in his learning, Padma tended to use "presentational" talk (Barnes and Todd, 1995) during class discussions. She did not think aloud, but rather said enough to show the teacher that she was listening. Accordingly, her teachers viewed her as bright and articulate. There was no indication that either Padma or her teachers realized that she was not engaging in appropriating a new discourse that would allow her to make sense of the science concepts so that she could use them to describe and explain real world phenomenon.

Thus, for Padma, the discourse perpetuated her image as bright and articulate while obscuring, probably even to Padma, that she was not engaging in the science content in ways which led to scientific literacy. As described in the previous chapter, Padma's responses on the Changes in Matter unit post-assessment were very similar to her responses on the pre-assessment. Thus, for Padma, science was not Discourse. Science was rehearsed speech and right answers.

The purpose of this chapter is to support the assertion that Casey was not an anomaly and that the majority of students (60%) in this class-- with its emphasis on using discourse as science and in which the discourse was part of the science curriculum-- developed a deeper understanding of the Changes in Matter unit concepts than they had at the start of the unit. Evidence of this can be found in the written pre- and post-test data. I begin this chapter by describing the written assessment instruments and the way in which the scoring rubrics for assessing changes in conceptual understanding were developed and used. I then quantitatively examine the change in conceptions across the unit for the whole class.

Description and Purpose of the Whole Class Pre- and Post-Test

Prior to instruction and again at the end of the Changes in Matter unit, the students were given a written assessment. All of the assessment items on the instrument were constructed response items in which the students were given an everyday phenomenon, such as snow melting when it is brought indoors, and asked to write a scientific explanation for the phenomenon.

The assessment was a "matched assessment" -- the majority of the questions on the pre- and post-assessment instruments were the same. The instruments were designed this way so that changes across the unit and progress toward a scientific conception could be determined through the calculation of gain scores. The one exception to this was a question on the pre-assessment which dealt with the concept of water in the air. Because this concept was not covered in the unit, the question was eliminated from the post assessment and replaced with a question about the temperature of an object sitting out at room temperature. I did not include these two questions in the quantitative analysis because they were not on both the pre- and post assessment. Additionally, although I had post-test data for both classes, I only had the pre-test data from Mrs. Runner's class (which included

both Casey and Padma). Therefore, I conducted the analysis for only the 21 students in Mrs. Runner's class.

Table 7.1 on the next page shows the pre- and post-assessment questions and the corresponding science goal conceptions. When examining the goal conceptions it is important to remember that the class is a third grade class in which the majority of the students are language minority students to whom even the concept of a Fahrenheit temperature was a new concept.

Table 7.1
Pre- and Post-Assessment Questions and Goal Conceptions

Assessment Item	Goal Conception
1a. Suppose you had a cup of hot chocolate. After drinking part of it you leave it sitting on the table. You come back an hour later. You feel the cup and taste the chocolate. What difference would you notice?	1a. The temperature of the hot chocolate would be cooler than it was an hour earlier.
1b. Why would this happen?	1b. The air in the room is cooler than the hot chocolate. When this cooler room air touches the surface of the hot chocolate it will cause the hot chocolate to cool down.
2a. You have been playing outside in the snow. When you come inside, some snow stays on your boots. After about half an hour, you come back and look at your boots. There is not snow, but there is a small puddle beside them. What do you think happened to the snow?	2a. The snow went from a solid (frozen water) to a liquid (room temperature water).
2b. Why would this happen to the snow?	2b. The air in the room is warmer than the snow on the boots. When the warm room air touches the snow it warms the snow up until it is above freezing temperature and it melts.
3a. You get a glass of cold water from the drinking fountain. You use a thermometer to find out the temperature of the water. What temperature do you think the water would be?	3a. 33-60°F (OR 1-15°C) (Below room temperature but above freezing)
3b. Why do you predict this temperature?	3b. It would be this temperature because it is cold so it is below room temperature but it is not frozen so it is above 33°F.
3c. You leave the cup of water on the table and come back an hour later. What do you think the temperature should be then?	3c. The temperature of the water will be about the same as the temperature in the room (about 70°F).
4a. It is a cold day in winter. The temperature outside is about 20°F (-3°C). You get another cup of cold water from the drinking fountain. You take this cup of water outside and leave it. You look at the cup of water again after about half an hour. The water is not frozen. You then check its temperature. What temperature do you think it would be?	4a. 33-50°F (OR 1-10°C) (Cold but above freezing)
4b. Why would it be this temperature?	4b. It would be this temperature because it is a cold day but the water in the cup did not freeze. This means that the temperature would be above freezing (33°F) but probably not a lot above that temperature or it would not be considered a cold day.

Table 7.1 (cont'd.)

5a. It is a cold day in winter. The temperature outside is below freezing. You take a thermometer outside and stick it in a snow bank. After a couple minutes you take the thermometer out and read the temperature. What would the temperature probably be?	5a. Below 32°F (0°C).
5b. Why would the snow be this temperature?	5b. The information in the question stated that it is below freezing so it would have to be below the freezing point of 32°F.
5c. Suppose the thermometer read 45°F (6°C)? How might this be explained?	5c. There are several possible theories: 1. The thermometer is broken. 2. I misread the thermometer. 3. I held the thermometer bulb in my hand. 4. I carried the thermometer inside and waited too long before reading it. 5. The thermometer was not left in the snow long enough.
5d. How could you test your explanation?	5d. Designs an experiment which tests <u>their</u> theory.

<u>Overview of the Rubric Development</u>

More than a right or wrong answer, I was interested in student progress <u>towards</u> the scientific conception. Therefore, I elected to develop and use rubrics to score the assessment items. Using rubrics allowed me to more accurately determine progress from pre- to post-assessment. For example, a student might give a response on the pre-assessment which represented a naive conception and would thus receive a low score according to the rubric (e.g. a "1"). On the same question on the post-assessment the student might not give a complete scientific conception, however, they might give a qualitatively better explanation of the phenomenon than they did on the pre-assessment. Although not quite at the scientific conception, their post-assessment response would be much closer to the goal conception than their pre-assessment response. Using a rubric, their score would reflect this progress and they would receive a higher score (e.g. a "4"). This higher score would then be reflected in the overall gain scores from pre- to post-assessment.

Following guidelines established by the MCREL (Mid-Central Regional Education Laboratories) assessment group, I developed a rubric for scoring each pre- and post-test item. (See Appendix E for a complete copy of the assessment rubrics). Typically rubrics are either four point rubrics or five point rubrics. However, my purposes were slightly different than those of the classroom teacher who might be using a rubric to assess a student for the purpose of assigning a grade. The rubric point assignment scheme I used reflected this different purpose. On the rubric I developed, the number of maximum points possible for each question varied depending on the complexity of the phenomenon. Thus for every question there was a range of points possible. For example, question 1a asked students to predict what would happen to hot chocolate if it were left sitting undisturbed in a cup for one hour. There is a limited range of reasonable possible responses to this question. Students might respond that the hot chocolate would cool or that its temperature would go down. They might respond that it would become the temperature of the room. They could respond more generally that it would "get cold" . They could also respond by guessing that it would get warmer, by saying "I don't know" or by not making a prediction. Because there are only four reasonable responses possible for this question (excluding "I don't know" and no response), the rubric for this question had only three points possible.

By contrast, question 1b asked the students to explain their prediction. There are a number of possible explanations. These responses were categorized as "air cooling", "air as cause", "room temperature", "heat leaves/material transfer", "inevitable temperature equilibration", description rather than explanation, or "I don't know" or no response (For a further description of each of these categories see the rubric in Appendix E). Because there are six possible reasonable categories of explanations (excluding "I don't know" and no response), there were six points possible on the rubric with "air cooling" receiving six points and a description with no explanation receiving only one point.

When developing a rubric for a question, I first wrote the "ideal" scientific response to the question. I then worked "backwards" to consider alternative responses which the students might give. To construct these alternative responses, I reviewed lesson transcripts and pre-assessment data to identify naive conceptions about the concept that the students held prior to instruction and early in the unit. I also consulted with Dr. Jones regarding common naive conceptions about the unit concepts of which he was aware. Once I had identified possible naive or incomplete conceptions or responses to the question, I qualitatively ordered them in a table in a continuum from "goal conception" to "naive conception" and assigned points. By convention, rubrics are constructed with the ideal response given first and alternative responses following in order of decreasing points. I followed this convention.

Once I had identified the categories, I went through the student responses to ensure that there were no responses which did not fit into one of the existing categories. Whenever there was a reasonable response which did not fit an existing category, the rubric was adjusted to create an additional category. Thus, when the rubric was completed, there was no student response which did not fit into one of the categories on the rubric.

Rubric Development - An Illustrative Example

As described above, question 1a. asked students what would happen to a cup of hot chocolate left sitting at room temperature for one hour. Question 1b asked students to explain their prediction. Table 7.2 below illustrates the rubric for question #1b:

Table 7.2
Sample Rubric, Assessment Question #1b

Code	Label	Description
6	Air as contacting	Cooler room temperature comes into contact with the hot chocolate which cools the hot chocolate.
5	Air as cause	Cites air as being cooler but does not specifically mention contact with air.
4	Room temperature	Cites room temperature or temperature of the room being cooler but does not mention air.
3	Heat leaves or Material transfer	Heat or hotness leaves OR Some kind of matter leaves e.g.... hot air left or hot air rises, OR Heat from the chocolate goes into the room air OR Cold from the room air goes into the chocolate.
2	Inevitable temperature equilibration	Hot materials always cool down and cold materials always warm up when left alone.
1	Description only	Describes instead of explaining e.g. "because it was left"
0	Doesn't answer	"I don't know" OR No response OR circular response.

The goal prediction (question 1a) the teachers were seeking was that the hot chocolate would cool when left at room temperature. The goal explanation (question 1b) was that the cooler air in the room would come into contact with the hot chocolate resulting in the hot chocolate cooling. Thus "air contacting" was the goal conception and listed first on the rubric table above.

Another possible but less complete response would be to say that cooler air was the cause of the cooling without mentioning the idea that there must be contact between the air and the hot chocolate. This idea is very near the scientific conception and so was identified as "air as cause" and placed on the table immediately following the goal conception. A slightly less complete response would be to say that the hot chocolate cooled because the room was cool. Because this does not involve the idea of air or air contacting the hot chocolate, this is not as complete as the first two responses. Thus, this was labeled "room temperature" and placed below "air as cause" on the table.

