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ABSTRACT

As part of a larger examination of student perspectives in science, social studies and communication arts, this report summarizes yearlong classroom observations and end-of-year interviews of fifth-grade students to examine ways in which students integrated their knowledge in meaningful ways. Teacher-researchers involved in the overall project included two fifth-grade teachers, one third-grade teacher, two university professors, and three doctoral students in teacher education. Case studies of two fifth-grade students were used to examine multiple ways in which students integrated knowledge within science and across subject matter areas. The report highlights ways in which many students connected their study of perspective in social studies to their learning in science and ways in which students connected their exploration of collaboration in a writers' workshop with their science learning. The report also describes three common characteristics in the teaching of science, social studies, and a writers' workshop that help explain what enabled students to make connections within and across subject matter areas: (1) features of the learning community in each subject matter; (2) epistemological orientations of the teachers in each subject matter; and (3) curricular centrality of students' personal lives and experiences in the three subject matters. Excerpts from student interviews and an appendix of the timeline of key concepts taught concurrently in each subject matter are included. (MM)

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INTEGRATION FROM THE STUDENT PERSPECTIVE: CONSTRUCTING MEANING IN SCIENCE

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and Constanza Hazelwood

Center for the Learning and Teaching of Elementary Subjects

Institute for Research on Teaching
College of Education
Michigan State University

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INTEGRATION FROM THE STUDENT PERSPECTIVE: CONSTRUCTING MEANING IN SCIENCE

Kathleen J. Roth, Kathleen Peasley,
and Constanza Hazelwood

with
Literacy in Science
and Social Studies Colleagues

Corinna Hasbach, Elaine Hoekwater, Carol Ligett,
Barbara Lindquist, and Cheryl L. Rosaen

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

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Abstract

Drawing from yearlong classroom observations and end-of-the-year interviews probing fifth graders' experiences and learning in science, social studies, and writers' workshop, the teacher-researcher authors examine ways in which students succeeded in integrating their knowledge in meaningful ways. Case studies of Nan and Nathan are used to examine the multiple ways in which students integrated knowledge within science: how they integrated science concepts studied across the school year, how they integrated the study of the nature of scientific inquiry with conceptual knowledge development, and how they integrated science knowledge with their personal lives, experiences, knowledge, and questions. While these kinds of integrated knowledge goals were intended by the teachers, cross-disciplinary integration was not an explicit goal of the various teachers involved in teaching these subjects to the students. Despite this lack of planned curricular integration, students revealed interesting ways in which they integrated across subject matter areas. The report highlights ways in which many students connected their study of "perspective" in social studies to their learning in science and ways in which students connected their exploration of "collaboration" in writers' workshop with their science learning.

The report describes common characteristics in the teaching of the three subject matter areas that help explain what might have enabled students to make such powerful connections within and across subject matter areas. The three characteristics that are analyzed are (a) features of the learning community in each subject matter area, (b) epistemological orientations of the teachers in the three subject matters, and (c) curricular centrality of students' personal lives and experiences in the three subject areas.

Prologue to a Set of Papers on Curriculum Integration

Integration from the Student Perspective:
Constructing Meaning in Science (ESC Series No. 63)
Kathleen J. Roth, Kathleen Peasley, Constanza Hazelwood

Integration from the Student Perspective:
Constructing Meaning in a Writers' Workshop (ESC Series No. 62)
Cheryl L. Rosaen, Barbara Lindquist, Kathleen Peasley, Constanza Hazelwood

Holistic Literacy:
Voices Integrating Classroom Texts in Social Studies (ESC Series No. 64)
Corinna Hasbach, Constanza Hazelwood,
Elaine Hoekwater, Kathleen J. Roth, Michael Michell

The Literacy in Science and Social Studies Project.

Each paper in this set explores integration from the perspective of fifth-grade students who were the focus of our collaborative teaching and research across the school year, 1990-91. We are a group of school-based and university-based educators who have been working together for the past three years in a project called the Literacy in Science and Social Studies Project (LISSS). In this project we have been exploring ways to teach for understanding in science, social studies, and communication arts, with an emphasis on studying ways in which discourse and writing can be used effectively to promote understanding.

Taking on Teacher/Researcher Roles

During 1990-91, each of the group participants (two fifth-grade teachers, one third-grade teacher, two university professors, three doctoral students in teacher education) took on what we called a teacher/researcher role. Through collaborative planning, teaching, and researching we tried out new ways of changing and studying our practice and new ways of studying students' thinking and learning as it develops in a classroom setting. Cheryl Rosaen and Barbara Lindquist co-planned and co-taught writers' workshop with the two fifth grade classes, with Constanza Hazelwood and Kathleen Peasley providing data collection assistance. Kathleen Roth and Kathleen Peasley co-planned for science across the fall; Roth taught science to Lindquist's fifth graders while Peasley taught science for Elaine Hoekwater's fifth-grade students. Hazelwood, Lindquist, Hoekwater, Hasbach, and Rosaen assisted in data collection while Roth and Peasley taught science. Social studies for both fifth-grade classes was co-planned and co-taught by Hoekwater and Corinna Hasbach, with Hazelwood again providing research assistance.

Although we often worked in subject-specific subgroups (science, social studies, writers' workshop) for planning and teaching purposes, the centerpiece of the LISSS Project was a weekly two-hour study group involving all project participants. During the first year of the project, this study group focused on study and discussion of what it means to teach for understanding, how discourse and writing can be used as tools for understanding, and what sort of learning community needed to be established for *all* students to develop personally meaningful understandings of social studies, science, and communication arts. When we took on the new teacher/researcher dimension to our work in our second year together, study group became a place to share in our study of our students' thinking and learning and to study our teaching practice. We reflected together on the changes that each of us was implementing in the classroom. We worked collaboratively to develop research questions and data collection techniques for the cases of teaching and learning we were developing. We talked extensively about the 47 fifth graders and their thinking and learning.

Our Initial Views About Integration

We began our work together with an interest in better understanding the role that writing could play in science and social studies teaching and learning. We believed that new approaches to writing and classroom discourse could support students in developing more meaningful understandings of science and social studies concepts. Our view of "understanding" initially emphasized two aspects of integration. First, we wanted students to develop connected networks of concepts in each subject area, not just to memorize lists of words and dates. Secondly, we wanted students to integrate their study of science, writing, and social studies with their personal lives and experiences and ideas. We did not address a third kind of integration--cross-disciplinary integration. Although our study group discussions cut across the three subject matter areas of interest, each teacher/researcher team was exploring teaching for understanding within one particular subject matter area. Integrated teaching of science, social studies, and writers' workshop was not a prominent aspect of our plan, although Rosaen and Lindquist did have some goals for getting students to write about subject matter topics in writers' workshop. We viewed teaching for understanding *within* each subject matter area to be a challenging enough task for our first year of joint planning, teaching, and inquiry. Thus, we made few explicit attempts to integrate our teaching of social studies, science, and writing instruction around a common theme or set of concepts. Students explored desert plant and animal adaptations at the same time that they conducted a study of the history of the school and wrote pieces about themselves. They studied concepts of food, energy, cells, adaptations, and evidence in science while they explored the concepts of racism, empathy, discrimination, freedom, democracy, power, exploitation, and perspective in social studies. Descriptive writing techniques, authorship, revision, collaboration, and point of view were emphasized in writers' workshop. While many of these topics and concepts could have been integrated in our teaching, we did not set that as a prominent goal. An exception was an author's design unit toward the end of the year in writers' workshop in which students were encouraged to write about science and social studies content.

Learning About Integration From the Students

Our students taught us about integrated *learning* even though integrated *teaching* was not purposefully planned. Each of us conducted in-depth interviews with a subset of the fifth graders at the end of the school year. Our interviews were clearly defined in our minds as science interviews, social studies interviews, and writing interviews. While each interview was planned to explore ways in which students integrated knowledge within each subject area and ways they integrated their school learning with their personal lives and experiences, questions designed to explore students' ways of integrating across these three subjects were few (because we did not intend in our teaching for such integration to occur). However, students' interview responses raised important cross-disciplinary integration issues. In the science interviews, for example, students used ideas from social studies ("perspective") and writers' workshop ("collaboration") in meaningful and interesting ways. Such data prompted us to reexamine integration from the students' perspectives both *within* and *across* subject matter areas.

This reexamination of the data from cross-disciplinary as well as disciplinary perspectives enabled us to develop a new framework for thinking about integrated learning and integrated teaching. As an analysis strategy, each subject matter team separately examined the data (individual and small-group student interviews across the year, field notes and transcripts of lessons, student writing in the three subjects across the year, videotapes of small group work in each subject area). Each team looked for evidence of students' cross-disciplinary integration while focusing on studying integrated learning within a particular subject area. The communication arts team (Rosaen, Lindquist, Peasley, and Hazelwood) asked; How did students integrate science and social studies knowledge, skills, and ways of knowing with their development as writers? The social studies team (Hasbach, Hazelwood, Hoekwater, Roth, and Michael Michell, a doctoral student in teacher education, who participated in analysis and writing) asked, How did students integrate their developing knowledge about history and social studies with their personal life experiences? The science team of Roth, Peasley, and Hazelwood asked, How did students integrate science concepts and ways of knowing taught across the year? How did students integrate ideas from social studies and writers' workshop with their science learning? Each of the three subject matter teams then wrote a paper based on their analysis.

Looking across the three papers: Differences. Each subject-matter focused paper describes cases of integrated learning, highlighting those aspects of integration that seemed most salient across the interviewed students. In social studies, the most striking kind of integration constructed by students was integration of social studies concepts with their personal lives, beliefs, experiences, and feelings. Integration of ideas about discrimination and racism, for example, were powerfully connected to the personal lives of students who had experienced significant discrimination. The students in the science paper revealed to us fascinating cross-disciplinary insights as well as meaningful integration of concepts taught across the year in science. Ideas from writing and social studies like "perspective" and "collaboration" appeared to be very useful to students in describing their understanding of scientific inquiry. In the writing case, links across subject areas were also striking, with students using ideas from social studies and science ("sexism," "discrimination," and "empathy") in their development as writers.

Looking across the papers: A new framework for thinking about integrated learning. As we looked across the three analyses, we found common characteristics in our teaching of the three subjects that helped us explain what might be enabling students to make such powerful connections both within and across subject matter areas. These commonalities suggest that our teaching across these subjects was integrated in many ways that we had not recognized while we were engaged in the teaching. Our teaching in the three subject areas shared common characteristics:

1. **Features of the learning community.** In our study group sessions, we jointly conceptualized the kind of learning community we were trying to create in each of our classrooms. We used Hermine Marshall's (1990) distinction between the metaphor of a classroom as a workplace compared to a classroom as a learning place and developed a list of related qualities that are important to us in creating learning communities that contrast with more traditional, work-oriented classrooms. In work-centered classrooms (like ours in the past) the emphasis is on each individual completing his or her work, often merely for the sake of "getting the job done" rather than for the purpose of learning. In a learning-oriented classroom, students still complete work, but there is an emphasis on how and why the work is being done. Thinking, questioning, discussing, making mistakes, trying new ideas, and so forth are valued and rewarded as much as completing a finished, correct product. We tried to create environments in which everyone's knowledge and experience was valued and respected and in which students as well as teachers felt ownership and engagement in the content of study. We designed strategies to engage students in meaningful learning tasks while avoiding teaching strategies and evaluation patterns that encouraged students to complete work at the expense of making sense and raising questions. Table 1 summarizes

some of the features of the learning community that we strove to create in teaching science, social studies, and writing.

2. **Epistemological orientations of the teachers--knowledge as tentative and socially constructed.** The features of our learning communities described in Table 1 are built upon some basic assumptions we share about the subject matters we are teaching. For example, an important aspect of our learning communities was collaboration. Collaboration was important to us not only because it is an effective way to engage students actively in their learning; collaboration is also a basic aspect of knowledge construction in science, social studies and history, and writing that we wanted to communicate. Rather than presenting science or history knowledge as something that was personal and private--the property of a single individual--knowledge in our classroom learning communities was created by students (and adults) working in collaboration with one another. This emphasis on collective cognition, rather than on the individual, is consistent with a social constructivist epistemology of science or history in which the knowledge rests not external to the individual, but rather is located within the discourse community, "within the corps of human beings with a common intellectual commitment "(King & Brownell, 1966, p. 68). We encouraged students to view their texts (including textbooks, other print sources, videotapes, visitors, statements by other students and teachers, experiments, etc.) as authored, as tentative statements of knowledge, as open to question and change. We wanted to communicate that scientific and historical knowledge are human creations just as are fictional stories created by writers. We wanted students to understand the rules of evidence that are used to create historical and scientific explanations and descriptions and to judge the merits of a literary work, while also understanding ways in which the biases and perspectives of the writer can influence the way knowledge is presented and which knowledge gets presented in official school texts. In all subject areas, students were supported in being critical readers of multiple texts.

Table 1

A Learning Setting vs. a Work Setting:
Creating a Conceptual Change Learning Community

A CONCEPTUAL CHANGE SCIENCE LEARNING COMMUNITY	A WORK-ORIENTED CLASSROOM SETTING
*Sense making and learning as the goal	*Getting the work done as the goal; getting facts learned or activities and projects completed
*Personal, emotional involvement in meaningful and authentic problem situations	*Depersonalized, unemotional relationship with work, getting the products made
*Ownership and commitment by each person; responsibility shared	*Teacher as executive in charge of everything
*Active inquiry and question asking are valued and encouraged	*Getting the right answer is valued and encouraged
*Expertise comes from everyone, is shared; learning is a collaborative process	*Expertise comes from the teacher and learning is a private activity
*Everyone's ideas are valued and respected as useful in the learning process; diversity is celebrated in a caring environment	*Workers need to keep quiet and busy; diversity is a problem for quality control and efficiency
*Good learners listen to each other	*Good workers listen to the teacher
*Public sharing and revising (working out) of ideas	*Only complete, polished final products are shared
*Evidence, not authority, is used to construct new knowledge and judge merits of ideas	*Knowledge comes wrapped in neat packages that are delivered from teacher or text to student; all packages are to be appreciated and not questioned
*Each learner starts and finishes in a unique place; learning as a process of conceptual change	*All workers create the same product or else are failures; learning as a "you have it or you don't" phenomena

NOTE: The metaphor of a learning vs. a work setting for thinking about classrooms was adapted from Hermine H. Marshall (1990) in "Beyond the Workplace Metaphor: The Classroom as a Learning Setting" in Theory Into Practice, 29, 94-101.

3. **Curricular centrality of students' personal lives and experiences.** In all three subject areas, we centered curricular planning around students' thinking and experiences. We thought about the content from the students' perspectives in planning and altered our teaching as we learned more about the students' ideas and experiences. We tried not to shy away from personal connections that might be emotionally laden; in writing and in social studies, students were encouraged to think about, draw from, and share experiences that were important to them--even though at times these experiences were hurtful ones. In science, students were encouraged to have personal reactions and feelings about the content of study. They were able to share their feelings of alienation from science without penalty; they were respected for having a wide variety of personal beliefs about the use of animals in scientific research, and they were introduced to scientists as human beings who had families and personal lives as well as passions for learning about the world around them.

These three commonalities across our classrooms gave us a new framework for thinking about integration from the students' perspectives. This framework for thinking about integrated *learning* is challenging our thinking about integrated *teaching*. We began this study assuming that we were not engaged in integrated teaching. But our students demonstrated some exciting ways in which they were making significant connections among ideas that we never expected. Thus the students challenged us to rethink our definition of integrated teaching. What is integrated teaching? What does integrated curriculum look like? Our entering view, consistent with the literature on integration, was that integrated teaching is built around a conceptually or topically integrated curriculum. Theme teaching, for example, is integrated teaching, because the curriculum is built around a topic or concept that cuts across disciplinary areas. When teachers get together to plan such theme teaching, their discussions focus on conceptual links across the subject areas--about curriculum content. Now we are thinking that such theme teaching may or may not result in integrated student learning. The students have challenged our belief that integrated curriculum is necessary in enabling integrated learning. Instead, we now see the three commonalities described above as critical factors in creating integrated teaching that supports integrated learning.