A class of naive conceptions that emerged on the pre-assessment was the idea that heat or "hotness" left the hot chocolate or that there was some kind of material transfer between the room and the hot chocolate. Students holding this conception would say that heat left the hot chocolate or that hot air rises from the hot chocolate and leaves it. Because this idea often included the idea of air and showed some understanding that there is some relationship between the temperature in the room and the temperature of the chocolate, this was identified as "material transfer" and placed next on the table.

Another naive conception that emerged on the pre-assessment I described as "inevitable temperature equilibrium". According to this conception hot materials always cool down and cool materials always warm up if left alone. This was placed next on the table.

On the pre-assessment many students responded to question 1b by giving a description rather than an explanation. For example, some said that the hot chocolate cooled because it was left at room temperature. This describes what happened but was not an explanation. This was placed after "inevitable temperature equilibrium" on the table. Finally, some students either said "I don't know", left the question blank, or gave a circular answer in which they repeated the question as their response. This was placed last on the table.

Once the process of identifying possible responses was complete, I assigned points for each response with this last category receiving zero points, a descriptive response receiving 1 point, and so on. I then "checked" the rubric against student responses looking for any responses that did not fit the rubric categories. When none were found I used this rubric as the final rubric for question 1b.

Results: Using the Rubric to Score the Students' Assessment Responses

Each student's response to a question was assigned a certain number of points based upon the rubric. These points were then added up to give a total number of points scored on the test and divided by the total number of points possible to give a percentage score on the test. Percent change from pre- to post test was calculated for each student.

Table 7.3 below shows the class results of the pre- and post tests and the % change from pre- to post test.

Table 7.3

Summary of Results on the Unit Pre- and Post Test For Mrs. Runner's class*

	Pre-Test Score in %	Post-Test Score in %	% Change
Padma	38%	48%	+10%
Casey	48%	71%	+23%
ST 1	24%	30%	+5%
ST 2	58%	65%	+7%
ST 3	48%	78%	+30%
ST 4	31%	69%	+38%
ST 5	27%	63%	+36%
ST 6	12%	96%	+84%
ST 7	44%	71%	+27%
ST 8	29%	58%	+29%
ST 9	33%	65%	+32%
ST 10	44%	38%	-6%
ST 11	42%	42%	0%
ST 12	25%	31%	+6%
ST 13	46%	40%	-6%
ST 14	17%	N/A	---
ST 15	38%	60%	+22%
ST 16	31%	38%	+7%
ST 17	17%	58%	+41%
ST 18	48%	N/A	---
ST 19	17%	60%	+43%
Mean Scores	38%	63%	+25%

*Pre-test data from Mrs. Lawson's class was not available.

Discussion of the Class Results

On the one hand, this data could appear to be discouraging, only four students scored 70% or better on the post-assessment. However, if progress towards the scientific conception is considered, the story improves. This data shows that there was a mean increase of 25% percent correct from pre-assessment to post-assessment. Furthermore, over half of the students (52%) scored over 60% on the post-assessment. This contrasts dramatically with the pre-assessment on which the highest score was 58%. This data indicates that the majority of the students made progress towards the scientific conception.

Some students, such as student #6 showed tremendous gains from pre- to post-assessment. This particular student was an Asian ESL (English as a Second Language) student who was new to this country in September. On the pre-assessment she answered only the first question. On the remainder of the questions on this pre-assessment she either placed a question mark or wrote "I don't know". In comparison, her post-assessment -- which was taken several months later -- contained detailed, and very accurate, responses to every question. For this particular student some aspect of the learning community allowed for dramatic growth in her understanding of the concepts. Although there is not evidence to support this assertion, it is possible that if the unit had consisted of only rapid teacher lecture, textbook reading, and independent worksheet writing, this student who was still learning the English language would not have experienced the success that she did. It may have been the opportunity to hear her peers discussing and struggling with understanding the concepts that allowed her to reach the understandings that she did.

One purpose of analyzing the class pre- and post-assessment data was to determine if Casey and Padma were typical of the students in the class. The range of gain scores was from -6% to +96% with a mean gain of 25%. Padma fell into that range, although on the low end, with a gain score of 10%. Casey fell very near the mean with a gain score of 23%. Thus, it can be concluded that neither student is an anomaly. Furthermore, Casey appears to be very typical of the students in the class with about half the students scoring gain scores above his gain score and about half the students scoring gain scores below his.

Examples of Student Pre- and Post-Assessment Responses

Table 7.4 illustrates typical responses given on the pre- and post assessment. Terrance, who was student #12 had a gain score of only 6% from pre- to post-test. By contrast, Klo, who is student #9, had a reasonably high gain score of 32%. Casey, with a gain score of 23%, and Padma, with a gain score of 10%, fell in between these two students. Casey and Padma's responses to the same questions are illustrated in Table 7.5

Table 7.4
Comparison of Two Students' Pre- and Post-Assessment Responses

Terrance, Pre-Test	Terrance Post- Test	Klo Pre-Test	Klo Post-Test
1a. Suppose you leave a cup of hot chocolate sitting on a table. You come back an hour later. You feel the cup and taste the chocolate. What differences would you notice?			
Cold	It was warm	Cup got colder	Chocolate got colder
1b. Why would this happen?			
No response.	Because you left it for an hour and it cooled off.	Because the hot air goes (evaporates) to the sky and when something hot goes away the place gets cold.	Because the cup is hot and the air is cold and there is more air then the hot in the cup so the hot disappears because the cold doesn't want the hot to be there. Then the cold will take the hot's place.
2a. You have been playing outside in the snow. When you come inside, some of the snow stays on your boots. After about a half an hour, you come back and look at your boots. There is not snow, but there is a small puddle beside them. What do you think happened to the snow?			
It melted.	It melted into a small puddle.	It melted.	It melted to a puddle of water.
2b. Why would this happen to the snow?			
It got hotter and hotter and then it turned to water	Because heat would melt the snow into water.	Because snow needs to be in the cold air but in the house (that's where you take off your boots) it is hot so the cold evaporates. And there is a mark in the boots where it evaporated.	Because if snow or ice touches hot air then the snow (ice) gets changed to a puddle of water.
3a. You get a glass of cold water from the drinking fountain. You use a thermometer to find out the temperature of the water. What temperature do you think the water would be?			
10	20	No response	Between 60° F and 70° F.
3b. Why do you predict this temperature?			
Because it is very cold.	Because I tasted the water and it tasted like 20.	No response	Because we are 98° F but the questions said that the water is cold so I took away 30 (or 48) and got 60°F.

Table 7.4 (cont'd.)

4a. It is a cold winter day. The temperature outside is about 20° F (-3 °C). You get another cup of cold water from the drinking fountain. You take this cup of water outside and leave it. You look at the cup of water again after about half an hour. The water is not frozen. You then check its temperature. What temperature do you think it would be?			
17	25 n.f.	No response	50 °F
4b. Why would it have this temperature?			
Because my dad did it.	Because it would be that cause of the heat.	No response	Because in question number 3 it said 60°F between 70° F and cold water.....it is colder so I think 50°F would be how cold it would be.
6a. It is a cold day in winter. The temperature outside is below freezing. You take a thermometer outside and stick it in a snow bank. After a couple minutes, you take the thermometer out an read the temperature. What would the temperature probably be?			
100	6°F	20° below	-20 to -30°F
6b. Why would the snow be this temperature?			
Because a snow bank is very, very cold.	Because it would be freezing outside.	Because it is very cold out there and I think 20F below would be about the snow temperature.	Because we did do this and I think I remember the temperature being between -20F and -30F.
6c. Suppose the temperature read 45° F (6° C). How might this be explained?			
I am not sure.	Because the thermometer went up.	It could be cold or hot out.	Someone was stepping on it or it went too deep and got that temperature
6d. How could you test your explanation?			
No response.	No response	I could try it and see if it works.	You could try stepping on it or putting it in deep.

Typically students who did well on the post-assessment gave explanations rather than restating the question or giving a description. An example of this can be seen in Terrance and Klo's responses to question 6c. When asked for an explanation, Terrance gave a description while Klo attempted an explanation. Students who did well on the post-assessment also included the idea of air coming into contact with a substance as an explanation of temperature change. Klo included this idea in her explanations in response to questions 1 and 2. Terrance did not include this idea in his response to the same questions.

The differences between Terrance and Klo's responses are typical of the responses given by students who did well on the pot-assessment compared with those who did not do as well. However, it is also important to note that "doing well" is defined as making progress toward the scientific conception. Although Klo's responses to many of the questions are qualitatively better than Terrance's, she is not necessarily at the scientific conception in all instances. However, the use of a scoring rubric enables me to illustrate her progress toward the scientific conception.

Discussion of Casey and Padma's Results

Table 7.5 compares Casey and Padma's responses on the pre- and post-assessment instrument. The qualitative differences between their responses becomes apparent when they are examined looking for use of the idea of air coming into contact with a substance to explain temperature change, and when examining for quality of explanation.

Table 7.5
Comparison of Casey and Padma's Responses on the Written Pre- and Post- Tests

Padma Pre-Test	Padma Post- Test	Casey Pre-Test	Casey Post-Test
1a. Suppose you leave a cup of hot chocolate sitting on a table. You come back an hour later. You feel the cup and taste the chocolate. What differences would you notice?			
Colder	Sort of cold.	Cold	Cold
1b. Why would this happen?			
Because if it was hot, hot chocolate and a hour later it has to be cold.	Because hot chocolate can't stay hot for a long time it will turn cold but if you left it for two minutes I don't think it will turn cold.	Because you would let it sit so long it would get cold.	The air cools it off and all the steam escapes. It cools them off.
2a. You have been playing outside in the snow. When you come inside, some of the snow stays on your boots. After about a half an hour, you come back and look at your boots. There is not snow, but there is a small puddle beside them. What do you think happened to the snow?			
It melted.	It melted.	It melted.	It melted and left a puddle.
2b. Why would this happen to the snow?			
Because of the heat inside the house.	Because outside and inside are different, right? So outside is cold, the snow stays how it is. But inside it is warm, so it would probably have melted.	Because the room temperature is too warm.	It is a form of water that is cold and warm air melted it.
3a. You get a glass of cold water from the drinking fountain. You use a thermometer to find out the temperature of the water. What temperature do you think the water would be?			
15	21	20°F	10°F
3b. Why do you predict this temperature?			
Because 15 is pretty cold and it said cold water.	Because 21 are sort of like the temperature of our drinking fountain in our hall and it is cold so that is why I think it is 21°.	Because the cold water in the fountains in the school seem about that temperature.	I drank some water and predicted it.

Table 7.5 (cont'd.)

4a. It is a cold winter day. The temperature outside is about 20° F (-3 °C). You get another cup of cold water from the drinking fountain. You take this cup of water outside and leave it. You look at the cup of water again after about half an hour. The water is not frozen. You then check its temperature. What temperature do you think it would be?			
30	32°	28°F	13°F
4b. Why would it have this temperature?			
After an hour it should be a little hotter.	Because water can't stay cold all the time it will become hotter I think every minute.	Because letting it sit would warm it up.	Because it doesn't increase very much in open air but it would increase a little.
6a. It is a cold day in winter. The temperature outside is below freezing. You take a thermometer outside and stick it in a snow bank. After a couple minutes, you take the thermometer out an read the temperature. What would the temperature probably be?			
0	13°	20° below	-20°F
6b. Why would the snow be this temperature?			
Because its very cold outside.	Because it is very cold day and if it is a cold day then the snow would probably be cold so 13° would be a good temperature I think.	Because it is cold, cold weather.	Because a cold day was 20 but below freezing would be -20°F.
6c. Suppose the temperature read 45° F (6° C). How might this be explained?			
Because it said its very cold and 0 is very cold 45 isn't.	I would explain it like a warm day the sun is sort of out and the wind is sort of hard and cold.	It would be too hot to have any snow at all.	45 degrees Fahrenheit ad 6 degrees Celsius. It would be a hot temperature. Hotter than on 5a.
6d. How could you test your explanation?			
Once I looked at the TV weather report and it said 0 and I went outside and it was freezing.	I would do it when it is 45°F (6°C).	I could put a thermometer in a snow bank to see the temperature and then do the same thing in summer/spring	Try it with a thermometer. Find the answer.

Although Padma's post-test responses are longer and appear at first glance to contain more information, they are primarily descriptive rather than explanatory and involve a lot of repetition of the same information. She says what she wants to say and then repeats it in a different way so that she has a longer answer. For example, question 6b asks students to explain their predicted temperature for snow. The goal conception is that because the snow is solid water the temperature must be below 32° F (0° C) which is the freezing point of water. In Padma's response to question 5a she relies on the information in the question rather than drawing on the knowledge learned in the unit and repeats the idea that it is a cold day or cold three times in the same sentence, "Because it is a very cold day and if it is a cold day then the snow would probably be cold so 13° would be a good temperature I think". Although she repeated the information in the question, Padma did not pick up on a critical piece of information in the question that it is below freezing. Thus, although she did give a temperature that is below freezing she only justified it by saying it was a cold temperature and did not further justify it by stating that it was below freezing.

Padma's response contrasts with Casey's briefer, but better, explanation, "Because a cold day was 20 but below freezing would be -20." Casey drew on information that was given in question #4 which made the statement "It is a cold day in winter (20°F) and applied it to question #5 which stated that it was a cold day. Casey applied the information in question #4 that a cold day would be 20°F to the information in question #5 that it is a cold day. Furthermore, he also noticed an important piece of information in question #5 which Padma did not take into account in her explanation -- it is below freezing outside so he has taken that into account in his final answer of -20. Casey's answer is closer to the scientific conception even though Padma wrote more in her response.

Another concept noticeable in Casey's post-test responses and noticeably absent in Padma's responses is the concept that air has something to do with temperature and temperature change. Casey includes the idea of the air coming into contact with an object and changing its temperature in four of his explanations. Padma never mentions the idea of air. And yet a major concept that was developed in the class discussions was the idea that when a warm object comes into contact with cool air the object will cool and when a cold object comes into contact with warm air the object will warm up. Casey understands and is using the idea of contact with air in his explanations while Padma is not. This provides further evidence that Casey engaged in the ideas in the discussions in ways that Padma did not.

Summary and Conclusions

From the initial pre-test data it can be concluded that Padma and Casey were typical of the students in the class in terms of their content knowledge. Post-test data revealed that while Casey made a great deal of movement along the continuum toward a deep understanding of the scientific conceptions in the unit, Padma did not learn quite as much. As was typical of students who made progress toward the scientific conception, Casey gave more detailed explanations on the post-assessment and also included the idea of contact with air as a cause of temperature change of an object.

This data supports the assertion that the exploratory talk in which Casey engaged supported his learning of the unit concepts to a greater extent than the presentational talk in which Padma engaged. While Padma began the unit at about the class mean in terms of her understanding, by the end of the unit she was 15% below the class mean on the post-test while Casey was still near the mean. This reinforces the assertions in this dissertation that while Casey was able to control and use the discourse in ways that promoted learning science, Padma, although she understood the importance of discourse in her learning, had not yet learn to control and use the discourse in productive ways.

Chapter 8

TEACHING SCIENCE THROUGH DISCOURSE: WHAT DOES THIS MEAN?

Introduction and Overview of Chapter

I began this dissertation with the assertion that although there is a growing body of research looking at discourse in elementary science classrooms, there are perhaps no studies which examine the extent to which the discourse helps or hinders science content learning. Chapters Four and Five of this dissertation provided a description of a classroom in which science was conceived of as Discourse -- a classroom where scientific literacy included the ability to control and use the discourse to describe and explain everyday phenomena using science concepts. Chapter Six looked closely at two students' discourse participation patterns and the relationship of these patterns to their science concept learning. Chapter Seven then showed the progression toward scientific understanding made by all students in the class. The purpose of this final chapter is to provide concluding comments about the research findings and to consider the implications of these findings for teachers, teacher educators, and researchers.

Conclusions

This study was an investigation into the role of discourse in two students' science learning in a classroom in which the teaching was undergirded by a social constructivist perspective. The research questions were:

In a classroom in which the teachers are emphasizing the role of discourse in science learning,

- What science knowledge do students construct?
- What is the nature of the students' talk in science class? What are the implicit and explicit rules for discourse in science?

•What is the participation structure in this classroom?

•What is the relationship between students' science learning and their participation in the classroom discourse?

What it Means to Use Discourse to Construct Understanding in Science

Through their discourse with the students, Mrs. Runner and Ms. Lawson shaped a learning community in which the classroom discourse and the interactions among the participants had aspects of didactic science, inquiry science, conceptual change science, and a constructivist approach to science. However, the final result was a learning community that built upon the successes of those initiatives but was uniquely different and reflected many of the characteristics of social constructivism as it is described in the theoretical literature. Students in this class were thinking through their ideas out loud and were making assertions supported by evidence which other students then agreed and disagreed with. Although the teacher's supported and directed the direction of the discourse, they were not the only authority for knowledge in the classroom and, except during instructional detours, did not "evaluate" student answers in the traditional sense. Additionally, the curriculum was not wholly predetermined but was responsive to issues that were raised in class by the students. Emergent activities and questions were designed to challenge the naive conceptions that the discussions elicited.

Teaching Students a Different Way of Talking in Science Class.

Many teachers may intend to use classroom discourse as a way to help students make sense of the science concepts as a group. However, in reality, sense-making though talk is, perhaps unintentionally, discouraged during most class discussions because of the size of the group, the struggle to get the speaking floor (Barnes and Todd, 1995), and the teacher's need to maintain order and to cover lots of content. As a result the most common form of classroom talk is the pattern of teacher initiation-student response-teacher evaluation of student response (I-R-E) (Mehan 1979). In this pattern the teacher initiates the discussion by asking a known-answer question. Known-answer questions are those questions to which there is a single answer which is frequently stated explicitly in the teacher's text. The structure of these questions does not allow for students to share their thinking and ideas, puzzle through a concept, or respond to a statement made by a classmate. Nor does a known-answer question allow for multiple interpretations and multiple responses. Rather, these questions typically require a single student to respond by giving a single piece of information so that the teacher is satisfied that the student has been listening and "learning" (Barnes and Todd, 1995). The teacher than evaluates the response. Thus, in an I-R-E structured discourse students generally use presentational talk in which they give brief assertions or a pre-planned answer (Barnes and Todd, 1995).

An I-R-E discourse pattern does not support students in thinking through their answers aloud, and it does not fit with a view of science as discourse. The goal of science education is scientific literacy. An individual who is scientifically literate is able to control and use the discourse (Gee, 1989) to work with others in the setting to make sense of everyday phenomena using scientific concepts (AAAS, 1996). The activity of talking with others to use scientific concepts to make sense of an everyday phenomenon, such as the "disappearance" of a puddle when the sun comes out, is a very different activity than individually listing the phases of the water cycle as precipitation, evaporation and condensation -- which would be a typical activity in an I-R-E discussion.

Thus, when using presentational talk through an I-R-E pattern of discussion the students tend to learn facts, terms, and definitions that they can use to answer questions. However, they do not learn to appropriate the discourse so that they can use the facts, terms, and definitions to explain everyday phenomenon (Rosebury, Warren, and Conant, 1990). Thus, students who are engaged in presentational talk are not learning to control and use the discourse of science (Gee, 1989), and are not becoming scientifically literate, even though they may be perceived by the teacher as being successful in class discussion.

By making scientific discourse a part of the science curriculum, Mrs. Runner and Ms. Lawson were attempting to change the discourse pattern in science in their class. Mrs. Runner and Ms. Lawson taught, and continually reinforced, a new pattern of interaction between students and teacher. This pattern included teacher initiation, student response, and occasional teacher evaluation. However, unlike the I-R-E, students also initiated, teachers responded, and there was student evaluation which was typically in the form of agreement or disagreement with the teacher or a peer. Additionally there were four other moves which are not present in the I-R-E: probe, reasoning, revoice, and reinitiation. These four moves could be made by either the teacher or the students. Further complicating the discourse pattern in this classroom was that, unlike the I-R-E with its fairly rigid format, the discourse pattern was much more flexible and each move was both content- and context- dependent. For example, depending on the content of a student's response, the teacher, or another student, might choose to probe, to evaluate, to revoice, or to redirect. The context also played a role. If a particular response was given in the context of a brief "instructional detour", the teacher was much more likely to evaluate the response than if it was given in the context of the more typical discussion in which the students were doing more of the evaluating using the agree/disagree format.

However, although there were more possible moves than in the I-R-E and although each move was content- and context- dependent, there was a definite pattern seen in the discourse. There were two different types of discussion which took place in this class. The first, and most common, was a sense-making discussion which had many of the characteristics of a social constructivist discussion. The second, and less common, was an instructional detour which looked more like an I-R-E discussion in terms of the length of the student responses and the amount and nature of teacher evaluation. Probing and elaboration were not seen in an instructional detour.

The most typical discourse pattern during the sense-making discussion was: I-R-P-RE-RV-RD-EV (Initiation-Response-Probe-Reasoning-Revoice-Redirect-Evaluate). In this pattern, the teacher initiated (I) by asking an open-ended question such as, "Did anyone notice anything interesting while they were collecting their data?" The student responded (R), the teacher probed (P) this response further, the student gave their reasoning (RE) for

their response, or gave their reasoning (RE) which the teacher revoiced (RV) and then redirected (RD) to the class by saying, "What do other people think? Do you agree or disagree?". Another student then responded with an evaluation (EV) and supporting evidence such as "I disagree because they were not sitting by the window".