Continuing Our Explorations of Integrated Teaching and Integrated Learning

We have learned many lessons about integrated learning from our students. In this paper set, we describe cases of integrated learning and our emerging understandings of the features of the instructional context that supported such learning. The papers focus purposefully on cases of meaningful and successful integration. We chose such a focus because we were surprised and excited to discover that so many students--including many students labelled "at risk"--were able to make such powerful connections. Given the wealth of studies that demonstrate the difficulties students have in transferring knowledge, we think these students' success stories need to be told.

To help us examine and question our emerging framework for thinking about integrated teaching, we want to continue our analyses of students who were less obviously successful in integrating knowledge within and across subjects. This is difficult to study using our existing data because our interviews were not designed to tap cross-disciplinary integration, and each interviewer made clear to the student that the interview was about science or social studies or writing. Students who appeared to have knowledge compartmentalized into disciplines may actually have made some rich connections among the subjects that were not elicited by very many of our questions.

In our future research and teaching collaboration, we want to continue to examine integrated teaching and learning. During the 1992-93 school year, we plan to continue our integrated teaching in terms of our new framework for thinking about integrated teaching: the learning community, epistemological orientations, and curricular centrality of students' personal lives and experiences. In addition, we will explore the role of curricular content integration in supporting integrated learning. Building a curriculum around the theme of "1492--The World 500 Years Ago and Today," we will incorporate as many subject areas as possible in our integrated teaching. Will this curricular integration around a topical theme enable students to make even more powerful connections than those made by the students reported in these papers? We are not convinced that such an integrated curriculum will appear integrated from the student perspective. We know we will learn a great deal about aspects of integrated curriculum that are meaningful only to the teachers versus aspects that are meaningful to students. We hope that such an inquiry into integrated curricular content will enable us to understand whether our future efforts should focus on teaching for understanding within each subject matter area or should be focused explicitly on integrated curriculum as well, or whether we should aim to strike a balance between integrated and subject specific teaching.

As you read one or more the papers in this set, you may find it helpful to refer back to our three commonalities that cut across all three papers. We also hope you will join us in considering the questions we are raising about integrated teaching and learning: What features of instruction are critical in supporting integrated student learning? We invite your reactions and comments and hope our work stimulates a lively dialogue about these important issues.

INTEGRATION FROM THE STUDENT PERSPECTIVE: CONSTRUCTING MEANING IN SCIENCE[1]

Kathleen J. Roth, Kathleen Peasley, and Constanza Hazelwood
with LISSS Colleagues[2]

Corinna Hasbach, Elaine Hoekwater, Carol Ligett, Barbara Lindquist, and Cheryl L. Rosaen

Emerging Views of Integration in the Literacy in Science and Social Studies Project

Three years ago we collaboratively developed a teaching/research project, the Literacy in Science and Social Studies Project, whose members include 3 elementary teachers, 3 doctoral students in teacher education, and 2 teacher education faculty from Michigan State University. Although the title of our project might suggest that we were interested in helping students integrate knowledge *across* these school subject matter areas (science, social studies, and literacy), we were initially focused on teaching for understanding *within* each of these subject matters. We each entered the project with particular subject matter interests and areas of expertise (the authors of this paper were initially interested in science); the commonality we shared was an interest in the role of writing and discourse in teaching for understanding in each of these subject areas. Thus, our project title reflects our respective subject matter interests and our shared interest in examining how writing and discourse could support students in developing meaningful understandings about science, social studies, and writing. It is important to highlight that we did not intend to explore cross-subject matter integration. It was our collaborative work together and insights from the

[1]This is one of a set of three papers on curriculum integration originally presented at the annual meeting of the American Educational Research Association, San Francisco, April 1992.

[2]Kathleen J. Roth, associate professor of teacher education at Michigan State University, is a senior researcher with the Center for the Learning and Teaching of Elementary Subjects. Kathleen Peasley and Constanza Hazelwood, doctoral candidates in teacher education at MSU, are research assistants with the Center. Corinna Hasbach, a doctoral candidate in teacher education at MSU is a research assistant with the Center. Elaine Hoekwater teaches fifth grade, Carol Ligett third grade, and Barbara Lindquist fifth grade at an MSU Professional Development School. Cheryl L. Rosaen, assistant professor of teacher education at MSU, is a senior researcher with the Center. The authors work together in the Literacy in Science and Social Studies Project at an MSU Professional Development School.

students' perspectives that led to a growing interest in the students' integration of knowledge both within and across subject matter areas.

As we worked together in multiple contexts (weekly study group sessions, co-planning and co-teaching both elementary students and prospective teachers, conducting research on our shared practice) across a three-year period we became intrigued with connections across the subjects we were investigating. We were all teaching and studying the same group, or subgroup, of 47 fifth graders, but some of us were involved directly only with the science instruction while others were involved directly with only the social studies instruction or the writers' workshop instruction. We came to recognize that our teaching of science, social studies, and writing, although not integrated in the sense of planned, conceptual or thematic connections across subject matters, shared important features in terms of the kinds of learning communities we were striving to create and in terms of the attitudes toward inquiry and knowledge generation we encouraged in each of these subject areas.

End-of-the-year in-depth interviews with the fifth graders about social studies, science, and writers' workshop made us aware of some powerful ways in which students were integrating knowledge both within and across subject matter areas. These interviews pushed us to reexamine our data from an integration perspective, looking closely at integration (both within and across disciplines) from the students' perspectives. This reexamination of the data from the students' perspectives helped us to define new ways of thinking about curricular integration. In this paper, we share the insights regarding integration that the students gave us through end-of-the-year science interviews and through science classroom interactions. We develop a view of integration that contrasts with planned, cross-disciplinary thematic integration and focuses instead on integrated visions of learning communities and integrated attitudes toward knowledge and knowledge generation.

We begin the paper the way our own learning about integration issues began--with an analysis of students' learning. Drawing from interview and classroom data, we present examples of students' integrated learning within science and across science, social studies, and writers' workshop. Following these case descriptions we analyze our teaching practice to explore the question: What aspects of the curriculum and teaching may have enabled students' integrated learning? The view of integration we are developing from such analysis is then presented in contrast with other theoretical perspectives on integration. Finally, we reflect on our own learning over the last three years as we taught and learned from these students and from each other.

Context of the Study

Our collaboration as a group of educators, working in the Literacy in Science and Social Studies Project in a professional development school, has focused on creating classrooms which are places in which *all* students can learn. In this context, we took on new roles and work schedules that allowed time for us to study, to deliberate, and to design, implement, and assess changes in our teaching and in students' learning.

The centerpiece of our collaborative efforts, around which all other activities revolve, is a weekly two-hour study group. During the first year of the project, study group was a time for all the members of LISSS to study and discuss what it meant to teach for understanding, how discourse and writing could be used as tools for understanding, and what sort of a learning community needed to be established in order for all students to learn science, social studies, and language arts.

In the second year of the project, the study group took on a new dimension as each member of the group assumed a teacher/researcher role in order to learn new ways to study students' thinking in a classroom setting and to study her own teaching practice. In this context, study group became a time to share and reflect on the changes that each of us were implementing in the classroom. We worked collaboratively in developing research questions and data collection techniques for the cases of teaching we were developing, and we spent time sharing and reflecting on preliminary data.

In this role of teacher-researcher, Kathy Roth taught science across the fall in Barbara Lindquist's fifth grade classroom while Lindquist and Constanza Hazelwood (who was also conducting research on writing and social studies teaching with the same students) assisted in data collection. Kathy Peasley (who also assisted with the data collection in writers' workshop) taught science across the fall in Elaine Hoekwater's fifth-grade classroom while Hoekwater and two other project members, Corinna Hasbach (who was also conducting research on social studies teaching and learning) and Cheryl Rosaen (who was also conducting research in writers' workshop) assisted in data collection. During the second semester, science was planned as a group effort, but primary teaching responsibility was held by the two classroom teachers (Lindquist and Hoekwater) and Lindquist's student teacher during January and February.

In addition to science class, all 47 of the students in these two classrooms attended two other classes in the morning taught by members of the LISSS Project. Writers' workshop was co-planned and co-taught by Lindquist and Rosaen, and social studies class was co-planned and co-taught by Hoekwater and Hasbach. Teacher/researchers met in subject matter groups (science, social studies, writing) to plan both instruction and research. The weekly study group meetings enabled the whole group to explore issues of common concern and to reflect on similarities and differences in our experiences in different subject matter areas.

Initial research questions for our study of the science teaching centered broadly around two related themes:

1. To what extent can writing and discourse help students understand the big ideas and connections in science, both within a typical teaching unit and across multiple units?

2. What are the characteristics of a learning community which supports students in using writing and discourse as a tool for understanding science?

The teacher/researchers in other subject areas had similar research questions about social studies and writing instruction. Each subject matter team of teacher/researchers collected data across the year that would be analyzed to develop a case study of our efforts to teach for understanding (in science, social studies, or writers' workshop).

In our third year, study group interactions focused on reflection and analysis of the data collected during Year 2 for the case studies. Each subject matter team brought to the larger group cases of student learning that they were examining. In these discussions, unexpected data emerged about students' integration, not just concerning writing and discourse within each of the subject matters as we had intended, but across subject matters. As this unplanned kind of integration emerged, we became excited about the connections the students were making across subject matters, and we felt that this student-constructed integration was something that warranted closer examination. In response, we constructed two new research questions:

1. How did students integrate knowledge within and across subject matters?
2. From the students' perspectives, what was it about the learning community, our approach to teaching and learning, and/or the curriculum that was being mutually reinforced in each of the three classes such that students were enabled to make connections themselves both within and across subject matters as diverse as science, social studies, and writers' workshop?

Methodology

The Students

Peasley and Hoekwater's fifth-grade class included 25 students, while Roth and Lindquist's had 22. The 47 fifth graders were primarily Caucasian, however Peasley's class included two students of Native-American descent, and Roth's class included one African-American student (a second African-American student joined the class midyear), one student of Native-American descent, and three Hispanic students. The students live in a semi-rural and semi-industrial, blue-collar community located adjacent to a midsize city. Michigan State University is located 10 miles from this small community. This elementary school is considered to have the largest number of "at-risk" students of the five elementary schools in the district. Many of the students come from low income families living in one of several nearby trailer parks. There is a growing professional population in the larger community, but only two students in Lindquist and Roth's class had parents who had completed college educations.

Data Sources

Due to collaborative development of research methods, all the teacher/researchers were collecting similar qualitative data both on our teaching and on target students' learning and perceptions of the learning community in the three subject areas. Data concerning science teaching and learning included the following:

Data on the teaching: Field notes taken by Hazelwood, Lindquist, and Hoekwater focusing on both whole-class and targeted small-group interactions. Field notes documented daily science lessons and small-group work across the fall and targeted units and lessons during the winter/spring. Whole-class and small-group interactions (two groups in each class were selected for special focus) were also audiotaped daily (and frequently videotaped) from September through December and periodically after that. The teacher/researchers documented reflections on their teaching through reflective journals, audiotaped planning meetings, and audiotaped study group sessions in which the teacher/researchers described and reflected on their teaching and their students' learning. All written documents associated with planning and teaching were saved.

Data on the students: Formal interviews were conducted across the year and at the end of the year with 6-8 target students in each of the two fifth grade classes. Additional students in Lindquist and Roth's class were interviewed in depth at the end of the year, with a total of 12 students in their class participating in these year-end interviews. The interviews were designed to probe students' understanding of the science content, their knowledge of the ways of being, or participating, in a science learning community, and the ways in which they were making connections within science across the year. Detailed notes were taken during the interviews, and interviews were audiotaped and transcribed. Some interviews, including all of the year-end interviews, were videotaped. While there was no explicit attempt made to determine if students were making connections between subject matters, in some instances they were asked to compare writing done in one subject, such as science, with writing done in another subject, such as writers' workshop.

The end-of the-year science interview protocol is included in Table 2. While many of these questions probed the connectedness of students' science knowledge, none of the questions explicitly asked students to reflect across the subject areas or to connect their science learning with their social studies and writing learning. We view this lack of explicit questioning about cross-disciplinary learning as both a strength and a weakness in our research strategy. It is a strength because the cross-disciplinary connections revealed in these interviews were clearly not cued by the

Table 2

End of Year Science Interview Protocol

- Look at the picture you drew at the beginning of the year of a scientist. How have your ideas about scientists changed since then? How have your ideas changed about the kinds of things that scientists do?

- Do you see yourself as a scientist in any ways?

- Do you imagine yourself possibly becoming a scientist someday? Why or why not?

- What is science all about? Do you think science is important? Why or why not?

- What is something you studied in science this year that you feel you understand well? Tell me about that. What do you think are the important things to know about that?

- What is something you did not understand very well in science this year? Tell me about that. What was confusing/difficult about it? What do you think is important to know about it?

- What do you notice in these pictures? Do these pictures/objects have anything to do with science? (banana boat and banana plant; people tapping trees for sap; a painting of Nobel Prize winner Dorothy Hodgkin writing at a desk; a bottle of aspirin; a picture of Stephen Jay Gould with a human skeleton).

- Do you see what this timeline is representing? It is a timeline of units we studied this year in science class. Let's look first at the Fall part of the timeline. On this line show me where you would place yourself for each unit of study. Place yourself toward this end of the line if you felt very comfortable in science class; put yourself here if you felt medium comfortable, here if you felt uncomfortable, etc.

very comfortable	medium comfortable	so-so	not very comfortable	very uncomfortable

What made you feel comfortable/uncomfortable?

- Look at this writing you did in your journal in science. Do you remember this? Tell me about what this writing was all about. Who were you writing this for? Do you think it was important for you to actually write this down? Why or why not? Would you be willing to show this writing to visitors to our classroom? Does this piece of writing tell something about you as a scientist?

questions; instead, these connections seemed to be genuine ways of thinking held by the students. The lack of explicit integration questions is also a weakness, however, because it is likely that we would have seen a wider variety of cross-disciplinary connections if students had been clearly cued that such connections were acceptable in a "science" interview.

In addition to the interviews, we looked for evidence of integrated learning in our analyses of classroom interactions across the year, in students' writing, and through an end-of-year concept mapping task. The end-of-the-year concept mapping task, which was used as a part of instruction, involved students working in pairs or threes to arrange 35 concept cards in a "word picture," an arrangement that "makes sense to you." The concepts included ideas about the nature of science and scientific inquiry (hypotheses, questions, experiments), specific concepts studied in science units across the year (adaptations, photosynthesis, digestive system, cells, energy, dinosaurs, etc.), and ideas about the role of writing and discourse in science and science learning (writing, discussion). Each pair of students then explained their word pictures to Roth, who videotaped and audiotaped their responses and also asked probing questions to encourage students to elaborate and clarify their explanations. In analyzing the explanations and word pictures, we looked to see if students would separate the concepts into "content" and "nature of science" groups or if they would integrate them. All 22 fifth graders in Lindquist and Roth's class completed this task and were interviewed about it in pairs.

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

Our analyses focus on a wide range of students, with only 2 of the 12 students interviewed at the end of the year considered to be academically strong students. Two of these interviewed students had repeated a grade, 2 were often pulled out of science class for speech therapy, 2 received Chapter I reading support, and 1 was labelled as special education (it was a new experience for him to participate in a regular classroom; in his former school, he worked in a resource room for special education students).

Evidence from all of these data sources points to well-integrated conceptual knowledge among the students. Students reported no difficulty or discomfort in tackling the concept mapping task or in talking during the lengthy interviews about the concepts they had studied. Students talked freely about the concepts they had studied and the understandings and questions they had about this content. "I don't remember" or "we studied that, but I forget about what it means"--typical responses that students use to avoid talking about specific content--were rarely heard in this set of 12 hour-plus-long interviews. The fact that students willingly engaged in such a long interview with very few signs of tiring also speaks to their comfort and pride in sharing their knowledge.

While there were certainly many ways in which students failed to make important connections, our analysis focuses on understanding the kinds of connections that students succeeded in making. We took this approach because (1) we already know about the many ways and contexts in which students fail to develop well-integrated understandings, and (2) we were impressed by the high level of integration and the variety of kinds of integration among a wide variety of students. We wanted to understand these successes.

Multiple Kinds of Integration Within Science

Integration Within Science: The Teacher/Researcher Perspectives

Throughout the year, fifth-grade science instruction was planned, taught, and studied by a collaborative team of teacher/researchers including the authors, two teachers (Lindquist and Hoekwater), and a student teacher. The science team met to plan and coordinate the science curriculum and to define goals. In terms of integrated learning, the team had the following goals:

1. Integrated science concept development across the school year.
2. Integration of study of the nature of science/scientific inquiry with conceptual knowledge development; this was an explicit focus of study in each unit throughout the school year.

3. Integration of science knowledge and approaches to inquiry with students' personal lives, experiences, knowledge, and questions.

4. Integration of writing and discourse into the science curriculum as learning tools used by scientists and student scientists.

The pre- and post-test data for science units focused primarily on conceptual integration (Goal 1 above). Such test data along with interview data provided strong evidence about student successes and failures at integrating concepts during a unit of study. In this analysis, we draw more heavily from the interview data at the end of the year, because it better reflects students' ways of integrating concepts across time and across units, and because the interviews provide more insights into other kinds of intended (Goals 2, 3 and 4) and unintended integration.

Integration Within Science: The Students' Perspectives

Our data provide many examples of student success in developing the kinds of integrated knowledge within science intended by the teacher/researchers. We will share examples from two students, Nan and Nathan,[3] to illustrate and emphasize the multiple kinds of integrations students made and the very personal and individualized ways in which students integrated knowledge within science. While Nathan's integration included strong conceptual connections, Nan's way of integrating was much more focused on ideas about the nature of scientific inquiry. Both students, however, succeeded in creating strong links between their study and understanding of scientific inquiry and their views of themselves as learners of science and as scientists.

"We are scientists!": An example of Nan's integration within science. "Stereotype" was a concept studied in science that Nan integrated in various contexts across the year in science and to her personal life. This concept seemed to be particularly meaningful for her because she started the year with a stereotype of science and scientists that excluded her. In fact, Nan felt excluded in many ways in school. She was a student with reading and speech difficulties and was often pulled out of class (often during science) for special help. Perhaps because of her learning and speech difficulties, she was often excluded socially, being perceived by her classmates as "different."

[3]Names of students are pseudonyms and their writing is reproduced without editing.

Reg ding science, in particular, Nan wrote in her journal on the first day science class: "I hate science." Her drawing of a scientist was a male who was using chemicals in a laboratory. She wrote on the first day of science about this scientist: "This scientists is making a lickwind [liquid]. I think this scientist work is important because. I think it is important but I cannot think why I think not like to be friends with this scientists because I do not liek scienc and I do not like scientist." And she explained in an interview that she had always been "bad in science." In the end-of-the-year interview, however, Nan looked back at this drawing she had done at the beginning of the year and spoke confidently about how her ideas about scientists had changed:

> Nan: I drew a scientist. Before we learned about, I forget what that word is, I put him with a white coat and glasses and it was a boy, with three desks. At one desk he was doing an experiment thing, and at the other desk there was books and at the other desk there was a volcano that he'd be working on then a bookshelf with a whole bunch of books he could research.
>
> Roth: Is the word "stereotype"?
>
> Nan: Yeah, it means you make people like the way that isn't always true, like a scientist they're not always wearing a white coat with glasses and he or she is not always a boy.

By the end of the year, it was also clear that Nan not only liked scientists--she saw *herself* as a scientist--and a good one! She integrated a new image of science and scientists with her personal stereotypes of scientists. Her responses to the end-of-the year concept mapping task (6/3/91), completed with Tiffany and Kelly, and to interview questions (5/24/91) show multiple ways in which she integrated her entering stereotypes of scientists with knowledge about important features of scientific inquiry (importance of questioning, use of evidence, use of writing and discourse, tentativeness of scientific knowledge), with particular concepts she had studied across the year about plants and the history of life on earth, and most strikingly with her personal beliefs about her ability to be good at science. Nan is a student who taught us a great deal about integration of knowledge about science and scientific inquiry with personal views of oneself as a learner of science. The following excerpts from Nan's concept mapping task and year-end interview highlight the connections she makes between her entering stereotypes of scientists, her new understanding of what is important in scientific inquiry, and her developing confidence in her own ability to know and understand science.

Integrating her entering stereotypes of scientists with a changed image of the nature of scientific inquiry and with personal beliefs about herself as a learner of science:

Tiffany:	Scientists do experiments to find out evidence for questions.	
Nan:	That's what we did!	Connects new image of scientific inquiry with her personal experience.
Tiffany:	They have discussions with other scientists...	
Kelly:	About what they think...	
Tiffany:	And then they add--excuse me--they add to their ideas. Different scientists can do different experiments. And then they talk together and they can add to their evidence.	
Nan:	We found evidence, too! We do the same things scientists do, because we **are** scientists!	Connects new image of scientific inquiry with her personal experience.

Roth:	Do you think this woman in the painting might be a scientist? (Picture of Dorothy Hodgkin, Nobel Prize Chemist, writing at a desk in what looks like a home setting)	
Nan:	Yeah, because scientists can do writing. She's trying to figure something out and most scientists--this is kind of that word that starts with an "s" [stereotype]--write stuff.	Connects idea that writing is part of new image of scientist; she tries to use the word "stereotype" to label this.

Roth:	What would be fun about being a scientist?	
Nan:	Going on trips. I'd get to interview kids. But I'm not a good writer.	Her entering stereotype of the scientist is challenged; she integrates view of a scientist as a good writer into her concept of scientist.
Roth:	What kinds of things do scientists do?	
Nan:	They clean the house, they work ...	
Roth:	What kinds of things do they do when they are working?	
Nan:	They take interviews, they test things, look at fossils and stuff.	
Roth:	Do they do any talking or writing?	
Nan:	Yeah, cause in interviews you talk. They discuss with other people what they're working on ... to get other scientists' ideas.	Her entering conception of the scientist working in isolation has been challenged; she now integrates idea that scientists interact and talk into her view of scientific inquiry.

Roth:	Was it frustrating not to get all your questions answered right away?	
Nan:	No, in science, . . . I don't know why I'm saying this, but I just remembered. In science, I always used to ask, "How do you know? What's your evidence?"	Unsolicited by a question, Nan offers evidence that she has integrated her personal beliefs about herself as a learner in science with her new image of scientific inquiry--the importance of demanding evidence to support knowledge claims.

Roth:	Would it be easy or hard to study about humans long ago?	
Nan:	Hard, because you gotta find a lot of evidence.	Integrates new image of science with entering conception of stereotypical scientist; evidence as a centerpiece for scientific inquiry
Roth:	What are you interested in knowing about the earliest humans?	
Nan:	How long they lived, how they ... if they could get married or not, if they had churches to go to to get married or if they had kids...Well, they had to have kids, but I mean if they had hospitals for them to go to.	Integrates new image of scientists as question askers with her emerging personal image of herself as a scientist--values her own questions
Roth:	How would scientists study about those things?	

Nan:	I don't know. It'd be hard because there's no ev...there's no proof. They'd have to go all over the world and try to find like a church, and if they found one they wouldn't know like if that's the church the early humans went to.	Integrates her new image of scientific inquiry (with its demand for evidence) with her personal questions about early humans.

In the following excerpts, Nan reveals the role that understanding well some particular concepts about science--in this case, about plants--played in her developing understanding of the nature of science. She uses her personal coming-to-know about plants to challenge her entering stereotypes of scientists and to develop a richer sense of what it means to be a good scientist.

Integrating her personal development of understanding about particular concepts studied in science (about plants) with her entering conception of stereotypical scientist and her emerging understanding of the nature of scientific inquiry:

Roth:	Do you feel like a scientist in science class?	
Nan:	I kinda feel like a scientist cause we discover, we try to, we had a lot of questions and we had to figure them out. Scientists have questions and they have to figure them out. Like we studied about plants, how they get food.	Connects her new image of scientific inquiry with her personal experience in coming to understand about plants.
Roth:	.efore this year, did you love or hate science or somewhere in between?	
Nan:	I hated it. It was not fun. All's we did was talk about stars. We didn't talk about the fun stuff like plants.	Connects her liking of science with her study and understanding of of plants.
Roth:	Before this year, did you think you were good at science?	
Nan:	No, I thought I was bad at it. I love it now.	
Roth:	What makes a person good at science?	
Nan:	They can understand it.	Highlights the importance of understanding in science; contrasts with her entering conception of scientists.
Roth:	Was anything else in science hard to understand?	

Nan:	I understood most of the plants like about photosynthesis. In the beginning I didn't understand it, but in the middle I sort of understood it and at the end I absolutely understood it. But it was hard at the beginning.	This series of interactions captures Nan's view that understanding is important in science, that she understands very well about plants, and that science is fun for her when she understands.
Roth:	Did you feel very comfortable, medium comfortable, or uncomfortable during the food for plants unit?	
Nan:	Food for plants, I felt very comfortable. I understood it, I was happy, I got to answer questions, I knew how to answer the questions.	Connects the importance of understanding with both expert scientists (good scientists understand things) and with her own emerging sense of herself as a scientist (I can understand some difficult things)
Roth:	How comfortable did you feel in the human body unit?	
Nan:	Uncomfortable. Because I didn't understand it that much. I couldn't answer a lot of the questions. I didn't really talk a lot, it was like I was in the corner.	Again connects understanding with feeling like a scientist, different from her original stereotypical conception of a scientist (I know their work is important but I don't know why).
Roth:	Like you weren't really there? Why?	
Nan:	Because I didn't get to answer questions. I felt embarrassed that I didn't answer a lot of questions.	

Nan clearly feels like she understood at least some parts of science, especially about the plants, and that the goal of understanding is at the heart of science. This represents a new image of science for her which she has integrated with her original conception of the scientist working alone in the lab: "I think it is important (work) but I cannot think why" (9/5/90 journal entry). Since she now defines good scientists as being able to understand, her personal success in coming to understand at least one set of concepts very well (about plants) gave her access to the realm of science. This challenged her entering conception of herself as a nonscience person. Despite her failure to understand the human body systems, despite the fact that she's "not a good writer" (an aspect of scientific work that she defines as important), and despite the fact that learning about the plants and photosynthesis was hard at first and took a long time to understand, Nan still feels confident about herself and her relationship with science and believes herself to be a scientist. Her developing self-confidence as a scientist was closely intertwined and influenced by her changing image of science, scientists, and scientific inquiry.

While Nan succeeded in making many of the kinds of conceptual links across the year that we had intended, these conceptual links seemed more limited in number and less elaborated than other students. Instead of developing solid understandings of key ideas in each of the four major units across the year and then fusing these big ideas together in meaningful ways (the more typical and expected pattern), Nan seemed to approach the year of science as a study about plants (the unit begun in the fall). She recognized that she never really understood about the human body systems or about the time periods in the history of the earth. But each of those units of study provided opportunities to help her solidify her understandings of plants. Our test and interview data confirm her sense that "in the beginning I didn't understand it [plants and photosynthesis], but in the middle I sort of understood it, and at the end I absolutely understood it. But it was hard at the beginning." Nan's written responses on the photosynthesis post-test in the fall reveals a rather solid understanding of the basic concept that plants use air, water, and sun to make their food in the leaves. She not only explains this basic idea when asked what food is for plants ("food for plants is sun air water mixs togather makes food for plants") and what is photosynthesis ("It mens that air water sun mix to make food that is photosynthesis"), she was also able to use this idea to explain novel phenomena:

Q: A man wanted to have an early garden. He planted some tomato seeds in small boxes. He kept the boxes in a closet where it was warm and dark. He watered them whenever the soil started to get dry. There was plenty of air in the closet. What do you think happened to the seeds?

Nan: Thely did not gorw becous they did not have enig [enough] air wather or sun lite for it to stay alive. They have to have air, water, and sun for food.

* * *

Q: A box was placed over the top of a plant so that all of the plant was covered except for one leaf. The plant was watered and had plenty of air, but only one leaf could get any sunlight. What do you predict will happen? Why?

Nan: The one life [leaf] will live. Becous that lifess gets air water sun The rest get air but not sun and water. It well make food and it will have food.

But one question on the test asked students to create a word picture to tell the story of how plants get their food and to explain the word picture to an interviewer. Nan's oral explanation of her word picture revealed some confusions about the concepts; although she was sure that plants mix sun, water, and air together in the leaf to make food, she was unclear how that related to the food stored in plants' seeds and fruits. She vacillated about whether or not water by itself is food for plants. She decided during the interview that water by itself is not food, that it has to mix with air and sun to make food, but her wavering on this is important because she had held onto the idea very strongly throughout most of the unit that water is food for plants (even when her friends were teasing her about not giving up on this idea). When plants were brought up during the human body/cell respiration unit, she seemed to have forgotten about photosynthesis as she slipped back into using her long-held idea that water is food for plants.

Nan made it clear that she enjoyed her study of plants and that she wanted to continue studying plants even after the official photosynthesis unit had ended. She was able to do this in the context of the science curriculum, because each science unit included explicit references back to earlier units. Nan may have had difficulty understanding how the human body systems interact to move food and oxygen to the cells, but the comparison of plants to humans in that unit helped her better understand movement of food (in addition to water) in the plant. Nan may have been baffled about many of the issues about the history of life on earth studied in the spring, but the discussions about the first plants on earth and how they got their food provided a meaningful context for her to integrate better her understandings about the relationships between plants, food, water, and energy. Her persistence across the year paid off in enabling her to develop (after much effort, time, and difficulty) an understanding that plants *don't* use water for food (as she thought for a long time) but instead make food out of air, sun, and water:

Roth: What was something you understood well this year in science?
Nan: Plants, finding out what is food for plants.
Roth: How do plants get food?
Nan: People water it, and also the plants outside in people's yards, people water them. And then rain gets water ...
Roth: Is water food for the plant?

Nan: No, not only. Sun, air, and water mix together and that is food for plants. Inside the plant, it goes to the roots and goes up in the plant and gives the plant food.
Roth: Did you know that before you studied it in science this year?
Nan: No, I thought that just people would water them and the plant would suck it up.
Roth: So your ideas changed?
Nan: Yeah. Um-hum. (5/24/91 interview)

Although Nan did not connect as many concepts together across the year as we had intended, her case helped us see how her coming to understand one set of ideas well was critical in enabling her to integrate her personal, entering conceptions of science and scientists with a richer picture of scientists and scientific inquiry *that included her*. The ideas about scientific inquiry that we had "presented" in class were not just ideas she had memorized; rather, she seems to "*really* understand" (Gardner, 1991) and make sense of "our" ideas about the nature of science by connecting them with her own personal experience as a learner and doer of science.

Our analysis shows that it was not just the discussion of stereotypes in the beginning-of-the year unit about the nature of science that enabled Nan to make such significant transformations in her stereotypical view of scientists and her personal relationship to science. She mentions several times in her end-of-the-year interview two aspects of instruction, taught as part of the explicit science curriculum, that helped her integrate this idea about stereotypes of scientists with her personal image of herself and her relationship to science.

First, she saw her fall teacher, Roth, as a scientist herself--a scientist who was studying fifth-graders' learning. Roth seemed like a "normal" person to Nan, and yet the fact that she was a scientist was evident to Nan throughout the year in science. The connections Nan made to Roth as a scientist in her end-of-the-year interview are highlighted in italics:

Roth: Have your ideas about scientists changed?