Variations in this pattern were seen when a student did not elaborate or give their reasoning in response to a teacher's probe or when the first student response took the form of an evaluation. In the first instance -- a student not responding to a probe -- the teacher often initiated with a new or rephrased question. When this happened the student, and the idea contained in their response, lost the speaking floor. In the second instance, a student evaluation in response to a teacher initiation, the teacher frequently redirected without probing or revoicing. This also resulted in the student losing the speaking floor, although in this instance their idea did receive some floor time as another student agreed or disagreed with it.

This social constructivist discourse pattern resulted in a participation structure which came much closer to representing a true discussion - one in which there is a back and forth sharing of ideas and questioning of those ideas -- where students listened to one another and agreed or disagreed and gave evidence to support their assertions. This also resulted in a more balanced distribution of power in the classroom. Although Mrs. Runner did control the discourse, she was not the only person who could question a student and evaluate the response that they gave. The students were also able to question each other and Mrs. Runner in ways that are not done in a traditional science class.

Science knowledge, from the perspective in this class, is the product of language-based interactions that take place in a social environment, and is influenced by a person's prior knowledge. In their conversations with the class, Mrs. Runner and Ms. Lawson placed an emphasis on drawing out the students' prior knowledge and making this prior knowledge explicit to themselves and the students so that it became part of the shared knowledge of the classroom. They then supported the students in reevaluating and, if necessary, modifying this prior knowledge in order to make sense of the scientific phenomena. This process of eliciting and supporting the modification of prior knowledge as a group in order to reach a group consensus and mutual understanding about the scientific phenomenon was a clear emphasis through the Changes in Matter unit.

Mrs. Runner's emphasis on the teaching of oral literacy and language in the "Changes in Matter" unit was also consistent with a social constructivist perspective which undergirds most of the recent research on the role of discourse in the classroom. Language, in the form of oral discourse, plays a central role in the social construction of understanding. According to Bruner (1966), it is oral language which allows children to take elements of their experience and organize them into increasingly more sophisticated thought structures, a necessary condition of learning. Vygotsky (1962) theorized that thought is the internalization of dialogue and that in order for students to think through new ideas they must first talk through the ideas with a "more knowledgeable other".

Barnes and Todd (1995) argued that the more a learner is able to control his own language strategies, and the more that he is enabled to think aloud, the more he can take responsibility for creating explanations, a central goal of science. Talk is much more than just a window upon mental processes and metacognitive concepts. Conversations are a significant environment in which such thoughts are formulated, justified, and socialized (Middleton & Edwards, 1990) and thought itself is enabled by language (Winogard & Flores, 1980). Thus there is a recursive relationship between learning to talk science and "knowing science" (Lemke, 1990; Bruner, 1966; Barnes and Todd, 1995; Vygotsky, 1962).

According to the literature, the discourse in a social constructivist classroom is often dialogic in nature. This is best exemplified by highly interactive discussion in which the scope, development, and direction of discourse are shaped by the interaction of what the teacher plans and what the students say (Burbulus, 1994). This dialogic discourse is not rigid, consisting of a pre-planned list of questions, but rather is flexible and content dependent. The classroom discourse is negotiated by the conversants, and each move depends on what was said in the previous move. In dialogic instruction the teacher questions are authentic questions such as "What ideas do people have about why the ice cube melted faster when it was held in their hand than when it was on the table?" This contrasts with the known-answer questions, such as, "name one of the states in which water can exist" which typically form the foundation of an I-R-E discussion, which is not dialogic in nature.

The dialogic nature of the discussions was clearly seen throughout the "Changes in Matter" unit. Nearly all teacher-student interactions began with an open-ended question in which there was not a pre-specified answer. Often this question took the form of a request for the students to share anything interesting they noticed as they were doing an experiment. Students were then encouraged to think out loud and to justify their ideas through the use of evidence. From there Mrs. Runner or Ms. Lawson often probed a student's response and the student would elaborate -- the teachers encouraged this elaboration to take the form of giving a reason. The students' ideas would then be revoiced to ensure that everyone heard the idea, and then the teacher would reinitiate, often by asking her students to agree or disagree. In this way Mrs. Runner and Ms. Lawson encouraged students to listen and respond not just to the teacher, but to one another.

Furthermore, although Mrs. Runner had both an overall unit plan and daily plans for the lessons, these plans were continuously shaped and modified by the interactions which took place between her and the students and among the students themselves. Because it was impossible to predict exactly what ideas the students might bring up in the discussion, it was impossible to predict exactly where the discussion would go. By asking for student thinking and ideas, probing those ideas, and having other students respond to those ideas Mrs. Runner allowed her interactions with the students to shape current as well as future discussions.

Dialogic instruction is also characterized by uptake, defined as the teacher's incorporation of a student's answer into a subsequent question (uptake refracts the student's voice through the teacher's) (Tharpe & Gallimore, 1988). Uptake of students' answers characterized the discourse pattern in the Mrs. Runner's and Ms. Lawson's science class. As described above, the teachers rarely evaluated a student's answer in the traditional initiation-response-evaluation mode. Rather there was uptake of a student's answer through revoicing, by using the answer to reinitiate the conversation, or a combination of the two. For example Mrs. Runner might say, "Padma just said that she thinks ice melted because of the warmth from her hand (revoicing). What do you think? Do you agree or disagree with her and why?" (reinitiating).

In Mrs. Runner's and Ms. Lawson's science class there was little emphasis on individual, isolated learning and accountability such as independent reading, worksheets, tests, and grades. In contrast to more traditional classrooms, there was not a science textbook, students did not read about isolated science facts, and there were no individually graded worksheets or tests where students displayed their knowledge of the "facts". The emphasis in the class was on sharing and discussing ideas, and generating and using evidence to support assertions about everyday phenomena.

Students did complete tasks - often experiments - and created written products in this class. However the tasks were not conducted independently but were always done with at least one other member of the class. And while the written products were sometimes individual data records or ideas written in a science notebook, more often the written materials were group-written products. These group writing tasks typically focused on writing the conclusions reached following an experiment and providing evidence to support those conclusions. Furthermore, although the teachers read the science notebooks and group worksheets, the students did not receive a grade for their "work". Instead the teachers gave them written feedback and asked them questions about their data and conclusions.

Social Constructivism: A Different Way of Participating in Science Class

A science class taught from a social constructivist perspective with an emphasis on discourse has a markedly different participation structure than a more traditional classroom in which the teacher didactically presents the scientific "facts". For example, in a classroom guided by a social constructivist perspective, language would be used as a tool for making ideas explicit by puzzling through these ideas with other members of the learning community as part of the sense-making process. This would result in a participation structure that differed from the norm. For example, rather than giving finite answers in the form of presentational talk, the students would puzzle through many ideas to explore alternative solutions to open-ended questions through exploratory talk. And rather than the teacher being the authority for determining the accuracy of a particular fact, the members of the learning community would puzzle over many ideas together until a consensus is reached by the group as to which ideas make sense and will become part of their newly constructed knowledge. In this way all knowledge is viewed as tentative and constantly evolving, and the members of the learning community play a role through their talk in shaping the knowledge that is learned in the classroom.

In Mrs. Runner's and Ms. Lawson's science class the participation structure was social constructivist in nature. The problems that were posed were real-world problems such as, "How could you quickly cool a bowl of hot soup," and the teachers pressed for explanations for real- world phenomena: "Why would adding an ice cube to the bowl of soup cool it down? What is happening when you add the ice cube?" Students were encouraged to listen to one another and to respond directly to one another's thinking and ideas (although turn taking was generally negotiated through the teacher).

This approach to science education highlights the importance of social interaction in learning. Students are not passive learners. They actively construct meaning for themselves as they interact with others in the learning community including teacher, peers, and text. Furthermore the meaning that they construct interacts with, and is influenced by, their existing mental framework - which may include a naive conception rather than the scientific conception. Thus learning is a highly complex phenomenon which is influenced by many factors both individual and social. This perspective is represented in most of the group discussions during the Changes in Matter unit. Every interaction between participants in the discussion became a part of the social fabric of the classroom, there were no individual or private conversations between the teacher and the students when they involved the science content.

Implications of Teaching Science as Discourse

This dissertation represents a small contribution towards a great need. Because social constructivism is a theory about how students learn rather than a teaching strategy, there is not a single way that a teacher holding this theoretical perspective would teach. Because there is no single strategy or set of steps to be followed, the best way to help pre- and in-service teachers conceptualize teaching from a social constructivist perspective is to provide illustrative examples for them to read or view and analyze. For example, I picture the description of the classroom context, the lesson, and Casey and Padma's participation and perceptions as one chapter in a book in which every chapter describes a different classroom in which the teaching is undergirded by a social constructivist perspective. Each of these classrooms would have some common themes such as an emphasis on science as discourse, the goal of scientific literacy, a shift in the authority for knowledge in the classroom, and non-traditional roles for teachers and students, but each would also be different. For example, the social organization would vary -- some classes would use primarily whole class discussions, some primarily small group work, and some a combination of these approaches. Other variations would include the pattern of the discourse, the implicit and explicit rules for participation, and the way in which the teacher communicated specific pieces of information. For example, Mrs. Runner used an instructional detour format. Another teacher might have a different approach.

When I teach undergraduate teacher education students about teaching elementary science, I am continually frustrated because I am trying to help future teachers imagine a way of teaching without having vivid examples of that teaching approach. The same is true when I conduct workshops with in-service teachers. I challenge preservice and inservice teachers to teach science differently than the way most of them were taught, yet I struggle to provide concrete images of what this teaching would look like. A great need for purposes of pre- and in-service teacher education is an anthology of images of classrooms such as I describe in this dissertation. This anthology could be a book, a collection of video clips, or a combination.

Additionally, this study provided insights into two students' participation in, and perceptions of, the discourse. Analysis of the discrepancy between Padma's talk and actions during class discussion gave some insights into why a student might not be participating in the discussion in productive ways. Padma appeared to understand the importance of talking though her ideas with members of the classroom learning community, but had not yet learned to control and use the discourse in order to do so. By contrast, Casey had learned to control and use the discourse to help him make sense of the science concepts even when his style of discourse did not always fit with the existing pattern of the class. Casey's case gives some insights into the power of the discourse in a social constructivist discussion to enable students, including those who might disappear between the cracks in a more traditional class, to use the discourse to support their learning. Insights such as those gained from Casey and Padma's cases can help teachers notice students who are using presentational talk rather than engaging in the science content more deeply and may help teachers consider ways to respond to students who do not participate in the discourse in the expected ways.