Nan: Yeah, I think scientists, *like you're a scientist and you don't wear glasses, and you're a girl, and you don't wear one of those white coats.* I changed my ideas about next time I make my drawing I'm going to make it a girl without glasses and without a white coat, in regular clothes.

* * *

Roth: Do you ever imagine yourself becoming a scientist someday?
Nan: Well, mmm, I like science and I think it's fun, but I've been wanting all my life, ever since I was three I've been telling my Mom I'm going to be a doctor at Sparrow Hospital ...

Roth: Why would you like to be a doctor?
Nan: I wanted to help people and I used to always play hospital. It's fun to help people.
I also think it would be fun to be a scientist, too.
Roth: What would be fun about being a scientist?
Nan: Going on trips. *I'd get to interview kids..*
Roth: What would you like about interviewing kids?
Nan: I love kids, well right now I love babies cause I am a kid.

Roth: What kinds of things do scientists do?
Nan: They clean house, they work, *they take interviews,* they test things, look at fossils and stuff.

* * *

Roth: Do scientists do any talking or writing?
Nan: Yeah, *cause in interviews you talk.* They discuss with other people what they're working on, with other scientists. *They could talk with parents and tell them what they're learning.*
Roth: They talk with other scientists?
Nan: Like if they have a problem, other scientists can help, because they're scientists, too.

By acknowledging that scientists clean house and work, Nan is clearly viewing them as everyday people (like Roth)--not the stereotypical mad scientist always locked away in *his* lab. Roth served as a model of a scientist--a female scientist--at work for Nan. Since Nan saw Roth at work--teaching, collecting students' writing, videotaping students at work, interviewing children--the stereotypical idea that scientists work with chemicals in labs or with exploding volcanoes was challenged in a personal way for Nan. She talked to Roth informally in and outside class about friends and family and about aspects of Roth's personal life (her children, the death of her father). Since Roth was seen both as a scientist and a caring person who respected and encouraged Nan's contributions in class, Nan received a strong personal message that she was good at science and that doing science can be connected with caring about people and helping people, qualities of humans which were very important to Nan ("I wanted to help people" . . . It's fun to help people." . . . "Like if they have a problem, other scientists can help"). These messages contrasted with those Nan had received before about scientists.

A second support for her learning that Nan identified centered around the importance of questions. Nan felt that science class was a place where her personal questions could be asked and pursued. Her questions were valued and not ridiculed or ignored. Thus, the idea that an important aspect of scientific work is asking questions was not just a sentence copied down in her journal after a class discussion in September:

Important Aspects of Scientists' Work:

- •Discover and describe our natural world
- •Explain the why's and how's of our world
- •Ask and seek answers to questions
- •Solve problems, figure things out
- •Study
- •Observe carefully and keep notes
- •Talk to other scientists
- •Write about discoveries, findings, questions
- •Read journals to find out what other scientists are learning

Instead, "questioning the why's and how's of our world" became enacted in the curriculum by Nan throughout the year. For example, she was a regular contributor to the class Question Notebook. While she would often ask questions during class discussions, she would also frequently quietly and independently retrieve the Question Notebook, enter a question in it, and sign her name. And she was unembarrassed, as we have seen in excerpts from the end-of-year-interviews above, to share her personal questions as worthy of scientific investigation. For example, her questions about early humans came pouring out during the interview, without hesitation, apology, or timidity: "How long did they live? Could they get married or not? Did they have churches to go to to get married? Did they have kids like at hospitals?" She saw herself like a scientist in science class because "we had a lot of questions and we had to figure them out. Scientists have questions and they have to figure them out." When asked what things helped her understand so well about the plants, Nan explained:

Nan: Asking questions helped me because I got the answer to questions I've had for a long time.
Roth: What advice would you give to teachers, is it important for students to be able to ask questions?
Nan: Students always need to ask questions cause they're always going to have questions and if the teachers don't let them ask them, they're not going to know what they're talking about.
Roth: What did you think about the Question Book?
Nan: That was good cause if we couldn't answer it right this minute, we could put in in the Question Book and people wouldn't forget.

Thus, in this science learning community, Nan felt that there was a place for her and for her personal questions. We believe that she was able to develop such a well-integrated understanding of the nature of science and scientific inquiry because she connected her understanding of scientific inquiry with her own experiences and developing understandings (especially about plants) in the science class. Her entering conceptions of scientists, of herself as a learner of science, and of how plants get food changed in tandem and seemed to reinforce and strengthen each other. Her conceptual learning about photosynthesis played a key role in supporting these developing understandings about science and about herself. As she learned that scientists don't always work alone and that questions and understanding the world around them are an important part of their work, she engaged in collaborative work and question asking in her study about plants and photosynthesis. Her questions were valued, and her collaborations paid off in enabling her to develop understandings about plants that satisfied her.

"I have ideas just as good as everybody else" and "They're all connected": An example of integration within science from Nathan's perspective. Nathan was a student who was not academically successful in school but who had never been identified as needing any kind of special resource room help or other special services. Our observations of Nathan at the beginning of the year suggested to us that this was a boy who could easily become invisible to teachers because of his quiet classroom behavior--although he needed help in order to succeed in school he did not call attention to himself, and his needs were not so glaringly obvious that teachers would notice him. Nathan seemed to have figured out that it was an advantage to be invisible in the classroom; it was a school survival strategy that he had learned well.

In science class, however, Nathan became a very visible participant, not only to his teachers but to other students and to himself. Throughout his end-of-the-year interview, Nathan repeatedly weaves this theme--"I have ideas just as good as everybody else"--into each part of the interview. This idea that he can be a visible and contributing member of our science class was integrated into his discussion of things he understood well in science (about plants and photosynthesis, about the human body, and about history of life on earth), into his discussion of the nature of science and scientists' work, and into his descriptions of the role of writing in science.

During the "dinosaur" unit, for example, Nathan shared privately with Roth (who was playing primarily a researcher role at this point but also assisting Lindquist in the teaching) and a friend, Lucas, some questions he had about the earliest living things--the one-celled plants that lived during the Precambrian era approximately 400 million years ago. Nathan was wondering how "they" (scientists?) knew that such one-celled plants existed if the cells didn't leave any bones behind. He also wondered about photosynthesis in these one-celled creatures. Lucas wondered about the make-up of the atmosphere back then--if there weren't any humans, where would the plants get carbon dioxide from? Roth was excited about these questions, especially since Lindquist had been encouraging students to identify a question or a problem about the history of life on earth that they cared about exploring. Roth and Lindquist took Nathan and Lucas's ideas and made them the centerpiece of a lesson. The whole class puzzled over Nathan's questions and explored different hypotheses and predictions about these one-celled plants and photosynthesis. In the end-of-the-year interview, Nathan refers repeatedly to his questions about one-celled plants to illustrate his belief that he has good ideas in science:

Roth:	Do you ever imagine yourself becoming a scientist someday?	
Nathan:	Maybe, because I like learning about dinosaurs and how they know there was one-celled plants right at the beginning of earth... Maybe they look at trees today and maybe there's like one particular cell that they look at and maybe that was just the one cell that was growing before and formed more.	Nathan's willingness to consider being a scientist someday is closely connected with his personal ideas and questions about one-celled plants that were valued and highlighted in this learning community.
Roth:	Could you explain that again? I'm not sure I understood.	
Nathan:	Maybe they look at a particular cell, in a plant, and maybe it mates with another one and makes a whole bunch more, and then it makes plants like we've got today.	This typically quiet and invisible student does not hesitate to expand on his ideas and thinking about how one-celled plants may have evolved into trees (a topic not discussed in class).
Roth:	If you were a scientist what would you like to do?	
Nathan:	Probably look at plants and see if there is one cell in particular that you can look at, that makes it grow and have more cells	
Roth:	Are there other things you might like to be when you grow up?	

Nathan:	A basketball player. Cause right now I just like to play basketball, and it seems like it'd be fun....You get paid a lot, too!	
Roth:	Why do we have science?	
Nathan:	If we didn't have it, then people wouldn't know the stuff that has been here before, like the dinosaurs, and they wouldn't know that there mighta been one-celled plants.	Connects his explanation of why science is important with his personal interest in his own ideas and questions about one-celled plants
Roth:	Why is that important?	
Nathan:	Cause maybe dinosaurs could have formed a different kind of animal that's living today. Like maybe an elephant could have been brontosaurus that shrunk.	
Roth:	Why would it be helpful today to know that?	
Nathan:	It'd probably be interesting because maybe people are wondering about things in the past, and they might not know nothing about it, and then they couldn't find out anything from other scientists' perspectives.	Again, Nathan defines the importance and usefulness of scientific knowledge in terms of how it integrates with his personal ideas and interests.

In the series of questions probing Nathan's level of comfort during different units of science study throughout the year, it is clear that whether or not his ideas were valued was the key deciding factor in determining whether he felt comfortable (highlighted in **bold**):

Roth: What about the food for plants unit? How comfortable did you feel?
Nathan: **Very comfortable. Cause I had ideas just as well as everyone else**, and some kids, they had ideas, and I would say something else about it, and some other kids would agree with me. But some wouldn't, and that sort of made me feel comfortable.
Roth: You felt you were contributing as much as everyone else?
Nathan: Yes. And **some kids were agreeing with me, and that felt really good.**
Roth: What about during the human body unit?
Nathan: So-so, because I sorta knew what a cell was, but I didn't really know how it grew, and some kids did, and **they thought some of my ideas were real dumb.** They said they didn't really go along with it, and that sorta made me not feel very good.
Roth: In the photosynthesis unit, you said some people didn't agree?
Nathan: Yeah, cause some people had different perspectives, and they thought some of my ideas were good, but some people didn't. Where in the Power Cell (human body unit), a lot of people didn't even think- well, **most of them didn't even think my ideas were any good.**
Roth: What about in the dinosaurs unit?
Nathan: Medium to very comfortable. Cause I liked learning about dinosaurs and I knew about some of the bones and names that other people didn't, and Lucas would always say stuff and I would try to answer his question for him, and **he thought I was real good.**
Roth: It seems like what makes you feel good in science is when other kids like your ideas?
Nathan: **Other kids, and maybe even the teachers might like them. Maybe some teachers might say it's a good idea,** like you did when I said how did they know about one-celled plants.
Roth: How could you tell I liked your idea?
Nathan: **Cause you said it was a good idea,** and you go "I'm wondering about that, too."

Nathan integrated this personal concern about his ideas being valued with his developing understanding of the nature of scientific knowledge and inquiry. Throughout his interview he emphasizes that scientists listen and to and value each other's ideas--this is the one aspect of scientific thinking that seems most salient to him (highlighted in **bold**):

Roth: What kinds of things do scientists do?

Nathan: They work ... they have to research stuff. **They have to look at different scientists' perspectives and see what they think; then they try to see if they thought it was any different, maybe find that scientist and talk about it.**

Roth: Tell me more about what you mean about perspectives?

Nathan: Like if they're in a book, they might read it, and get some ideas, and they might say "well, I don't think this is right." and they might change their mind.

Roth (a few lines later):..... Was that new to you this year?

Nathan: **I didn't know that they looked at different scientists' perspectives.** I thought they just said what they thought it was.

Roth: What kinds of people become scientists?

Nathan: **People that learn to get along with others.** They work hard. Cause sometimes scientists are in a group and if they didn't get along they wouldn't be able to find out what the other people thought, they might only have their perspective, and it might be wrong.

Nathan also described scientific arguments as important both in scientific inquiry and in his science learning. He described scientific arguments as helpful because "you got to see other people's ideas and what they thought." He attributed his liking of science to this process:

Roth: Do you like science? Why?

Nathan: Yeah, it's sorta *fun*.. I like working with other kids in the class and seeing what they think, kinda matching up your ideas and seeing if it's about the same thing.

He described scientific arguments and their importance several times during the end-of-year interview. It is clear that he developed a collaborative view of science that centers around a respect for each person's ideas as well as a willingness to change ideas and that this idea was important both in scientific inquiry and in Nathan's learning:

Nathan: When we were in groups and we talked about ideas about what we thought and then we got together and we had like a scientific argument. And then someone thought it was one idea and someone thought it was another, and then it just kept going on.

Roth: What would happen if your answer was wrong?

Nathan: Someone might say I think that's right, and I might agree with them. And then they might go "I thought that was a good idea, but I didn't think something was right, right there." And I might go "Oh, yeah, that might be right."

* * *

Roth: Were there things I said or did that showed you how to have a scientific discussion?

Nathan: When like Rachel had that idea about how hair might help some stuff grow, and you go "How would hair get into a plant?" and she goes, "I don't know, maybe it just fertilizes it." And everybody gets going right after that, and they start asking her different questions.

Nathan also integrated this collaborative view of scientific inquiry into his understandings of the role of writing in science. He emphasized the importance of the writing in journals as a way of starting conversations (scientific arguments), which he saw as the beginning of a learning process. You couldn't change your ideas until you had a chance to "match up your ideas with other people."

Roth: Did writing in journals help you learn this?

Nathan: That sorta did, cause after we wrote in the journal, we talked about it, and we shared our ideas. And some people didn't think it was right, and you thought it was right, and it just went on. And some people said they didn't know.

During the interview, Nathan was asked to look back at a journal entry he had written in October. His discussion of this journal entry shows how he integrated this idea of each person's ideas being valued and important with his writing in science, with his understanding about the nature of science knowledge and inquiry, and with his personal entering conceptions about how plants get their food (he thought they got their food from the soil at the time of this October journal entry). In the journal entry, students had written down their ideas about whether or not soil was food for plants. They were asked to give one source of evidence for their position. Nathan wrote that soil is food for plants and described an observation he had made about our grass plant experiment: He noticed that the soil level seemed to be going down as the grass plants grew.

Nathan's discussion of this journal entry at the end of the year shows how his ability to talk about the role of writing in science learning was closely intertwined with his memory of learning a particular idea--that soil is *not* food for plants. His understanding of this conceptual idea and his developing understanding of the role of writing also seemed to be closely linked to his continuing theme about his ideas being valued. In this case, Roth responded in writing in his journal by praising his careful observation of the soil level in his grass plants and asking him if he could think of alternative explanations for this observation (besides the idea that the grass plants were eating the soil). The fact that Roth valued his observations and ideas in the journal seemed to be a critical aspect of his willingness to reconsider and change these ideas, and his last comment in the following exchange shows how he integrated his understanding of this particular writing activity with things that are valued in scientists' communities:

Nathan (describing his journal entry): You asked us if we thought our soil went down in our plant a little, and I thought it went down a little. But then I thought it was wrong, cause based on VanHelmont's experiment....I said it might have been the water pressure. And I thought maybe the white foamy things were food, but they weren't.

Roth: What was vonHelmont's experiment?

Nathan: He had a tree, wanted to see why, how much bigger do you think it will get, do you think it will die or....

Roth: Did he find something out about the soil?

Nathan: Yeah, he found it wasn't [food for plants] cause the soil stayed the same. And I thought mine went down a little. But then I said it mighta been the water pressure making the dirt mud, maybe it soaked the soil down a little.

Roth: Do you think it was important for you to write your ideas down?

Nathan: Probably, cause if you asked us to write 'em down, we'd write 'em down, and we might talk about 'em, and then some kids might think that their soil *did* go down a little, and you might go "Well, I thought mine went down, but it didn't." And then you might get talking, and they might go, "Oh, yeah, maybe mine did too."

Roth: So writing it down is important because it gets you talking?

Nathan: Yeah.

Roth: Do you ever read these things that I write to you [in the journal]?

Nathan: Yeah. I like to read 'em to see if you guys have any other questions you might have to ask me, or if you want to tell me something you might know, or if you might have an experiment to help me learn something. I like it [your writing] on everything I write cause I like to read 'em and see if you guys think it's good.

Roth: If we showed this writing to someone, would it show anything about you as a scientist?

Nathan: Maybe, cause they could tell I was thinking a lot, like if the white foamy things were food. And they could tell if I thought the soil was food, too, cause of the pressure. And they might think that I'm thinking really good. They might think I have a good idea, but they might think it's wrong.

So this writing process in science helped Nathan integrate his emerging view of science as collaborative with his emerging view of himself as a person who has valuable ideas. He is not ashamed of the ideas in his journal even though he recognizes that in an important sense they are "wrong." He contrasted his comfort in sometimes "being wrong" in science with his discomfort with grades:

> Roth: Would you rather get grades on your writing or questions and comments fromthe teacher?
>
> Nathan: Questions.
>
> Roth: Why?

Nathan: It just seems like they're more helpful. They get you thinking more.
Roth: If we had given you grades in science, would you have worked harder?
Nathan: Not really , cause if you write to us and ask us questions, that gets us working harder, cause we've got to think about your questions.

Another theme that was woven throughout Nathan's end-of-the-year interview was one of conceptual *connections*. He explicitly points to the ways in which knowledge in science class was connected across the year. During the end-of-the-year interview, for example, Roth pulled out the timeline of topics studied during the year in science, and Nathan did not wait for her question:

Nathan: Oh, it's stuff that we studied...
Roth: This year in science.
Nathan: Well, all of them sort of connect.
Roth: Oh? Tell me about that.
Nathan: Cause we learned about stereotypes of scientists, and then there are scientists who found out about food for plants. And then, *The Power Cell* [title of student text about the human body systems and cell respiration]--what's food for humans? And that sort of connects in. And then we were trying to figure out how dinosaurs breathed, and that sort of connects, too!

* * *

Roth: What do you think about science this year compared to other years?
Nathan: It just seems funner this year, cause you don't do one thing the whole year. You learn about more stuff that sorta like connect to each other.

He also shows in less explicit ways that he did integrate knowledge studied in different units of science instruction--even though these units were taught by different teachers (Roth, the student teacher, Lindquist). Nathan's understandings about photosynthesis as described at the end of the year, for example, include ideas studied outside the official plants unit - ideas about cells studied in the human body unit and ideas about the evolution of plants in earth's history from the "dinosaur" unit.

When asked in the end-of-the-year interview about something he understood well in science, Nathan quickly identified "photosynthesis." Although this concept had been studied in the fall, Nathan's explanation of photosynthesis on May 20 reveals a well-integrated, conceptual understanding of the key ideas about this food-making process. The following portion of the interview also shows three other kinds of integration from Nathan's perspective: (a) his genuine integration of ideas about important aspects and dispositions of scientific inquiry (question asking, demand for evidence, appreciation and wonderment about scientific findings) and the nature of scientific knowledge (that it changes, that scientific authority can be questioned) with his discussion about photosynthesis, (b) integration of concepts taught across the year in different units, and (c) integration of his entering personal conceptions that food for plants is water and fertilizer with the scientific explanation of photosynthesis. The question that starts the exchange asks Nathan to describe something he understood really well in science, and portions of his response (such as "I wonder how they figured out about that") suggest strongly that for Nathan "understanding" science really well includes acknowledging the tentativeness and incompleteness of knowledge, questioning scientific authority, and demanding evidence. Other portions, where ideas about cells (studied in the human body unit) are embedded in Nathan's understanding of photosynthesis illustrate the importance to Nathan of connectedness of knowledge. The concept of "cells" was not discussed during the photosynthesis unit. His consistent explanation that water is one of three things needed for plants to make food reflects how well he has integrated the scientific explanation of photosynthesis with his entering belief that water by itself and fertilizer by itself are two kinds of food for plants. Look for these multiple kinds of integration in Nathan's description of photosynthesis (**connections of photosynthesis with the nature of science and scientific inquiry are highlighted in boldface**, *connections to the human body unit are highlighted in italics*, <u>connections with Nathan's entering conceptions and beliefs are underlined</u>):

Roth:	What's something you studied in science this year that you understood really well?	
Nathan:	Photosynthesis.	
Roth:	Tell me about photosynthesis.	
Nathan:	Photosynthesis is when sun, light and ... <u>wait, sun, air, and water mixing together and the plant takes them all in, and it makes food out of them</u>. And it stores the food or *eats it.*	Contrasts with entering conception of water and fertilizer in the soil as food for plants. Talks about process of plants "eating" food in same way that he talks below about human cells using food.
Roth:	How does it store the food?	
Nathan:	In the leaves and stuff, *there's like little things that it can store stuff in, and then it eats it when it's hungry.*	Connects ideas about cell respiration in human body with cell respiration in plants
Roth:	How do they eat it?	

Nathan:	I don't know, *I think it just goes around in the plant, and then it goes into the tiny cells that are in it.* **I wonder how they figured out about that?**	Connects cell respiration in humans with cell respiration in plants. Demand for evidence, questioning authority.
Roth:	Do you have any ideas about that?	
Nathan:	**They do experiments, like we did.** Or if it didn't have the sun, like that grass, it turned all brown. Then if you don't give it water at all it might die, or it might not even start to grow.... I don't know. ***Maybe they cut open a plant and then look under a microscope and they see little things moving around and going into the cells.***	Demand for evidence, willingness to try to figure out a way to solve the problem. Using ideas about cells and microscopes from the human body unit.
Roth:	Have you seen cells under the microscope?	
Nathan:	*Yeah, we did that when we learned about the human body.* [He's referring to an examination of their own cheek cells under the microscope]	
Roth:	Did that surprise you?	
Nathan:	**Yeah, there was a lot of them!**	Appreciation and wonderment about findings from scientific inquiry
Roth:	Anything more you can tell me about photosynthesis? Like where does it happen?	
Nathan:	How it gets water is the roots, it soaks in through them. And the air goes through the little green stuff that's in the leaves, 'cause there's tiny holes in the leaf, and the sun goes through the leaves, too.	
Roth:	Then what?	
Nathan:	<u>They get together and they make photosynthesis, which is food for the plant.</u> And then the plant stores them or eats them right then, to grow.	
Roth:	Are you saying that sun, air and water are kinds of food for the plant?	
Nathan:	<u>Not alone, they're not, but mixed together they are.</u>	At the beginning of the unit, Nathan believed that water was food for plants. Here he has integrated that view with his new understanding of photosynthesis.

This example of ways in which Nathan integrated knowledge studied in different units across the year, integrated his conceptual understandings in science with his understandings of the nature of scientific knowledge and inquiry, and integrated knowledge with his personal experience and beliefs was not an isolated one. It is a pattern throughout his end-of-the-year interview and in the concept mapping task that he completed with Lucas. In describing their concept map (see next chart), for example, Nathan explains about the body systems and cell respiration in the context of scientists finding solutions and evidence to answer questions. He not only reflects a strong integrated knowledge about the human body systems, emphasizing in his description the interactions of the digestive system, circulatory system, and respiratory system, he also views this integrated knowledge as socially constructed by humans--"men and women"--and connects this knowledge with his thinking about the plants and the dinosaurs (**bold type highlights connections with nature of science and scientific inquiry,** *italics highlight connections of concepts studied in different units across the year,* and underlining highlights connections with Nathan's entering conceptions about water and fertilizer being food for plants):

Lucas: This is what we've learned about in science this year. Men and women....	
Nathan: **Came up with evidence to find out a solution to a problem to a question like about the digestive system.** The digestive system has the esophagus. *The esophagus has muscles that function to help food so it can digest.* It also has the stomach. The stomach churns so it can digest better. It also has small intestines. The small intestines has villi that takes food and can use, not the waste. The food goes through the bloodstream, carries it through the respiratory system so it can get the oxygen and the air. The oxygen mixes with the food. The food goes in the cells. The cells eat or store it. If it's waste, it...in the small intestine, it goes to the large intestine. The large intestine takes it to the rectum. Then it comes out. *You can use it for fertilizer for plants.* Plants have tubes in the leaves that help it do photosynthesis. The roots help it do photosynthesis, too. Plants, the plant needs the air and the sunlight and the water to help it make photosynthesis. ***Some people are asking question if dinosaurs do photosynthesis. Can humans do photosynthesis?*** **Ask some people.** Dinosaurs lived millions of years before the earliest humans.	Digestive system connected to scientific inquiry--not seen as just a bunch of facts, but as knowledge collected to answer a question. "Function" idea was studied in first unit of year about adaptations. Connects human digestive system with an idea about plants that was of particular interest to him from the beginning of the plants unit - fertilizers. Connects photosynthesis with the human body, dinosaurs, and scientific inquiry--Nathan sees scientific knowledge as subject to change and is wondering if humans will one day be able to do photosynthesis.
Roth: OK, now I'll ask some questions. Do humans do photosynthesis?	
Lucas: I don't think either one of them (humans or dinosaurs) do, because humans don't need sunlight, air and water. Usually we only need food....	
Nathan: **Scientists don't know much about dinosaurs, just have their bones.**	Demand for evidence: Nathan was intrigued with idea that we don't have much evidence about the insides of dinosaurs - relates to his comment above about whether dinosaurs did photosynthesis.

Nathan's statement that "some people are asking questions if dinosaurs do photosynthesis," reflects his own inquiry and wondering. Such an idea may seem farfetched: Why would he expect animals to be able to do photosynthesis in the past, if animals in the present cannot do photosynthesis? Lacking evidence to the contrary, Nathan felt free to imagine the unexpected. In his interview he talks about the importance of scientists having good imagination. He and his friend, Lucas, who had repeated two grades and received Chapter 1 reading support, were able to imagine life in the past as being more "advanced" than present life. After all, as Lucas pointed out, the first one-celled plants on earth could make their own food, and humans, with all their billions of cells, are still unable to do this!

Integration Across Subject Matter Areas

Connections Across Science and Social Studies

Teacher/researchers' perspectives. The teacher researchers in science, social studies, and writing did not plan conceptual connection across the three subject matter areas. We initially viewed our efforts as connected only in the sense that we were trying in each subject matter to "teach for understanding" and to integrate writing and discourse into content teaching in ways that would support student understanding. As we got into planning our first units, we realized that there were many parallels between our explorations of scientific and historical inquiry. But we viewed this more as an interesting observation from our perspective as curriculum planners than as an important pedagogical strategy. As the year unfolded, our collaborative sessions helped us see similarities in the ways we were approaching knowledge and pedagogy in these two subject areas, yet we still failed to see the power of these similarities from the students' perspectives. At no time during the year did we start to plan conceptual or other kinds of explicit content connections across the subject areas.

Students' perspectives about "perspectives". An occasion when the students caught our attention with their cross-subject matter connections was when 7 out of the 12 students interviewed at length about science at the end of the school year used the word "perspectives" to describe science, scientists, and their own learning in science. It was fascinating to us that although the concept of perspective was never explicitly used in science class, most of the students used the word in describing their understandings of science.

"Perspectives" *was* an idea that had been explicitly taught in social studies; it was one of the core concepts that linked the students' study of different time periods in American history. Since each unit of study in social studies included an examination of the time period from the perspectives of underrepresented groups (women, African Americans, Native Americans, Hispanics), the notion of perspectives was one that students had explored in many contexts in social studies. The term was also used in social studies as students examined a variety of resources, including the textbook, other print references, art and photographic representations, video resources, and interviews with family, neighbors, and visiting experts. Recurring questions that students explored when using these sources were: Whose perspective is being told here? What perspectives are missing?

We would have expected that such transfer of knowledge across classes would have to be explicitly taught and supported. We believe that so many students made this connection between "perspectives" and science, because the epistemologies and pedagogies in both the science and social studies classrooms were so consistent. For example, in both science and social studies knowledge was regarded as socially constructed by fallible human beings who bring their own experiences and biases to the inquiry task. In both subject areas, knowledge was regarded as more useful, accurate, and meaningful when many alternative positions, theories, or perspectives had been considered in constructing the explanation. Just as scientists were presented as always testing existing theories and remaining skeptical until multiple sources of evidence enabled development of consensus, historians were presented as constantly looking for different interpretations and sources of evidence in creating stories of America's history. Neither science nor history were presented as having all the answers neatly tied up in textbook chapter packages, and in both subject areas students were encouraged to question "expert "authority and to not accept a theory or interpretation without personally convincing evidence. Instead, knowledge was regarded as tentative, subject to different interpretations, open to challenge.

Pedagogically, both subject areas were represented as being organized around central questions. In both science and social studies, organizing questions were made visible to the students daily. In social studies, an organizing question for much of the year was displayed in large letters on a banner in the room: What social conflicts continued to fester after colonization which helped contribute to the outbreak of the Civil War and erupted again during the civil rights era? In science, each unit was organized around a question: Do you think there are more different species of plants and animals on the desert or in Michigan? What is food for plants? What happens to the air you breathe and the food you eat? Instruction was organized around big ideas in each of the subject areas (in science--energy, food, photosynthesis, systems, cells, organisms, species, adaptation, structure, function, etc.; in social studies--democracy, justice, discrimination, racism, sexism, perspective, etc.), rather than around sets of facts (memorization of all the parts of the body in science or chronology of events in American history). In both subjects, students were regarded as active learners who would bring their own personal knowledge and experiences to bear on the subject matter. In both subjects, a conceptual change approach to instruction placed high value on the students' ideas and interpretations; instruction began by eliciting students' ideas (about food for plants or about the meaning of terms like discrimination, power, justice, exploitation) and instructional activities were chosen that would engage students actively in considering new ideas and ways of thinking about the central questions. In both subjects, students were encouraged to write and talk about their ideas and were encouraged to reflect on how their ideas were changing.

In each of these subject areas, we strove for a consistency between the epistemological stance toward knowledge and the pedagogical approach. The pedagogical approach was built on our constructivist, conceptual change orientation to the learning process. We viewed processes of meaningful individual learning as parallel to the ways that knowledge grows within a discipline. Students were encouraged to learn in the same ways that historians and scientists learn. They were rarely asked to study history and science from the outside--to learn about what scientists do by simply reading or talking about what scientists do. Instead, they explored subject matter from an insider's perspective.

Could these kinds of epistemologcial and pedagogical integrations across the subject matters explain the ways in which fifth graders integrated their understanding of "perspective" from social studies class into their understandings of science? The following excerpts from the year-end science interviews illustrate the variety of ways that Lucas, Nan, Michelle, Heidi, Laticia, Matt, and Nathan wove the idea of "perspectives" into their responses to questions about science class. In some cases the students explicitly acknowledge that this idea came from social studies class, but they seem comfortable using the idea to talk about science:

LUCAS		Lucas was in developmental kindergarten for a year prior to regular kindergarten. He later repeated a grade in school. He was seen regularly by the Chapter 1 reading teacher.
Roth:	What questions do you have about early humans?	
Lucas:	How they looked, how their culture was.	
Roth:	How would you find out about their culture?	
Lucas:	Books, but books are not always true. Try to find out from knowledge from when you were a kid.	
Roth:	Books are not always true?	
Lucas:	Some books, you don't really know what you'll find out until you read it. Books could say different things. If you're a scientist, you could make a book with your **perspective** and different peoples'.	Integrates idea that scientists are writers with his idea of critical reading of text. Critical reading of text was an idea addressed and practiced in social studies class.
Roth:	Scientists have different perspectives?	
Lucas:	Yeah.	
Roth:	Is that good or bad?	
Lucas:	That's good because if you have different **perspectives** on something, you can pick the one you like the most.	
Roth:	Can you give an example?	
Lucas:	Like when we read about the "Trail of Tears" in the textbook, it was a white man's **perspective**, not the Cherokees' **perspective**. It's good to read two different **perspectives**.	Although Lucas has been talking about science, his example is drawn from a social studies class experience.
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Roth:	What advice would you give to teachers about whether to have groups all boys or mixed boys and girls?	
Lucas:	Have them mixed. Girls could have better ideas than boys and boys could have better than girls. Sometimes girls have different **perspectives**. Some of them do. Some girls think of different ideas.	