In addition to the need for illustrations of a social constructivist classroom and individual student perceptions and participation, there is also a need for research on teaching using a social constructivist perspective which focuses on the teacher. One area for future research is teachers' beliefs about social constructivism and how these are represented in the classroom. A deeper knowledge of this would allow us to work on helping pre-service teacher education students examine their own beliefs and to contrast those beliefs with the ones held by teachers holding a social constructivist perspective. If we want to help teachers move towards teaching from a social constructivist perspective, we also need to help them change their beliefs about how learning proceeds.

One other area to explore would be teacher decision making. How do teachers coming from a social constructivist perspective make decisions about science curriculum and science pedagogy? Again, this has implications for pre- and in-service teacher education. Questions to be addressed would include: How does a teacher holding a social constructivist perspective determine the curriculum? To what extent is the curriculum teacher driven and to what extent is it student driven? How do teachers holding a social constructivist perspective make decisions about which ideas in a discussion to pursue and which ones to leave untouched?

What Does It Mean to be Successful in Science?: Three Perspectives

Padma, Casey, and the teachers all had different images of what it means to be successful in science. As part of the curriculum designed to teach discourse as part of the science content, Mrs. Runner had an image of what a successful science student would be doing during class discussion which she articulated both in her description of her goals for student learning and in her description of Padma.

From Mrs. Runner's perspective, a student who was successful in science would agree and disagree with the ideas presented by others in the class. As part of this agreeing/disagreeing, successful students would provide experimental evidence to support their assertions. When they presented their assertions and evidence, the discourse of these successful students would be clear, concise, and articulate. It would not be long, rambling and confusing like Casey's. Their speech would have a pre-planned or rehearsed quality to it such as that seen in presentational speech and in the majority of Padma's responses during small group discussion. Their speech would not have an unrehearsed quality to it such as the exploratory talk in which Casey engaged.

Another characteristic of successful students is that they are visible. They sit where Mrs. Runner can see them and they frequently talk to the teacher, either during discussion or at other times. Padma, who sat front and center and frequently talked to Mrs. Runner -- often during non-instructional times such as recess -- was viewed as a successful student. By contrast, Casey sat off to the side on the outer periphery of the group. He did not often participate in the discourse often because he did not figure out the implicit rules for this participation. Mrs. Runner did not consider Casey a successful student. She did not recommend him to be a target student and expressed surprise when I told her that he was one of my target students.

Padma was a student who was very visible to her teachers and myself because she was always eager to take a note to the office, wash blackboards, or stay after school or in from recess to talk to the teacher or to be interviewed. She also participated in small group discussions on a semi-regular basis (1-2 times each discussion) by answering known-answer questions or calls for data. Additionally, Padma understood the implicit rules for gaining the speaking floor when necessary. She always sat in the middle of the group, directly in front of the teacher and knew when hand raising was required and when "calling out" was appropriate. When considered from a traditional perspective on teaching and learning, Padma is a very good student. It was probably these behaviors that led Mrs. Runner to characterize Padma as a good student. It was also these behaviors which led me to notice her as a potential target student.

However, discourse analysis revealed that most of the activities where Padma captured the attention of Mrs. Runner and myself were non-instructional activities, or activities that did not involve Padma engaging with the science concepts in a meaningful way. Thus, when Padma's participation is considered from a social constructivist perspective, a different image of Padma emerges. Although she understood the importance of talk in her learning, Padma did not learn to control and use the discourse as a tool for learning science. In contrast to her visibility during "non-instructional time", during the intellectually engaging discussions where the students were constructing their understanding of the science concepts, Padma rarely raised her hand to participate and seemed invisible. Because Mrs. Runner had to attend to the participation of forty students during discussion and because there were enough opportunities during the day for Padma to participate in some form of discourse, Padma was allowed to "shut down" and remain silent when the more conceptually challenging discussions were taking place without drawing Mrs. Runner's attention to her lack of participation.

Padma engaged in other behaviors that Mrs. Runner viewed as the behavior of a successful student. She was clear and articulate, using predominantly presentational speech which answered the questions Mrs. Runner asked. However, although Padma, either consciously or unconsciously, engaged in many of the activities of a successful student from Mrs. Runner's perspective, she did not engage in many of the behaviors that characterized Mrs. Runner's social constructivist goals -- agreeing, clarifying, giving reasons, etc. The structure of the discourse allowed Padma to be successful in traditional ways in science while obscuring, from both Mrs. Runner and Padma herself, that she was not learning to control and use the discourse to make sense of real world phenomena.

Casey also did not fit all of Mrs. Runner's characteristics of a successful science student as is illustrated in Figure 8.1. In contrast with Padma, he excelled in giving reasons and in agreeing and disagreeing with his peers. In this way he fit Mrs. Runner's image of a good student. However, the ways he reasoned aloud and his failure to use some traditional strategies obscured him from Mrs. Runner's view as a good science student.

Casey did listen closely to his peers and had learned the discourse strategy of "agree/disagree". However, although Casey was agreeing and disagreeing-- which was a discourse strategy recognized by his teachers as successful-- the way in which he made his assertions and provided evidence for these assertions did not seem to "fit" with the image of a good student held by Mrs. Runner. For example, Casey frequently used "unrehearsed" exploratory talk which was much longer and included more repetition of key words and phrases than the "presentational" talk of his peers. Because his talk didn't fit the more polished pattern, Mrs. Runner did not always respond to his contributions following the same pattern used with the other students. He also learned to make assertions and give evidence to support his assertions when agreeing and disagreeing with his peers. However, his evidence tended to be logical evidence rather than the experimental evidence that Mrs. Runner valued and expected.

Casey was also non-traditional in his behavior of sitting quietly on the periphery of the science class during discussion, not waving his hand or making other noises to catch the teacher's attention when he wanted to answer a question. Thus his bid for the speaking floor often went unnoticed, and he did not participate in the learning community as frequently as other students.

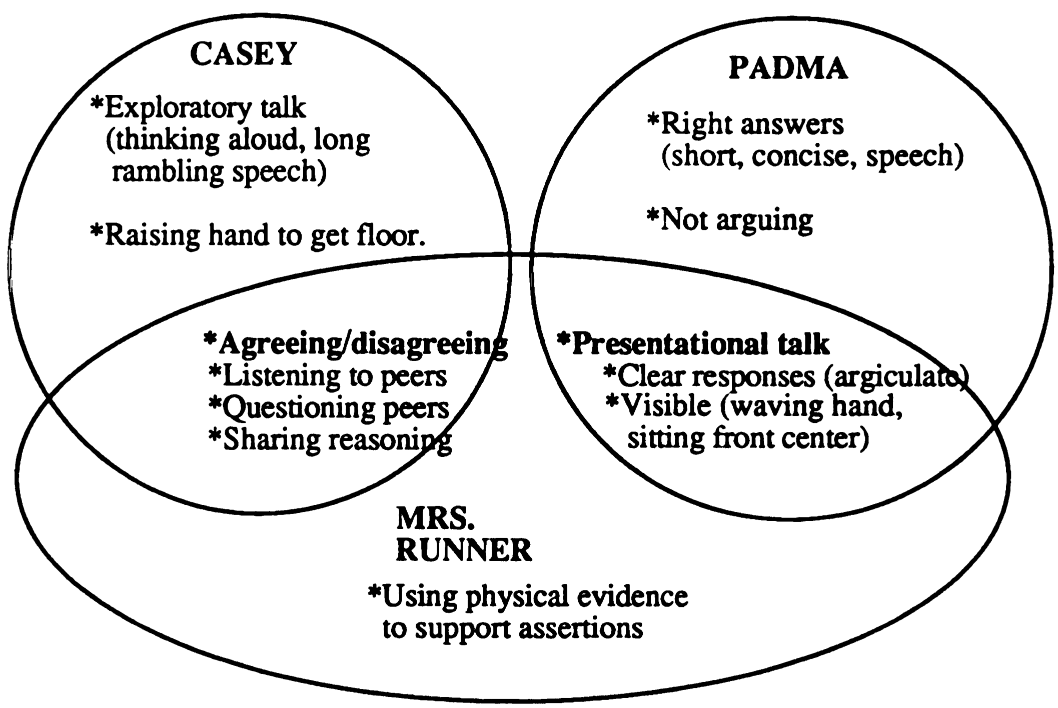
Because of these factors, Casey in many ways challenged Mrs. Runner's image of a good science student -- showing her another discourse style that could clearly be characterized as one legitimate way to puzzle and make sense of ideas. This strategy was accepted in this discourse community and enabled Casey to learn the science concepts so that he was able to use them to explain the everyday phenomena on the post-assessment. One explanation for his success is that the very structure of the learning community enabled and encouraged Casey to use discourse strategies which promoted his understanding of the science content even when he was sometimes apparently neglected by the teacher. Thus, for Casey, the discourse allowed him access to the science concepts even though he was not engaging in the discourse in the same way as the majority of his peers.

Casey introduced into the learning community a new style of discourse that was accepted by the teachers as consistent with their social constructivist goals. Although it took awhile for him to gain the speaking floor and although the teachers had some difficulty figuring out how to respond to his rambling speech, Casey was not silenced.

The story of Casey, which illustrates that it is possible to construct a learning community in which students who might "slip through the cracks" in a traditional classroom can participate productively and learn science, presents a picture of hope. Casey did not do well in a traditional classroom and was not considered a good student by his teachers and peers --probably because they didn't notice him. However, against what appeared to be odds against it, Casey was successful in learning the science concepts in the unit. Casey's story illustrates that science can be accessible to all students, even those who are not accepted as "smart" students in the traditional sense.

The Venn diagram in Figure 8.1 below illustrates the relationship between Casey and Padma's behaviors and Mrs. Runner's image of a successful science student.

Figure 8.1
Successful Science Learning: Three Perspectives



Exploratory vs. Presentational Talk: Changing Images

The determining factors in whether a student would be perceived as successful in this science class appeared to be the nature and form of the student's talk -- whether it was presentational or exploratory and whether the student was able to use the agree/disagree format. However, these two factors were somewhat in conflict because it was possible to use the agree/disagree pattern as part of exploratory talk -- which was not valued in the same way that presentational talk was. Thus, although Casey engaged in the valued agree/disagree pattern he was not seen as successful because he did so through exploratory talk rather than presentational talk.