NAN		Nan receives resource room help for speech and reading. She had been viewed by other children as different and had troubles fitting in socially.
Roth:	What about arguments in the whole group--did they help you understand?	
Nan:	Arguments in the whole group helped because you get others' **perspectives**, that kinda helped me.	Nan connects the idea of perspectives to her own learning.
	************************************	
Roth:	Were small-group or whole-group discussions more helpful to you?	
Nan:	Whole-group discussions because we got more **perspectives**, more ideas.	
Roth:	Is it important to know what other students are thinking?	
Nan:	Yeah, cause it gives you more **perspectives**. I always say that word, but it does.	

MICHELLE		Michelle is a quiet member of the class. She is a cooperative student who had learned to get by in school by being hardworking and persistent. Although she was popular socially, she was not typically recognized by students or teachers as being academically strong.
Roth:	Why is it important for people to do science?	
Michelle:	To find out different things, so they aren't going with just one point of view. Like when we did the bean plant, we weren't just looking at the book.	Michelle values different perspectives in her own learning and in scientists' learning.
Roth:	Why is it important not to go with just one point of view?	
Michelle:	Cause you'd be getting your *own* ideas, too. Like when we were reading books on plants, we weren't just going by that **perspective**, we were going by *our* **perspectives**, too. Like doing different experiments with beans.	Integrates her own knowledge about plants from experimental evidence with ideas from books.
Roth:	Why was that important to you?	
Michelle:	You could think what *you* thought about it, not just what the book thought about it. I like finding out different things, finding bones and stuff, more about plants. You could get different ideas, different from reading in books.	Michelle seems to value highly her own perspective and see it as valuable as those in books.

HEIDI		Heidi is an academically strong student.
Roth:	Would it be hard to answer your questions about early humans?	

Heidi:	It could be pretty hard if you don't have any evidence. You can't just sit there and think, "This is how they did this." You have to have some kind of evidence. Like when you go to a meeting, they ask you "What'd you find out?" You say, "Well, I found out that they made their clothes like this." And they say, "What's your evidence?" "I just thought it up." You can't say that, you have to find some evidence.	
Roth:	Do scientists ever look at some evidence and explain it in different ways?	
Heidi:	Yes. We learned something like this in social studies, different **perspectives**. Like there's, let's say, like I went to a New Kids on the Block concert. And the stage is here, and I was sitting over here to the side. And there was another side and there was a front and a back. But here is right in front of the lights and I don't think they could see much. These peoples' [on the side opposite from Heidi] perspective, their thinking could be different than mine because they see it from a different view. And these people [in the front] could think differently because they have a different view. And these people back here wouldn't have much of a perspective, I don't think, and they would see things differently, too.	

LATICIA		Laticia was new to the school in mid-October. She came from a mostly black school, but here she was the only black student in her class. She had difficulty making friends; other girls saw her as too bossy and assertive. She worked hard to please teachers but struggled with conceptual learning.
Roth:	Why did we draw this picture (of the scientist)?	
Laticia:	To think what our **perspective** of a scientist was.	
	**********************************	
Roth:	Do you ever feel like a scientist outside of school?	
Laticia:	Yeah, when I'm looking at rocks. I was going to the store and I saw these rocks. They were pink and orange and they had holes in them. It was interesting. I was thinking that something coulda ate it or it could have chipped off. Or I think snakes live by rocks ... the holes could have been from the snakes.	
Roth:	In what ways were you like a scientist?	
Laticia:	I was trying to figure out what, how the holes got in the rocks.	
Roth:	Did you figure out a way of answering your question?	
Laticia:	I think you could take it to a scientist or a museum and ask them and see what their **perspective** of it is.	Views scientists as experts with perspectives to share, not answers.
Roth:	Do scientists have different perspectives?	
Laticia:	Yes, sometimes they argue, too. I mean they listen to their ideas. I remember our class had a little argument because I was thinking about something, whether soil was food for plants, that's what the argument was about. And it isn't.	
	******************************	

Laticia:	(Referring to some writing she had done back in November in her science journal and Roth's written responses to her journal) You were helping us think about food for plants. We had to do a lot of thinking. Here I wrote soil is food for plants but I changed my mind cause of vonHelmont's experiment.	
Roth:	That helped you change your mind?	
Laticia:	Yeah.	
Roth:	You said talking together helped you learn this?	
Laticia:	Seeing what other people's **perspectives** were, and we thought about what they had on theirs and what we had on our own. And that gave us more questions when we worked in groups. That's when we mostly wrote in the Question Book.	Connects idea of perspectives to her own learning in science.
	******************************	
Roth:	Writing your thoughts helped you learn?	
Laticia:	Seeing other people's **perspectives** helped. When you asked us, "Do you want to share anything?" I like seeing what other people think they know, and what other people think about what I think.	

MATT		Matt is a verbal, academically strong student.
Roth:	What kinds of talking and writing do scientists do?	
Matt:	They talk with other scientists to mix their ideas, collaborate, to see if they can solve a problem. A lot of scientists don't work just by theirselves. They collaborate to come up with some better ideas.	Idea of collaboration was explicitly taught in social studies and writers' workshop but not in science.
Roth:	Are you like a scientist in some ways?	
Matt:	Well, in math, we, if like one person's stuck, we help each other out, not quite give somebody the answer , but help them. Give them clues and evidence.	
Roth:	Is that an important part of science?	
Matt:	Yeah, they have to provide it to their fellow scientists.	
Roth:	Do scientists travel?	
Matt:	Yeah, they have to move around a lot, from state to state or even a different country to find something new or like for meetings with other scientists to share their **perspectives** and to collaborate to mix what they have with some others, to form some better evidence.	Integrates ideas of perspective and collaboration with his new, less stereotypical image of a scientist.
Roth:	What helps you learn?	
Matt:	When we get stuck a lot, somebody will come over and ask you if you want to work with them. If you get stuck or they get stuck you can mix your ideas and collaborate.	

NATHAN		Nathan is the usually invisible average student who we saw above was so successful in connecting ideas together within science.
Roth:	What kinds of things do scientists do?	
Nathan:	They have to research stuff. They have to look at different scientists' **perspectives** and see what they think. Then they try to see if they thought it was any different, maybe find that scientist and talk about it.	
Roth:	Can you say more about perspectives?	

Nathan:	Like if they're in a book, they might read it, and get some ideas, and they might say, "Well, I don't think this is right." They might change their idea.	Connects idea of critical reading of text taught in social studies with scientists' learning.
Roth:	Was that idea new to you?	
Nathan:	I didn't know that they looked at different scientists' **perspectives**. I thought they just said what they thought it was.	Emphasizes importance of his new view of scientists as having perspectives rather than clear cut answers.
	**********************************	
Roth:	What kinds of people become scientists?	
Nathan:	People that learn to get along with others. They work hard. Cause sometimes scientists are in a group and if they didn't get along they wouldn't be able to find out what the other people thought, they might only have their **perspective** and it might be wrong.	Integrates new image of scientists as social beings in contrast with entering stereotypical scientist in isolation.
	**********************************	
Roth:	Why would it be helpful today to know about life in the past?	
Nathan:	It'd probably be interesting because maybe people might be wondering about things in the past, and they might not know nothing about it, and then they couldn't find out anything from other scientists' **perspectives**.	Integrates idea of perspectives with his new image of scientific inquiry
	**********************************	
Roth:	What other things helped you learn about plants so well?	
Nathan:	The skits cause we got to see other people's **perspectives** about how they thought the bean plant grew.	Integrates idea of perspectives with his understanding of his own learning in science
	**********************************	
Roth:	How was talking about ideas in groups helpful to you or not?	
Nathan:	When we were in groups, and we talked about ideas about what we thought and then we got together and we had like a scientific argument. And then someone thought it was one idea and someone thought it was another, and then it just kept going on.	
Roth:	Was that helpful to you?	
Nathan:	Yeah, cuz you got see other people's ideas and what they thought.	Integrates idea of perspectives with his understanding of his own learning in science

<u>Students' perspectives about "stereotypes"</u>. The concept of "stereotype" was introduced to students in science class at the beginning of the year in the context of talking about stereotypes of scientists. The stereotype of scientists as male was of particular interest to many of the fifth graders. All the students in Roth and Lindquist's class drew pictures of males when asked to draw a picture of a scientist in September. In the spring unit about the history of life on earth, Lindquist asked students to draw a picture of a scientist studying dinosaurs. This time all of the girls drew female scientists. Although "stereotype" was not an explicit focus of instruction in social studies,

the students brought it to Hoekwater and Hasbach's attention during a lesson in February as a useful word to label some of the ideas they were discussing about the beliefs about male and female differences that people in our society hold. The students made explicit reference during this class discussion to their exploration of stereotypes in science: "It's like we talked about in science!"

In the year-end interviews about science, students used the idea of stereotype to describe images of scientists as males (with crazy hair!) working alone with chemicals in a laboratory, but they also used the idea to discuss their own social interactions. Thus, a concept that was introduced to help students develop a richer understanding of scientific inquiry was used by many students to think about social interactions between males and females. Students integrated this knowledge about stereotypes in quite personal ways, using it to think about their own interactions with members of the opposite sex. Some students also linked this idea to larger social settings, to discuss and explain discrimination against women in American history.

We saw earlier that "stereotype" was an important concept in helping Nan challenge her own stereotype of scientists. It provided an entryway for her to begin to see herself as a person who can understand, contribute to, and enjoy science. But Nan also used the idea of stereotype in a cross-disciplinary way to think about social studies issues--especially her own interactions with boys and girls in her class. Although she struggled for many months at the beginning of the year to work effectively in her small group of all girls (Heidi, Michelle, and Tiffany), she reported during both midyear and year-end interviews that she felt good about her improving interactions and her growing acceptance by the group. She felt particularly good that Heidi, a popular and academically strong student, had become a close friend:

> I would always get stuck with Heidi and Michelle [in small groups], and I didn't like Heidi back then but we turned out to be best friends. (5/24/91 interview)

But Nan was especially intrigued with her success in having her ideas heard and valued by boys when she started working in small groups that had both male and female members. She uses the idea of "stereotype" to make sense of this observation about her personal social interactions:

> Roth: Were your ideas heard as well when you switched to groups with both girls and boys?

Nan: Yeah, cause I'm surprised that the boys listened to me. The boys got a lot of ideas, but I mean they listened to my ideas.
Roth: Did the boys listen more to you than the girls?
Nan: About the same but most boys, this is one of those words that starts with an "s", that most boys never listen to girls cause they don't like them.[Nan's speech difficulties made words like stereotype and photosynthesis a challenge to pronounce--throughout the interview she referred to "stereotype" as the "s" word]
Roth: So your stereotype of boys changed?
Nan: Yeah.

In a year-end small-group interview conducted by Hazelwood, Nan continued to explore her ideas about boy and girl interactions, using the idea of stereotypes to think about these issues in a conversation with Heidi, Michelle, and Tiffany (the small group of girls that had such difficulty working collaboratively at the beginning of the year). Hazelwood had asked the girls to consider whether they thought teachers should have them work in small groups that are all girls and all boys or small groups that have a mix of boys and girls. In this interaction, Heidi brings up the notion of stereotypes and uses it effectively to get Nan to reconsider her position that boys are "yucko" and that she didn't want to work with them. Notice also how ideas about "perspective" and "discrimination" (ideas discussed in social studies class) get woven into this conversation and how the girls bring up issues that are quite personal and important to them both now (training bras) and in the future (marriage). Thus, the girls in this conversation are integrating ideas studied in science and social studies with their personal concerns and experiences (**bold type** highlights students' explicit use of ideas from science and social studies):

Nan: To not put boys with girls.
Tiffany: I think you should because ...
Hazelwood: Ok, wait a second. Let's go one at a time. You say no. Why not, Nan?
Nan: Because boys are yucko.
Hazelwood: What do you mean yucko?
Nan: They fool around too much.
Heidi: And we don't?
Tiffany: I talked about [inaudible] before. She just said I think you should because later on in life when you work in a business, men and women have to work together and if you don't get used to it now, you're not going to do it later.
Hazelwood: What do you think about what Tiffany said?
Tiffany: And not all boys fool around.
Nan: I agree with her, but I also agree with me.
Heidi: I think, I think you should put boys and girls because then you can, **then you can get different perspectives** cause boys have different things that, different, sometimes they have different things that girls don't think about and ...
Tiffany: **And discrimination too.** Like with things like that.

Heidi: And in middle school you're going to be with a lot of boys and stuff and you're going to, and you're going to want, and then you're going to want to, to have boys in the group cause then you'll be going crazy over boys.

Girls: [More discussion about middle school follows]

Hazelwood: If you were with boys and boys were with girls, what do you think you can learn from each other?

?: That you can work with different people.

?: You don't have to work with all the same people.

Heidi: And that boys have good things to say just as well as girls and you can, you can, if you do have boys and girls **you can learn different perspectives by working with different people.**

Hazelwood: That's interesting.

Michelle: It's not all girls in the world and it's not all boys in the world. It's like a mixture?

Hazelwood: [To Nan] Is that convincing to you? You were saying ...

Heidi: If it's all girls in the group, all we would end up doing is fooling around talking about bras and junk like that [Much laughter and t lking over each other].

Tiffany: If not, you should still learn to work with boys because later on you're gonna have to a lot.

?: Yeah!

Nan: I take my thing that I said back.

Hazelwood: You don't have to. You can have a really good argument.

Nan: **I changed my mind.**

Hazelwood: Well, you don't have to, Nan. You can think whatever you want.

Nan: I think there should be a girl and a boy.

Hazelwood: I just want to know why.

Nan: In a group. Cause, see, boys, you don't really get into a conversation with.

Hazelwood: Why not?

Nan: Cause, I don't know. But they are very, they like say stuff about sports and the girls, they don't wanna talk about sports.

Heidi: **That's a stereotype! It's a stereotype I tell you, it's a stereotype!**

Hazelwood: Do you think so, Nan?

Nan: Well, boys, well, boys like to talk about different things than we do. And they, they'll start giving up with different subjects than what we want to talk about.

Heidi: Well, like we want to talk about our hair and our, and our training bras and stuff like that... **Yeah, that's a stereotype. Those are stereotypes, I think.**

Tiffany: Yeah, but still you're going to have to get used to it when you get married. Because your husband might watch sports or something.

Michelle: Uh, huh. My dad, my stepdad does. But some sports are interesting to watch...

Hazelwood: You know what's so interesting, is that you are not considering the possibility that you may make the boys talk about something else. Because they're there that your presence is so important to them, they're not gonna talk about sports, they're not gonna, get into conversations that you're not interested in. You know what I'm saying?

Girls (over-lapping) Uh-huh. Yeah. Completely.

Hazelwood: No matter if you're there or not they're gonna talk about things you're not interested in. Your husband might be interested in sports. Well, your husband will be interested in your life. What about that? What about considering that if girls are in the groups with boys, they can change the way they look at things, the way they can discuss.

Nan. Uh-huh. You can get to like things that the boys like and the boys can get to like things the girls like.

5

It's interesting that several of the boys also talked about this idea that girls and boys would bring different perspectives to a small-group discussion. The boys, however, did not get as personal in their consideration of what those different perspectives might be like:

Roth: What advice would you give teachers, to have all boys in a group or mixed with girls?
Lucas: Have them mixed. Girls could have better ideas than boys and boys could have better than girls.
Roth: Do girls have different perspectives?
Lucas: Some of them do. Some girls think of different ideas.

* * *

Roth: What advice would you give teachers, to have all boys in a group or mixed with girls?
Jesse: Mixed so we can see the girls' opinions and the boys' opinions and so we're used to having girls in our group and boys. Like when we grow up, we won't have to go, "Yuck, I don't want her in my group."

When Justin talked about stereotypes of scientists in his interview, it led to an interesting exchange with Roth about larger social issues such as why women are not as well represented in the sciences as men. Although there had never been explicit discussion about discrimination against women in science class, Justin uses this idea of "discrimination," which was a central concept in his social studies class, to explain why there are so few women scientists. Unfortunately, Roth did not pursue with him whether or not he thinks discrimination against women in science is "still true today":

Roth: So women can be scientists, too?
Justin: Yeah, you're a scientist.
Roth: Why do you think it's a stereotype that scientists are men?
Justin: Because men always discriminated against women long ago. They were the only scientists because men owned 99% of the world's resources.
Roth: Did you learn that in social studies?
Justin: Yeah.
Roth: Is that still true today?
Justin: It's true today.
Roth: What do you think about that?
Justin: They should let women own some, too.

We use these examples of "perspectives" and "stereotype" to illustrate ways in which students took concepts studied in social studies and used them appropriately in the context of science and vice versa. We also saw examples of explicit connections students were making across science and writers' workshop .

Connections Across Science and Writers' Workshop

Integration from the teacher's perspective. In our science teaching, there was a consistent practice of choosing pedagogical strategies that coincided with our views of learning as a process of conceptual change. Integration in the science curriculum, from the teacher's perspective, could be characterized as the convergence of the teacher's epistemologies of subject matter, learning and teaching in a learning community. We will use a lesson example to illustrate ways in which we perceived such integration in the teaching of science to be supportive and parallel to our colleagues' efforts to represent writing and learning to write in writers' workshop.

In this lesson Roth is supporting students in using writing as a thinking tool to change their ideas about how plants get their food. Her emphasis on students' conceptual change was consistent with her view of scientists as people who are willing to change their ideas in face of new evidence. She identified learners as scientists developing a disposition towards knowledge that allowed them to modify their thinking. In the following lesson example, Roth describes her disappointment with the writing efforts of the previous day. The task had engaged students in writing about how their ideas about how plants get their food had changed since the beginning of the unit. Her knowledge about learners and about science and scientists supported her pedagogical decision of asking students to revise their science writing:

Roth: I was sort of expecting people to be real good thoughtful scientists. I was expecting to see a more thoughtful answer.... Scientists when they get good evidence they are willing to reconsider their ideas...change them.... I gave you your yellow sheets [the pretests about food for plants] back.... I want you to write to me just as if you were talking to me after class or at recess time about whether or not your ideas have changed and why.

Student: Do it over again?

Roth: Do it over again.

Writing assignments integrated in the science curriculum promoted thoughtful reflection about the learning process and enhanced students' use of personal knowledge to explain natural phenomena. Roth's interaction with Nan, while students were writing in their journals, illustrates how writing fostered Nan's disposition to integrate her personal knowledge and question about plant food with subject matter content and to challenge the assertion that water is not food for plants:

Roth: [Reading Nan's paper] ...What is this word?..."but I think water is food...and plant food"...
Nan: Yeah! Why do they call it "plant food" if it's not food?!
Roth: O.K. Why don't you add that to your answer?

The learning community became a dynamic place where students shared their individual ideas and celebrated learning together. Roth took on the role of integrating individual parts to compose a coherent whole. She orchestrated and highlighted solo parts to create a composition whose authors were the members of the learning community.

As Roth walked around the room looking over students' shoulders to read their journals, she emphasized the idea that thinking changes over time as a disposition that students were developing through writing. This was consistent with ideas being explicitly taught about writing in the context of writers' workshop .

Roth: Oh!!! We have a good question here. Let's come back together as a group right now. As Laticia was writing, sometimes this happens when you're writing, thinking about your ideas you come up with some new questions and realize you're not sure about some things [pause]. What was your question, Laticia?

Laticia: [Inaudible]...for plants?

Roth: Is sun food for plants? That's what she started thinking about. And I think I saw that on several people's papers that they're thinking about sun right now. Because of the experiments we did the sun seems to be really important. Laticia, would you make sure we get that in the question book?

Roth: I think I read everyone's and on Matt's he wrote something that I don't think anybody else had. Read your answer Matt.

Matt: I think that sun is food for a grown up plant and the cotyledon is food for the seed.

Roth: Did anybody else put cotyledon for the seed? [Pause].

Does anybody else agree with him that the cotyledon would be food...how many people agree that the cotyledon would be food for the embryo?

[Everyone raises hands].

Roth: O.K. Let's add cotyledon to our list. We don't have it up there, do we?

[Roth walks towards the chart in the corner of the classroom and writes the word "cotyledon" at the bottom].

Roth: That's a hard one to spell.

In this exchange Roth integrates a science lesson with writers' workshop in a very explicit way. In her opening comment, for example, she talks about the value of writing as a thinking tool. However, we see many other ways in which the norms and values in this learning setting are integrated with those in the writers' workshop setting. The integration is not limited to such explicit connections about subject matter. For example, the following interactions surrounding the science "hypotheses" chart remind us of similar discussions surrounding the "author's day" routine in writers' workshop. Just as public sharing of ideas on author's day was used to support writing revisions and to celebrate progress and accomplishments in a cooperative rather than a competitive way, so the science hypotheses chart served as a centerpiece for public sharing of science thinking, as a tool to support revision and changing of ideas, and as a focus for celebration of accomplishments of the science community.

Change in the science learning community was made visible on this chart posted in the front of the classroom. A large bulletin board was covered with a list of ideas and hypotheses that represented students' thinking about what constitutes food for plants. Students took votes regularly and compared how their ideas were changing in light of new evidence. The chart displayed the votes along with descriptions of accumulating evidence that students would record on "yellow stickies" and post on the chart. The "taking a vote" routine on November 29 began after students had finished the discussion of their journal writing. Roth encouraged students to consider ideas put forth by other students during the discussion. Then the voting routine began:

Roth Now we're gonna take a vote, but before we do would you look at what you wrote down yesterday? I want you to only vote for those things that provide food energy for plants....How many people today think fertilizer is food for plants?

[Roth reads down the long list of student hypotheses about food for plants - air, water, soil, dirt, insects, juice, hair, etc. - tabulating the votes and half-votes which represented the "not sures." There is no item on the list that receives unanimous approval. Finally, Roth reaches the bottom of the list:]

Roth: How many people think the cotyledon is food? [All students raise hands]. One, 2....21. All right!!!!! We all agree on something!!

Chorus: Yeahhhh!!!!!

From our teacher/researcher perspectives, this science lesson emphasized norms of participation and processes of writing and revision that were consistent with the norms and processes emphasized during writers' workshop . Although this lesson contrasted with writers' workshop because there was no student choice of topic and because students were all writing about the same topic, we were more impressed by the similarities across these two subject areas. We saw the same emphasis on writing as a thinking tool, the importance of revision, and the sharing of the revision and "publication" process. But we wonder about the students' perspectives. Did they see the connections we saw between science and writers' workshop? Did they make other connections? We use a similar analysis of a lesson in science to examine the students' perspectives about science and writing workshop.

Integration from the students' perspectives. In the context of science lessons, we found evidence that students integrated the dispositions and views of the writing process they had begun to develop in writers' workshop. This type of integration seemed connected to the initiation of a writers' workshop approach and the establishment of "author's day" routine. On author's day, one volunteer would share a piece of writing with the whole class and receive feedback from the learning community. This activity helped students develop critical attitudes towards text and identify authors as people whose purpose and meaning they needed to understand and critique.

This text-author connection was particularly interesting during a science classroom interaction between students and Roth, who was the author of the science textbook. A group of two girls and two boys were reading and discussing an explanation in the text about photosynthesis. After they had read and discussed several paragraphs, Michelle noted a problem with the writing:

Michelle: You guys, all these things said different things.
Annie: Yeah, I'm confused
Chorus: Yeah!!!
Justin: Did you write this? [calling to Roth] It's confusing. [facing Roth].

Roth approached the group and the students explained why they thought the text was confusing. Annie and Michelle mentioned that in one paragraph it said that sun is food and the next paragraph said that sun is not food "Then," Annie added, "you go on to a completely different thing and you didn't say why."

Roth responded by looking carefully at the written text:

Roth: O.K. let's go back, let's do a really good reading. Let's go back to page 18 and see why you got confused. In the second paragraph... it says **if** light is food for plants you need to know more about plants than we can observe in this experiment. A good explanation must tell us more than what happened, it must tell us why the plants need light, so that's not saying that light is food. We need to find out.

Annie: But in this one it says... sun is not food for plants... plants are able to do something amazing with the light. Then it says up here the grass plant experiment showed how plants need the light to grow... that means light is food for plants and that one says light is **not** food for plants.

Roth: "I see what you mean [nodding]. O.K. look at this sentence over here. It says but sunlight does have something to do with food for plants.... What I was trying to say was that the sun itself is not food for the plants, but the sun does have something to do with food for plants".

Annie: Maybe you should explain it more.

Roth: I think I should, and you're really helping me think about how to re-write it.

While attempting to understand the ideas presented in this piece of text, students connected the writing process to the act of reading and challenged the writer. The brief verbal encounter between the students and their teacher, reminiscent of "author's day," echoed the norms, rules and dispositions that teachers were fostering as explicitly taught goals in writers' workshop: formulating constructive critiques to a piece of writing and receiving comments and accepting suggestions for revision on the part of the writer. The students psychologically placed Roth in the author's chair. While Roth had not considered explicitly encouraging students to reflect on her writing of the text in this way, the students made this connection for her. It was the students who integrated what they had learned about writing and authors in writers' workshop with their approach to reading about photosynthesis in science, a task that could easily have been reduced to a mindless routine of oral reading. Because Roth had established norms of inquiry and thoughtfulness and openness to change in science, the students felt comfortable taking their criticism to her even though she had never told them that it was OK or a good idea to criticize their science text. They might have had the same kind of criticism if they had been reading the text in a more work-centered classroom, but it is unlikely they would have voiced their criticisms in a classroom where the teacher (and her text) is viewed as the sole authority and expert. The congruency of norms in her science classroom with those in writers' workshop enabled Roth to immediately recognize this event as important and to value and support the connections that the students had made. She responded to their critiques thoughtfully and showed her eagerness to revise the text to make it more understandable. She learned from her students' perspectives about integration, and next time she will actively encourage such critical reading of her text.

The Learning Setting: What Enabled Integrated Learning?

These examples of integrated learning (as well as others described in Rosaen, Lindquist, Peasley, & Hazelwood, 1992, and Hasbach, Hazelwood, Hoekwater, Roth, & Michell, 1992) were striking to us. Both the literature and our own teaching experience told us not to expect students to make even the most basic connections without a lot of explicit instruction. But when we stopped looking only for those connections *we* intended and allowed students to tell us about the ways *they* were putting ideas together, a wealth of evidence of meaningful integration by the students was revealed. Since our instruction and curriculum were not designed to create cross-disciplinary integrated teaching, what enabled Nathan and Nan and the others to use the idea of "perspective" so effectively outside of a social studies context? What enabled them to use the idea of "stereotype," introduced to them in a science context, to describe behaviors of girls and boys in their own social world?

In this section, we describe the science learning setting--the science curriculum, the instructional model, and the learning community. We then consider aspects of this learning setting that were congruent with the social studies and writers' workshop s learning settings. From this analysis of commonalities across the three learning settings, we present our emerging view of integrated teaching and learning, comparing and contrasting our perspective with those held by others (thematic integration teachers, cognitive psychologists, science educators).

Overview of the Science Curriculum

The Appendix summarizes key concepts taught in units across the year in science, also showing which topics and concepts were being taught concurrently in social studies and writers' workshop . The chart illustrates two aspects of the science curriculum that may have been significant in terms of students' integrated learning: (1) Concepts introduced in one unit were used again in different contexts in subsequent units; and (2) ideas about the nature of scientists' work and scientific inquiry introduced in the first unit were woven into each unit across the year.

The year in science began with a short introduction to the nature of scientific inquiry, which was a thread that would continue throughout the year in an effort to intertwine study of the nature of science and scientific inquiry with the science concept development. The initial focus was on challenging students' stereotypes of scientists and scientific work, with an emphasis on the role that writing and discourse play in scientific inquiry. The conceptual context for exploring scientific inquiry was a study of adaptations of desert plants and animals. This unit took approximately one month, and led into a unit about plants and photosynthesis which continued from the second week in October through December. In the desert adaptations unit, we had explored diverse ways in which plants and animals found and conserved water. In the food for plants unit, we considered some new questions about plants: Why do plants need water, anyway? How do plants get their food? During the winter months, the focus was on cell respiration in humans which was explored through a study of two central questions: What happens to the food we eat? What happens to the oxygen we breathe in? Students considered interactions among three human body systems--digestive, circulatory, and respiratory--in constructing new answers to these questions. Later in the unit students considered cell respiration in plants and other animals, with an emphasis on the idea that all living cells need to get food and oxygen which interact in the cell to release stored food energy for use by the cell and the organism. The year ended with a unit focused around a student-selected topic, dinosaurs. The "dinosaur" unit was, in fact, much more than a unit about dinosaurs. The teacher/researchers used the topic to integrate concepts studied across the year (organisms, structure, function, adaptation, photosynthesis, body systems, interactions, cells, energy, etc.) and to highlight important aspects of scientific inquiry. The conceptual focus was on the history of life on earth: What do we know about life on earth before humans? What don't we know? What were the relative lengths of time that different organisms lived on earth (especially plants, dinosaurs, and humans)? In the spirit of scientific inquiry, students catalogued the history of changing beliefs about dinosaurs over time and the many still unanswered questions and were encouraged to pick a question that was of interest to them to explore.

We did not explicitly set out to integrate science knowledge with the knowledge being taught in social studies and writers' workshop . As can be seen by the curriculum chart in the Appendix, topics being taught in social studies (colonization, Civil War and civil rights, etc.) and in writing (descriptive writing, author's design, poetry, etc.) did not have obvious thematic connections to topics being studied in science (how plants get food, human body systems, etc.). However, there were some unintended overlaps and relationships among the key concepts being taught in the three subjects across the school year. For example, discussions about "perspectives" in American history were conceptually closely linked to issues of "point of view" in writing and use of evidence in science, and the focus on stereotypes of scientists was related to issues of discrimination in the social studies curriculum.

The Instructional Model

The curriculum was initially organized around a conceptual change model of instruction, which was how the LISSS group originally conceptualized teaching for understanding. The text used for the photosynthesis unit was a slightly revised version of the *Food for Plants* text (Roth, 1985) which adapted the activities in the SCIS Producers unit (Knott, Lawson, Karplus, Their, & Montgomery, 1978) to a conceptual change approach. A similar conceptual change-oriented text, *The Power Cell* (Anderson, Roth, Hollon, & Blakeslee, 1988), was used in the human body unit.

What was critical to us in this model was the centrality of students' ideas and thinking in our planning and teaching. Science education researchers have shown that students have a wealth of experience-based conceptions of natural phenomenon (Clement, 1982; Dai, 1990; Driver, Guesne & Tiberghien, 1985; Erickson, 1979; Shayer, 1981; Stead & Osborne, 1980; van den

Berg & Sandaru, 1990). These conceptions are variously referred to as misconceptions, alternative conceptions, naive conceptions, commonsense notions, everyday knowledge, or personal theories. To the student these ideas, although not necessarily congruent with scientifically accepted ideas, make sense and therefore "work" for them in that they are able to use them to describe and explain phenomenon in the natural world.

In our vision of a conceptual change model of instruction these ideas are not ignored as if the student were a "blank slate," and they are not belittled as "wrong" or silly ideas held by kids. Rather they are taken seriously. They are listened to and valued as students are carefully supported in considering their conceptions in light of emerging evidence from experiments, other students' ideas, and scientists' explanations. It is stressed to the students that their conceptions are valid and can contribute to our collaborative study and learning. We also stress that scientists are always searching for better explanations of the world around them and that they are open to changing their minds as new evidence becomes available. Students, like scientists, are encouraged to change their explanations--when it makes sense to them that other explanations are more powerful--and to value such change and growth in their thinking.