Figure 8.1 above illustrates that Casey did engage in many of the activities which Mrs. Runner encouraged students to do. He listened to his peers and asked them questions, he used logical argument, and he evaluated his peers ideas and argued with them based upon this evaluation. However, the way in which Casey engaged in these activities was through the use of exploratory talk. This contrasted with Padma. Although she was not engaging in many of the activities which Mrs. Runner valued, Padma had "mastered" using presentational talk. When she did participate orally in class, the responses that Padma gave were clear, concise, and clearly addressed the question that Mrs. Runner had initiated. Because of the way in which she made use of presentational talk over the course of the unit, Padma appeared bright and articulate even though she was not engaging in such activities as agreeing or disagreeing with a peer, or listening to and questioning a classmates thinking. Thus, her failure to learn the science content as indicated by the post-assessment was initially surprising. It was only through subsequent analysis of the ways in which she participated in science class that her lack of engagement with the science concepts became visible.

This presents a bit of an anomaly. Casey's exploratory speech was often long, rambling, and difficult to follow, especially when compared with Padma's. However, it was useful to Casey in making sense of the science concepts. Mrs. Runner probably wanted students to engage in the exploratory talk that Casey used, however she had not had students in the past who took this invitation to think aloud so seriously. As a result, Casey's talk did not conform to the image of the talk of a successful science student. As described earlier, a teacher such as Mrs. Runner would probably benefit from a description of Casey and Padma's participation in the learning community and their science learning. Such a description might help her understand the ways in which Casey is using the discourse to promote his learning. This understanding would lead to valuing exploratory talk over presentational talk to the extent that students could be taught how to use their talk in this way. Understanding the ways in which Casey was using his talk would also lead to greater understanding of the ways in which to respond to exploratory talk so that it becomes a valued form of science learning.

A further problem with changing the norms for classroom discourse from primarily presentational to exploratory talk is that there will always be students like Padma who have been successful in science and will not easily make the transition to participating in the discourse in different ways. A challenge for the teacher is to become aware not only of the talk of successful students like Casey, but also of students such as Padma. They then need to continue to work with them more explicitly to change their understanding of what it means to be a "good student" in science class.

I strongly suspect that Padma exemplifies a common problem when a teacher is trying to change the norms for participation in the science discourse. Padma was successful in science by the traditional definition. Her teacher believed that she was a good student. A limitation of this study is that I do not have data on Padma's participation in science in previous years nor samples of her tests from these years. However, I suspect that she did well in the past on science recall tests. It must be confusing to Padma, that she did not do well on the science post-assessment. During discussions she didn't appear to understand what the teacher was looking for with her questions, she was not participating in the discussion, and when she did participate she relied on strategies that didn't work to promote her learning although they did help her maintain an illusion of being a good student.

Implications of the Stories of Padma and Casey: More Questions than Answers

More research is needed to identify and confirm my assertion that Padma is not unusual and that there are many students like Padma who suddenly find themselves struggling and are not as successful in science (e.g. on a post-test) when the norms for classroom discourse are changed from the traditional norms to one in which the purpose of the talk is to make sense of ideas. Questions to be addressed in future research are: Are there other students like Padma who struggle with the change in discourse norms? And, if so, what strategies do they use when they participate in the discourse? Do they use some of the same, less productive, strategies that Padma used?

Padma's case has implications for pre- and in-service teacher education as well. She raises an interesting dilemma: What can a teacher faced with a classroom with several students like Padma do so that these students' self concepts in science don't suddenly plummet? Certainly the learning of these students cannot be sacrificed so that the learning of students like Casey' improves. How can one structure the discourse community to meet the needs of students like Casey as well as students like Padma?

Teachers and teacher education students need to be aware that when they try teaching using a social constructivist perspective, there are going to be students like Padma and Casey. Students like Casey will challenge the teacher with new discourse styles while students like Padma will rely on traditional participation structures and avoid wrestling seriously with ideas. Changing these students' image's of what it means to be good in science is not as simple as just saying, "I want you to listen to your peers and decide if you agree or disagree based upon the evidence."

As they change the norms for discourse in their science classrooms, teachers are going to have to work hard at drawing students like Padma into the discourse at the very times when they want to retreat from the discourse. Mrs. Runner tried to do this on one or two occasions; however, she did not follow through -- perhaps because it was painful for both she and Padma. However, persisting in drawing Padma in and helping her understanding more productive ways to participate in the discourse is important if Padma is to learn science content.

Furthermore, teachers need to help students like Padma change their image of what success in science is. Although the teachers were very clear that they wanted the students to participate in the discourse, the idea that in order to be successful in understanding science it is mandatory to participate orally in the discourse was never made explicit. It will take time and self conscious effort on the part of the teacher to help Padma change her image of what being good in science means and looks like. However, this is time well spent. If this is not done and Padma is allowed to continue to rely on her ineffective strategies, she is going to find herself slipping further and further behind her peers in her understanding of the science concepts as is illustrated by the lack of progress she made from pre- to post-test in this unit when compared with her peers.

Casey participated in the class in different, and more productive ways, than Padma. The questions that the story of Casey raises for me is: Is Casey an anomaly? Or are there other students like him who are not perceived of by teachers and peers as good students in the traditional sense who are quietly making sense of the content in very productive ways when they are in a social constructivist classroom?

One need for further research is to study other classes which reflect a social constructivist perspective to see if there are other students like Casey -- students who are not getting the speaking floor or who get the speaking floor but using it in ways inconsistent with the norm for traditional classroom discourse, yet are making sense of the science content in productive ways. One way in which the learning community was so powerful for Casey was that, while he had a unique style for participating in the classroom learning community - using exploratory rather than presentational talk - this classroom accommodated Casey's unique style so that he was able to use his way of talking to productively make sense of the science content. Another question, then, is: Is this typical of a social constructivist discussion - that many different discourse styles can be accommodated in such a positive manner?

And, if there are other classrooms which accommodates the discourse of students like Casey: Are these students using similar discourse strategies to Casey's? How common are the strategies of unrehearsed speech, repetition, and use of organizing phrases? Are these strategies commonly used by students who successfully use the discourse to make sense of the science content? If they are, this has implications for how we teach students to talk about their ideas in science.

The story of Casey highlights the challenge and potential power of creating a classroom discourse community in which participation in the discourse is an option open to all students. Many of my teacher education students write admirable lesson plans which include a statement such as, "my role will be to facilitate discussion and make sure that every student participates in the discussion." While this is admirable, it is also simplistic as the story of Casey illustrates. In a class of twenty or more students, there are always students who are better than other students at gaining the speaking floor. Some students quickly figure out the implicit rules for participation and in fact, may have a role in shaping these implicit rules, while others never quite figure out the rules.

A social constructivist discourse pattern is challenging even for experienced teachers. There are many moves than in a traditional I-R-E discussion and these moves need to be used in a flexible way. In a traditional discussion a teacher needs only decide if a student's response is correct or incorrect, evaluate it was such, and either move on to the next question or call on another student to answer the same question. By contrast, in a social constructivist discussion, the teacher must listen to the student's response, probe the student to give their reasoning, then decide the next move based upon the student's response. This next move might be an instructional detour, a reinitiation, a revoicing, or might be to redirect the response by calling for agreement or disagreement from the students.

Casey's story raises the idea of making explicit the implicit rules for participation. Both in-service and pre-service teachers who are learning to teach from a social constructivist theoretical perspective need to be aware that there are always going to be implicit rules for participation -- I believe that as soon as the implicit rules are made explicit other implicit rules will take their place. They need to consider that students like Casey who are not participating may be doing so because they have not figured out the rules, not because they do not understand, or have interest in, the concepts being discussed. They also need to be open, like Mrs. Runner and Ms. Lawson were, to new ways of talking that may be productive learning tools for different students. They need to learn to not shut these new styles down, but use them to learn more about discussion participation patterns and their effects.

Summary of Key Ideas

The perspective on discourse in science developed in this dissertation is that science is discourse and in that order to be scientifically literate students must learn how to appropriate, control, and use the discourse to describe and explain everyday phenomena using the concepts of science. This dissertation focused on describing the discourse and learning of the students in one science class in which learning to appropriate, control, and use the discourse was a central part of the science curriculum.

The social constructivist discussions described in this dissertation differed from the traditional discussions in some important ways. The most common form of classroom discourse in a traditional class is the Initiation-Response-Evaluations (I-R-E) pattern in which the teacher asks a known-answer question (initiation), the student responds by giving the called for piece of information (response) and the teacher evaluates that response (evaluation) either explicitly through statements such as "good", or implicitly by calling on another student in the case of a wrong answer or continuing on with the next question in the case of a correct answer. The teacher and student roles in this discussion rarely, if ever, vary. The teacher always initiates. The questions that the students ask are procedural questions rather than calls for information. A student always responds and the teacher typically evaluates. It would be very unusual for a student in an I-R-E discussion to evaluate another student's response because the teacher would have already evaluated it. Thus, the student would either be supporting the teacher's evaluation or disagreeing with the teacher. This is something that does not occur in traditional classrooms.

A social constructivist class discussion includes the discourse moves of initiation, response, and evaluation. However these moves may be made by the teacher or a student. Additionally, in the discussions analyzed in this dissertation, there were four additional moves: probing, reasoning, revoicing, and reinitiation. Typically, but not always, a teacher asked an open-ended question (initiation) and a student responded (response). What followed after this was considerably more flexible than the evaluation that followed in the I-R-E and was both context and content dependent. Most commonly either the teacher or another student followed a response with a probe for more information (probe). In response to this probe the original respondent would elaborate on their response by giving their reasoning (RE). The teacher then typically revoiced or restated the student's response and reasoning (revoicing) and turned the response back to the class for comment (reinitiation) by calling for agreement or disagreement. At this time a student would often agree or disagree with the original responder (evaluation) and provide evidence for their assertion.

Additionally, in this class there were two different types of class discussion. The first, and most common, was the sense-making discussion which followed the pattern described above. The second was an instructional detour. During an instructional detour the teacher presented information or checked for understanding in a rapid exchange which had many of the elements of the traditional I-R-E including considerably more teacher evaluation than was seen during the sense-making discussions. In these ways pattern, the roles of the participants, and the goals of the discourse in a social constructivist class are very different from those in a traditional class.

Learning from a social constructivist perspective is different than learning in a traditional classroom. Learning in a traditional classroom involves paying attention to the teacher and repeating the information given at appropriate times. Learning in a social constructivist class involves becoming a participating member of a discourse community (Lemke, 1990; Edwards and Mercer, 1987) in which the science is discourse (Gee, 1989). The "Changes in Matter" unit was planned and taught with an emphasis on having students make sense of the science by talking about their ideas with their peers. Over the course of the unit Mrs. Runner, Ms. Lawson, and the other teachers provided many opportunities for the students to share their thinking and ideas, to agree and disagree with one another, and to work on consensus building as members of a discourse community. For example, nearly every discussion began with a question such as, "Who has something interesting they noticed they would like to share?" From there the discussion shifted to students responding to the ideas on the floor by agreeing or disagreeing and providing evidence to support their assertions. Throughout the unit Mrs. Runner implicitly and explicitly stressed the value of classroom talk and sharing thinking and ideas as a way to learn.

There were problems as well as benefits associated with the social constructivist discourse. Although some students, like Casey, who do not do well in a more traditional science discourse community, thrived in Mrs. Runner's class there were other students, like Padma, who, either consciously or unconsciously, became invisible during class discussion because of the structure of the discourse community.

The complication of creating a discourse community of any type is that it evolves and is shaped by the participants. There are both explicit rules for participation and tacitly agreed upon implicit rules for participation. Because many of the rules are implicit they are often difficult for some students to figure out. The struggle to figure out the implicit rules for participating in the discourse was seen in different ways in the cases of Casey and

Padma. Casey struggled to figure out the implicit rules for participation in the classroom discourse while Padma struggled to figure out the purpose of the classroom discourse. This struggle is a valid struggle that goes on in all classrooms. However, it is more pronounced in a classroom in which the norms are being altered than in a classroom which follows traditional school norms.

The classroom described in this chapter provides a much needed concrete example of one elementary science classroom in which the teaching is undergirded by a social constructivist perspective. The students in this class participated in the discourse in different way than the traditional and, as a group, did well on a science post-assessment which measured the growth in their ability to use the concepts learned to explain everyday phenomena. However, this was not the perfect classroom - no such thing exists. The story of Casey represents what is possible when teaching from this perspective and the story of Padma represents some of the problems encountered when teaching from this perspective.

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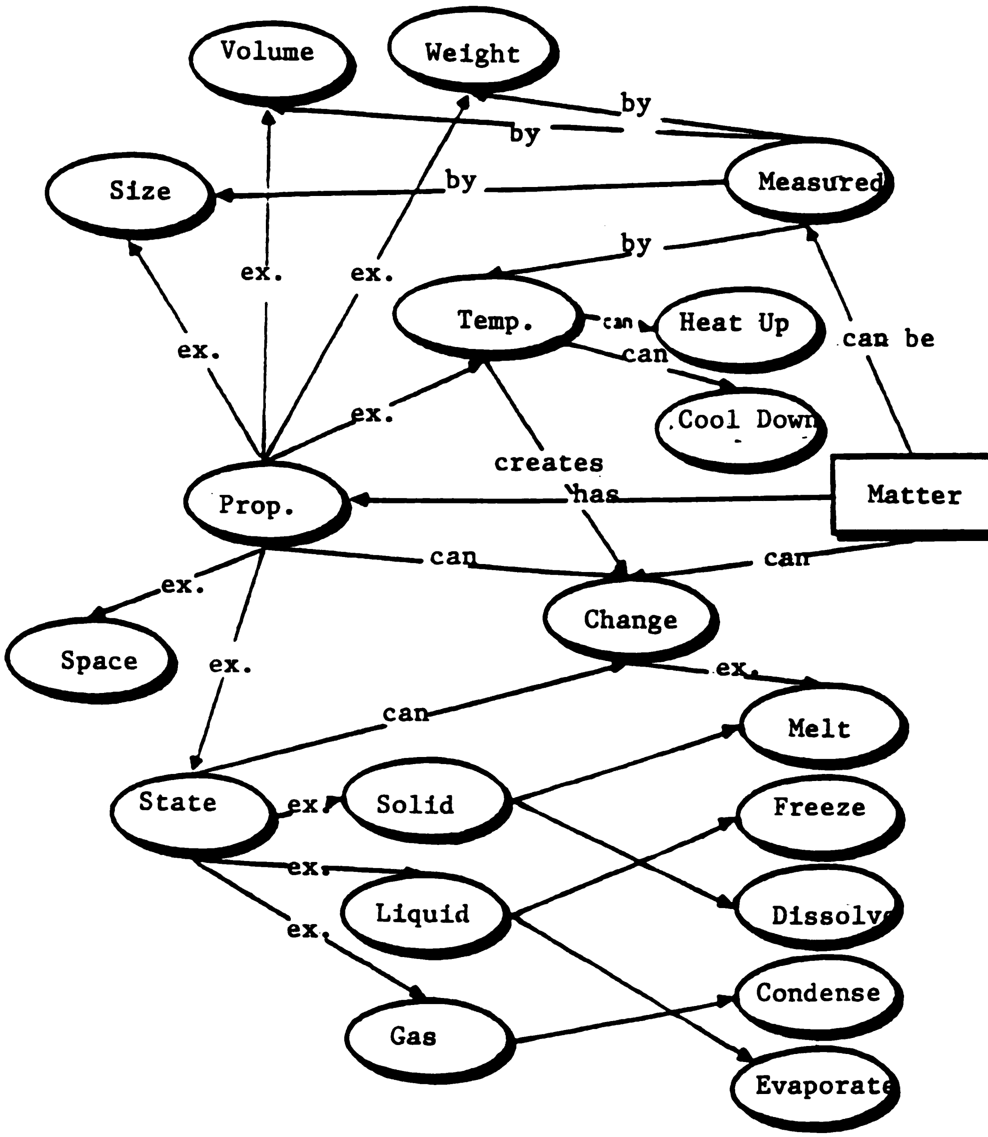
APPENDICES

APPENDIX A

TEACHER'S PLANS

APPENDIX A

TEACHERS' PLANS



3/3/93

Changes in Matter
Problem 4

recorder: ____________________

illustrator: ____________________

investigator: ________________

1. Predict what will happen to an ice cube when you hold it in your hand.

2. Explain why you think this will happen to the ice cube. (List all of the reasons your group can think of.)

PROBLEM/ACTIVITY 6

Goal: To discover room temperature

I. **Goal: To find approximate hand temperature from last Thursday.**

Whole group

1. Find approximate hand temperature based on the table on overhead.
2. Compare body and hand temperature.
   - Record hand and body temps in science notebook (complete chart)
3. Answer this question in notebooks:

   Why do you think body temperature is higher than hand temperature?

II. **Goal: To discover room temperature**

Whole group

1. Vist 8 stations - go in order - clockwise around room.
   - Move at the same time - wait for teacher directions.
   - Complete worksheet (attached) -- Need help? Ask other people that are at the
   - No need to shake the thermometer, but may pick it up to read it. Then replace it.
   - Why wouldn't it go below 70 on Thursday? Speedometer, ovens.
   - 70 what?
2. Discussion - Team area
   - What did you notice/obvserve about temperatures?
   - Why are these thermometers at 70? F or C? Why doesn't the temp. go below 70F?
   - **What is temperature?** * (The degree of hotness or coldness)
   - What is this measuring?
3. Answer question, ***What is temperature?** in science notebooks. ??

4. Based on the data you collected, work with your group to answer the following questions:

a) What happened to your ice cube? Why do you think so?

____

____

____

____

____

____

____

b) What happened to your hand? Why do you think so?

____

____

____

____

____

____

____

c) Develop your group's conclusion:

We believe ____

____

because ____

____

____

____

APPENDIX B

STUDENT INTERVIEWS

APPENDIX B

STUDENT INTERVIEWS

Interview #1
The Role of Writing in Science

Part I. General

1. Tell me about yourself.

2. I want to talk to you about your science class. How would you describe science class to a person who has never been to school before?

3. Tell me what you are learning about in science.

4. Is science class this year different from, or pretty much the same as science class last year (in second grade). What is the same? What is different?

5. Tell me what you are learning about in science.

Part II. Perceptions of the writing

1. You do a lot of writing in your science notebooks. Why do you think your teachers have you write so much in these notebooks?

2. Does writing in your science notebook help you learn science? How does it help you learn/not learn science?

3. Who reads your science notebook? (Probe: self, friends, parents, teacher, other)

    a. Do you ever go back and read what you wrote? Show me something you have gone back and looked at (or think you might like to revisit).

    b. Would you ask anyone to read your science notebook? Who? Why would you ask them to read it? (why or why not?)

4. Do your teachers grade your science notebook? Do you think they look to see if you have the right answer? Is it always important to have the right answer? Why or why not?

5. Show me something you wrote in your science notebook that you really like/ think is pretty good, What do you like (or think is good) about what you wrote?

Interview #2
Learning about Science

1. One day that I watched your class you measured the temperature of snow, oatmeal, and hot soup.

   a. What did you find out from doing that?
   b. Do you remember about what the temperature of each of these was? Snow? Oatmeal? Hot soup?
   c. What happened to the temperature of the hot soup when it was left out in the room? (did the temperature ever change)
   d. What happened to the temperature of t he hot soup when you put the ice cube in it?
   e. Why did t he soup cool off (or whatever they say) when you put the ice cube in it?
   f. What do you think happened to the ice cube when you put it into the soup?
   g. Why did the ice cube melt (or whatever they say) in the hot soup?

2. Tell me one new thing you learned from the science conference.

Interview #3
Group Problem Solving Task

1. Ice Cube Melting Race

   a. What did your group decide was the fastest way to melt the ice cube?
   b. Why do you think this made the ice cube melt faster?
   c. What if I said I didn't believe you. What could you do to get evidence to convince me?
   d. Why do you think I had you do the ice cube race?
   e. Why do you think I had you work in small groups on this problem?

Name ________________

Ice Cube Melting Problem

Suppose you wanted to melt an ice cube as fast as possible. What are some ways that you might make it melt faster using only thinks in your classroom? For each way, explain why that would speed up the melting

Ways to speed up melting	Why would that speed up melting?

APPENDIX C

CHANGES IN MATTER PRE- AND POST-TEST

APPENDIX C

Changes in Matter
Pre-Test

The purpose of these problems is to explore the ideas you have as we begin our unit on changes in matter. Try to explain your ideas instead of just answering with one or two words. This will help your teachers in planning our unit. Your answers will be useful even if you are not sure that someone else would agree with them.

1. Suppose you have a cup of hold chocolate. After drinking part of it, you leave it sitting on the table. You come back an hour later. You feel the cup and taste the chocolate. What different would you notice?

Why would this happen?

2. You have been outside playing in the snow. When you come inside, some snow stays on your boots. After about a half an hour, you come back and look at your boots. There is no snow, but there is a small puddle beside them. What do you think happened to the snow?

Why would this happen to the snow?

3. You get a glass of cold water from the drinking fountain. You use a thermometer to find out the temperature of the water. What temperature do you think the water would be?

____

Why do you predict this temperature?

You leave the cup of water on the table and come back an hour later. What do you think the temperature of the water should be them?

____

4. It is a cold winter day. The temperature outside is about 20°F (-3°C). You get another cup of cold water from the drinking fountain. You take this cup of water outside and leave it. You look at the cup of water again after about half an hour. The water is not frozen. You then check its temperature. What temperature do you think it would be?

____

Why would it have this temperature?

5. It is a cold day in winter. You and a friend are riding in the back seat of a car. After a few minutes, you notice that the window beside you has "fogged up".

What is the "fog" on the window?

What evidence or other support can you give for your answer?

Try to explain how the "fog" formed on the window.

What evidence or other support can you give for your explanation?

6. It is a cold day in winter. The temperature outside is below freezing. You take a thermometer outside and stick it in a snow bank. After a couple minutes, you take the thermometer out and read the temperature. What would the temperature probably be?

____

Why would the snow be this temperature?

Suppose the thermometer read 45° F (6° C). How might this be explained?

How could you test your explanation?

Changes in Matter

Post-Test

The purpose of these problems is to explore the ideas you developed from our unit on changes in matter. Try to **explain** your ideas instead of just answering with one or two words. This will help your teachers understand your ideas. Your answers will be useful even if you are not sure that someone else would agree with them.

1. Suppose you have a cup of hot chocolate. After drinking part of it, you leave it sitting on the table. You come back an hour later. You feel the cup and taste the chocolate. What difference would you notice?

Why would this happen?

2. You have been playing outside in the snow. When you come inside, some snow stays on your boots. After about a half an hour, you come back and look at your boots. There is not snow, but there is a small puddle beside them. What do you think happened to the snow?

Why would this happen to the snow?

3. You get a glass of cold water from the drinking fountain. You use a thermometer to find out the temperature of the water. What temperature do you think the water would be?

____

Why do you predict this temperature?

You leave the cup of water on the table and come back an hour later. What do you think the temperature of the water should be them?

____

4. It is a cold winter day. The temperature outside is about 20°F (-3°C). You get another cup of cold water from the drinking fountain. You take this cup of water outside and leave it. You look at the cup of water again after about half an hour. The water is not frozen. You then check its temperature. What temperature do you think it would be?

____

Why would it have this temperature?

5. It is a cold day in winter. The temperature outside is below freezing. You take a thermometer outside and stick it in a snow bank. After a couple minutes, you take the thermometer out and read the temperature. What would the temperature probably be?

____

Why would t he snow be this temperature?

Suppose the thermometer read 45°F (6°C). How might this be explained?

How could you test your explanation?

6. If you were to place a thermometer on your desk and leave it there for ten minutes, what temperature do you think it will show?

____

Why would it show this temperature?

Suppose you held the ball of t he thermometer between your thumb and finger for two minutes. What do you think the temperature reading would be then?

____

Why would it show this reading?

APPENDIX D

PRE- AND POST TEST SCORING RUBRICS

APPENDIX D
SCORING RUBRICS

Question 1a
Prediction of Hot Chocolate Cooling

Code	Label	Description
4	Cooling	Predicts chocolate getting "cooler" or the temperature goes down.
3	Room temperature	Predicts chocolate will come to about room temperature.
2	Get cold	Predicts chocolate getting "cold"
0	No cooling	No mention of cooling or temperature change "I don't know", no response, or circular answer.

Question 1b
Explanation of Hot Chocolate Cooling

Code	Label	Description
6	Air contacting	Cites cooler air contacting the choc.
5	Air as cause	Cites the air being cooler but does not specifically mention contact with the air.
4	Room temperature	Cites room temperature or the room as being cool (no mention of air)
3	Heat leaves / Material transfer	Heat or hotness leaves OR Some kind of matter leaves e.g. hot air left or hot air rises OR Heat from the chocolate goes into the room air OR Cold from the room air goes into the chocolate.
2	Inevitable temp. equilibration	Hot materials always cool down and cold materials always warm up when left alone.
1	Description only	Describes instead of explaining, e.g. because it was left or cooled.
0	Doesn't answer	Don't know OR No response OR circular response.

Question 2a
Prediction of Snow Melting

Code	Label	Description
4	Solid to liquid	Predicts snow will turn from solid to liquid
3	Turn to liquid	Predicts snow will turn into liquid water
2	Turn to water	Predicts snow will turn into water
1	Melting	Predicts snow will "melt"
0	Doesn't answer question.	"I don't know", blank, or circular response

Question 2b
Explanation of Snow Melting

Code	Label	Description
6	Air contacting	Cites warmer air contacting the snow
5	Air as cause	Cites the air or air being warm (not contact with air)
4	Room temperature	Cites room temperature or the room being warm (no mention of air)
3	Heat transfer/ material transfer	Heat from the room or from the room air melts the snow OR Warm air went into the snow.
2	Heat as cause	Heat or hotness melted the snow (no mention of where it came from)
1	Description	Describes instead of explaining. e.g., because it was left inside.
0	Doesn't answer question	"I don't know", no response, or circular answer.

Question 3a
Prediction of Drinking Fountain Water Temperature

Code	Label	Description
3	Room temperature	61-75° F or 16-24° C
2	Below room temperature but above freezing	33-60° F or 1-15° C
1	Below freezing or above room temp.	Below 32° F,or Above 75° F OR Below 0° C or Above 24° C
0	No answer	Leaves blank

Question 3b
Prediction of Water Warming

Code	Label	Description
4	Room temperature	Predicts water will come to about the temperature of the air in the room.
3	Specific temperature	Predicts a specific temperature warmer than the one they gave.
2	Warming	Predicts water getting "warmer" or temperature goes up
1	No change	Predicts the temperature will stay the same.
0	Doesn't answer question	Says "I don't know", no response, or circular response.
3	Cooling	Predicts water getting "cooler"

Question 3c
Explanation of Cold Water Warming

Code	Label	Description
6	Air contacting	Cites warmer air contacting the water
5	Air as cause	Cites the air being warmer (but not contact with the air).
4	Room temperature	Cites room temperature of the room being warm (no mention of air)
3	Heat or material transfer	Heat goes from the room air into the water. OR Some kind of matter enters the water e.g. warm air got into it.
2	Heat enters	Heat or hotness enters (no mention of where it came from)
1	Inevitable temp. equilibration or Description	Temperature of objects always changes. Hot objects cool, cool objects warm. OR Describes instead of explaining, e.g. because it was left it warmed up.
0	Doesn't answer question	"I don't know" , no response, or circular response.

Question 4a
Prediction of Cold Water Placed Outside

Code	Label	Description
3	Cold but above freezing.	33-60°F or 1-15°C
2	Outside temp	20°F or -3°C
1	Below outside temp	Below 20° F or -3°C
0	Doesn't answer question	"I don't know", no response, or circular response.

Question 4b
Explanation of Cold Water Placed Outside

Code	Label	Description
4	Cold air as cause, water not frozen	Outside air temperature is cooler than the water but water is above the freezing point because it is not yet frozen.
3	Outside temp, water not frozen.	Outside temperature cooler than water (but does not mention contact with air) but water is above freezing point because it is not frozen yet..
2	Outside temperature OR Water not frozen	Takes into account the outside temperature but doesn't take into account the water isn't yet frozen OR States that the water isn't frozen so the temperature isn't below freezing but doesn't mention role of outside air temp.
1	Description only	Describes instead of explaining, e.g. Because it was left outside or it cooled.
0	Doesn't answer question	"I don't know", no response, or circular response.

Question 5
Not analyzed. This concept was not covered in unit or on the post test.

Question 6
Prediction of snow temperature

Code	Label	Description
3	Reasonable temperature below freezing.	Below 32°F OR 0°C
2	Freezing point	32°F OR 0°C
1	Above freezing point	Above 32°F OR 0°C
0	Does not answer question	"I don't know", no response, or circular response

Question 6b
Explanation of snow temperature prediction

Code	Label	Description
2	Cites freezing point	It is below freezing so it must be below about 32° F or 0° C.
1	Descriptive	Because it is below freezing
0	Doesn't answer question	"I don't know", no response or circular response.

Question 6c
Explanation of 45 F Thermometer Reading

Code	Label	Description
3	Provides a theory	Student provides a reasonable theory for the discrepancy such as 1. Broken thermometer 2. Misread thermometer 3. Delayed reading thermometer until it had warmed up. 4. Held thermometer by bulb raising temperature. 5. Thermometer not left in snow long enough.
2	Error with reading but no explanation.	Gives the explanation that 45°F has to be wrong but doesn't give explanation why.
1	No dilemma seen	Describes 45F as kind of cold but not freezing. Does not indicate that this reading is problematic.
0	Does not answer the question.	"I don't know", no response, or circular response.

Question 6d
Testing the explanation

Code	Label	Description
4	Appropriate experiment for testing their theory	Designs an experiment which tests <u>their</u> theory.
3	Appropriate experiment but does not test their theory	Designs an experiment which is accurate but does not test <u>their</u> theory.
2	Attempts experimental design.	Designs an experiment which would not test theory .
1	Descriptive	States that you could do an experiment.
0	Does not answer the question.	Does not give an experiment OR says "I don't know" or gives a circular response or no response.

Question #7a
Prediction of temperature of thermometer on desk.
(Post-Assessment Only)

Code	Label	Description
2	Room temperature	61-75°F OR 16-24°C
1	Above or below room temperature	Above 75°F or 24°C OR Below 61°F or 16°C
0	Does not answer question	"I don't know", no response, or circular response

Question #7b
Explanation for prediction of temperature of thermometer on desk.

Code	Label	Description
4	Air as cause	Cites the air in the room as being measured
3	Measuring desk temperature	Said that the desk is the same, warmer, or cooler than the room and predicted accordingly.
2	Room temperature	Says it will be the same as the temperature in the room but does not say why.
1	Description	Describes instead of explaining, e.g. because it is in the room, on the desk, etc.
0	No answer	Leaves blank

Question #7c
Prediction of temperature of thermometer in hand

Code	Label	Description
3	Value determined in unit to be hand temp.	90°F
2	Body temperature	98°F
1	Above or below hand temperature.	Above or below 90°F
0	No answer	Leaves blank

Question #7d
Explanation of temperature of thermometer in hand

Code	Label	Description
3	Body temperature warmer than R.T.	Argues that body temperature is warmer than room temperature so if you are holding the thermometer the temperature would go up to body temperature.
2	Describes experimental evidence	Describes findings in unit with regard to hand temp.
1	Cites experimental evidence.	"Because this is what it is when I did it in class"
0	Doesn't answer question	"I don't know", no response, or leaves blank.