Consistent with this emphasis on focusing instruction on students' knowledge, we were emphasizing not only integration of scientific concepts across multiple science units but also another kind of integration, one that is often left out of science class. We were helping students integrate their everyday, personal, practical knowledge and experiences with the ideas that they study in science. In the food for plants unit, for example, students were supported in integrating their initial experience-based ideas and hypotheses about sources of food for plants with the data they collected from experiments in science class (and at home) and with the scientific explanation of photosynthesis that they examined and questioned.

<u>The Learning Community</u>

Although we were using a conceptual change text and model, our vision of that model changed as a result of our collaborative efforts. We added an important piece in our description of our teaching model that is not an explicit part of the conceptual change model we had been using

(Posner, Strike, Hewson, & Gertzog, 1982). Largely through our study group interactions, including both readings from the literature in subjects other than science and discussions held among LISSS group members holding different subject matter interests and orientations, we became aware of the importance of the social context that supported and motivated student construction of knowledge. We came to view the social context of the science classroom as a science learning community. Our efforts focused on creating a learning community in which students felt safe enough to share, and puzzle over, their uncommon ideas about natural phenomena through their classroom talk and writing, and to work together to "socially construct" new understandings of these phenomena. This learning community of scientific inquiry is consistent with the way in which scientific knowledge is constructed, at least ideally, by scientists.

To characterize the kind of learning community we were trying to create, we found it helpful to use Hermine Marshall's (1990) distinction between the metaphor of a classroom as a *workplace* compared to a classroom as a *learning place*. An important contrast between these two metaphors is in what is communicated to the students to be valued and worthwhile--the difference in relative emphasis on completing assignments versus learning. In a work-oriented classroom the emphasis is on competing the work--sometimes at the expense of learning. While in a learning-oriented classroom the students still complete work, but there is an important emphasis on how and why the work is being done. Thinking, questioning, discussing, making mistakes, trying new ideas are valued and rewarded as much as completing a finished product. We extended and elaborated Marshall's metaphor and created a list of related qualities that are important to us and that tend to contrast with more traditional, work-oriented classrooms, with an emphasis on each individual completing their work, often merely for the sake of "getting the job done" rather than for the purpose of learning. We included the following qualities on our list and contrasted them with a "work"orientation as shown in Table 1 in the prologue.

It needs to be emphasized that these two metaphors, classroom as a workplace and a learning place, illustrate a tension, rather than a distinct dichotomy, since it must be acknowledged that all students complete "work" of some kind in any type of classroom setting. In our classrooms the emphasis was on *learning* science, rather than on *displaying* science knowledge in the form of a finished product to be graded by the teacher.

An important aspect of the learning community in science was collaboration. Rather than science knowledge being something that was personal and private--the property of a single individual--science knowledge in our classroom learning communities was something that was created by students working in collaboration with one another, in pairs, in small groups, or in whole class discussion. Eric summarized this collaboration saying, "You listen to each other's ideas... and people add onto other peoples ideas... until you have an idea that makes sense that you all agree on."

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

Many of the other aspects of our learning community are a part of working collaboratively as a discourse community to construct scientific knowledge. For example, an important aspect of collaboration is valuing and respecting the ideas of others, especially those of peers. In a more traditional classroom the teacher may be the only person to whom the students look for answers--the authority for knowledge--and thus the teacher may be the only person whose ideas are valued and respected. However, in our science classes the students were encouraged to value each other's ideas as much as, and sometimes it seemed even more than, the teacher's. They often built upon one another's ideas and would reference an individual student's experimental data or statement even if it had been given days previous.

When students had a question such as, "Is just water food for the plant, or can any liquid be food for the plant?" rather than the teacher directly answering the question, the student was encouraged to set up an experiment which would provide evidence that they, and the rest of the class, could use, either alone or in conjunction with other evidence produced by their classmates, to answer their own question. The students set up many such experiments either during class, at recess, or at home, and their peers waited eagerly for the results as is illustrated in the comment made by Casey during a class discussion: "Can Chip tell us what is happening with his experiment now?" (11/7/90 field notes)

The result was that the students felt a tremendous sense of ownership over the scientific knowledge they had helped to create. In fact, students had such a strong sense of ownership over their ideas, and the atmosphere of trust in the class was such that students often disagreed with the teacher or the text, and were encouraged to do so.

Theoretical Perspectives on Integration

An Emerging Perspective From the LISSS Project

In what ways were the social studies and writers' workshop learning settings similar to this science learning setting? Through regular interactions in our study group over time, we began to notice many interesting connections and similarities across subject areas. We saw these connections even at times when the subject matter in different classes seemed at one level to not be related at all: What does the human body have to do with creating an adventure story? What does studying about the history of plants and animals on earth have to do with the Trail of Tears? What do desert adaptations have to do with creating a history of the school? What does photosynthesis have to do with colonization, discrimination, racism, or poetry?

We have identified four ways in which integration of our knowledge as teacher/researchers enabled us to create learning settings that shared important features. We believe that these shared features of the learning setting may have been critical in enabling the students to construct useful connections within and across subject matter areas. As we studied our practice across the subject matter teacher/researcher teams, we found that we integrated four kinds of epistemologies: (1) our epistemologies about our respective subject matter fields (knowledge about how scientific knowledge grows), (2) epistemologies about learning (knowledge about how students learn), (3) epistemologies about curriculum (knowledge about how curriculum can match disciplinary understandings and students' ways of thinking and learning), and (4) epistemologies about practice/teaching (knowledge about pedagogical strategies). Although we did not plan thematic units across subject areas or match up lists of concepts being taught in different subject areas, we did succeed in supporting some very interesting kinds of integration from the students' perspectives. We are thinking now that the integration across subject areas was enabled by similar attitudes toward knowledge in the disciplines (science, history and literacy epistemologies) being emphasized in each of the three classes, similar views of learning held by all the teacher/researchers, and similar choices being made about curriculum and about pedagogical strategies that were consistent and integrated with our views of learning and knowledge growth in the disciplines (see Table 3).

Although our efforts at this kind of integration were far from ideal in each of the subject matter areas, they did represent significant efforts that contrasted sharply with usual instruction in these subject areas. We first noted the intersection of our efforts midway through our second year together as we worked together to create our learning versus workplace metaphor, an effort that we undertook in order to explain to others what we were trying to do in our classrooms and why it felt so dramatically different from ways we had taught in the past. Our collaborative creation of the learning setting vs. workplace metaphor enabled us to see important connections across these subject areas in terms of the kinds of learning communities we were creating even though the content was not explicitly linked around a topic or conceptual theme.

Thematic Integration

Our view of integration differs from a thematic view of integration that many elementary teachers, because of their responsibility for teaching multiple subject areas, have found appealing. As increasing demands are made on elementary teachers to spend more time teaching some subject areas (more mathematics, more science, more writing) and to teach more kinds of knowledge and skills within the subject matters (metacognitive strategies, health, drug education, sex education, process writing, mathematical problem solving, etc.), the appeal of curricular integration increases.

Table 3

Learning Communities
In Science, Social Studies, and Writers' Workshop

Epistemology of Subject = View of Learning = Curricular Focus on the Learner = Pedagogical Epistemology

Similar attitudes about knowledge in each subject area supported similar approaches to teaching and learning:

•Epistemologies of subject areas:

Knowledge is socially construct... -it is human made, meaning is constructed, does not simply exist "out there"; all humans are both knowers and creators of knowledge
Socially constructed knowledge is organized around big ideas, concepts, or themes representing consensus of experts in the domain
Knowledge is not absolute and immutable--it is to be challenged, created and recreated continually--knowledge change takes place over time and is linked to what has gone before and grows in response to people's prior knowledge and experience, their interests and questions
Knowledge is not separated from process in disciplines; real understanding cannot be isolated into either content or process--if you only know one or the other or if you know them as separate pieces, you have a significant misrepresentation of the subject area

•View of learning is consistent with this epistemology:

Learning as a social and active ve...ure--meaning must be constructed for it to be meaningful
Learning as a process of knowledge, skill, and attitude change that takes place over time and is linked to learner's prior knowledge and experiences
Understanding content in isolation of processes or processes in isolation of content leads to misunderstandings about the nature of knowledge and inquiry in a discipline.

•Curricular choices consider both disciplinary views of knowledge and student views of knowledge

Centrality of the learner and the learner's experiences, prior knowledge in making curricular choices
Curricular knowledge reflects view of disciplinary knowledge as tentative, changing, socially constructed
Expectation that curricular view of knowledge must be challenged and questioned by students for genuine understanding (personal meaning making) to occur

•Pedagogical epistemologies are consistent with epistemologies of subject areas and theory of learning:

Classrooms as learning communities in which all are learners, and instruction encourages and supports active construction of meaning in collaboration with others; learners act as writers, scientists, historians.
Conceptual change model, central questions and big ideas
Content and process interwoven and mutually reinforcing

Thematic integration is seen as a way to improve student understanding and use instructional time efficiently at the same time.

In thematic integration, the emphasis is typically on integrated planning and teaching. A teacher, or often a team of teachers, plans a curriculum that integrates multiple subject areas around a theme. For example, a school in our area uses a theme of bubbles to explore science, mathematics, literature, writing, architecture, and art. Children do experiments with bubbles in science, and they use bubbles to study shapes and shape relationships in mathematics. They read stories and poems about bubbles and write both imaginatively and scientifically about their experiences with bubbles. Bubbles are used as inspiration for art activities and for a study of architecture.

As another example, teacher/researchers in our school (including ourselves) are collaborating across grade levels to develop a cross-subject matter theme curriculum for the 500th anniversary of Columbus's "discovery" of the Americas. Organized around a 1492 theme, the curriculum will explore:

- **history and the social sciences** (What were different ways of life around the world in 1492? How did Columbus's explorations start a period of encounters and social conflicts between different cultural groups? How have historians learned about Columbus and how have their images of him changed over time? What was life like for women and children? Why weren't there women among Columbus's crew? How do we know about the Native Americans who did not leave written records?)
- **science and the history of science** (What was science like in 1492? How did the explorers' lack of knowledge of disease processes impact their encounter with the Native Americans? What discoveries of plant and animal life were made?),
- **technology** (How did the European, Native American, and Chinese technologies differ? Why didn't the Native Americans discover Europe? Why didn't the Chinese discover America?),
- **the arts** (What was art and music like in different cultures in 1492?),
- **mathematics** (How did the explorers use mathematics to calculate distance?),
- **geography** (How did Columbus come up with his predictions about how far it would be to reach the Indies by sailing West? What did maps in 1492 look like?),
- **the humanities** (How was religion important in explorations of the Americas by Europeans? What was the experience of the Jews in Spain in 1492?)
- **literature** (How do different authors tell the story of Columbus? Who wrote books in 1492? What kinds of books were written?),
- **and writing** (How might we write our own stories and/or histories of Columbus and the encounter with the Native Americans?).

As we prepare for such thematic integrated *teaching*, we are reflecting on what we have learned about integrated *learning*. We are cautioning ourselves not to get too caught up in the connections we as adults see and to keep our curriculum open enough to allow meaningful student connections to flourish. We are approaching this thematic *integrated teaching* as a context in which to further explore our new understandings about what enables *integrated learning*. Will thematic teaching allow students to make stronger and richer connections within and across subject matters than those made by Nan, Nathan, Michelle, and the others reported here? Will the theme teaching simplify or complicate our efforts to teach for understanding? Maybe we will find that it is easier to focus on teaching for understanding in each subject matter area, creating learning communities in each subject area that are consistent in their approaches to knowledge and learning. We have many unanswered questions and enter this thematic teaching experience without any assumptions that such thematic teaching will necessarily result in integrated learning. We plan to look carefully at students' learning and to compare their learning with the students reported in this paper.

Integration From Cognitive Psychologists' Perspectives

When we started this project, we shared the cognitive psychologists' perspective that integration, or connectedness, is a key aspect of "understanding" in science or history or any other discipline. We were convinced from cognitive psychology studies of experts in different domains that we should focus on a disciplinary-focused kind of curricular integration.

These studies provided convincing evidence that a key characteristic of experts' knowledge (whether in physics, mathematics, biology, medicine, writing, etc.) is that it is well integrated. Experts' knowledge is organized in closely connected sets of concepts and "big ideas" that enable experts to use their knowledge flexibly in problem solving situations. Experts can easily see the connections between their subject matter knowledge and particular situations that confront them. The studies also convincingly contrasted such expert knowledge with the kinds of understandings that students typically develop in studying the respective subject matters in school (even through college). Students often graduate from high school with a fragmented view of knowledge, seeing knowledge as divided into school subject matter categories: literature, writing, history, social sciences, mathematics, biology, chemistry, physics, art, music, physical education, health, etc. Within each of these subject matter areas, high school graduates (and many college graduates) have quite fragmented views of knowledge. The only "big idea" that most students use in history, for example, is chronology, and the idea of chronology of historical events does not go very far in helping them remember and organize the long lists of facts that they may have once memorized. In biology, the typical organization of textbooks organizes biological ideas around classification of living things. Although this classification system is helpful to biologists who understand other big ideas (such as evolution, cellular similarities, structural similarities, biochemical similarities, biological unity and diversity) that make this classification scheme sensible, students often see biology as a parade of disconnected chapters about different living things--protozoa, invertebrates, seed plants, mosses and fungi. Without an organizing conceptual framework, learning biology becomes a tremendous memorization task, and biological knowledge is fragmented rather than connected.

Based on our experiences with this group of fifth graders, we are wondering whether the development of connected understandings *within* disciplines was a key factor in enabling students to make meaningful links *across* subject matter areas. Was Nan's coming-to-know about plants and how they get their food and how scientists study this question a critical foundation that enabled her to make connections across science and social studies?

Integration From Science Educators' Perspectives

What does this study have to say to science educators? How do science educators' perspectives on integration compare with the one we are developing? In science education, researchers and teachers are concerned about the lack of integration of students' knowledge. Numerous research studies provide convincing evidence that students' science knowledge is not conceptually integrated. Even the best science students--those who go on to major in the sciences in college--are unable to use their knowledge flexibly in real-world problem solving situations. Students' science knowledge is often disconnected from their real world experiences and everyday knowledge; they see science as isolated in school or textbook science. They dutifully memorize definitions and formulas about photosynthesis but do not connect that knowledge to the plants in th · homes, gardens, etc.

Gardner (1991) describes a personal example of this learning problem. His daughter called home from college distressed about her physics course: "Dad, I don't understand my physics." When encouraged by her father to seek help, to not worry about grades, and to just try to understand the material, Kerith Gardner replied: "You don't get it, Dad. I've *never* understood it." (Gardner, 1991, p. 5) Gardner uses this example in conjunction with the large body of research literature to elucidate the great gap between what passes for understanding in schools and genuine understanding:

> In schools--including "good" schools--all over the world, we have come to accept certain performances as signals of knowledge or understanding. If you answer questions on a multiple-choice test in a certain way, or carry out a problem set in a specified manner, you will be credited with understanding. No one ever asks the further question, "But do you *really* understand?" because that would violate an unwritten agreement: A certain kind of performance shall be accepted as adequate for this particular instructional context. (Gardner, 1991, p. 6)

Gardner describes this gap as separating both the intuitive learner (who often experiences difficulties in school if he or she persists with intuitive thinking) and the traditional "good" or school-smart student from the disciplinary expert.

To address this problem in science, an international group of science educators is pursuing several different lines of research and curriculum reform to tackle Gardner's question "But do they *really* understand?" Through studies of student thinking in both school and informal contexts, they are exploring students' intuitive ideas and the relationship of those ideas to formal science instruction in schools. Building from a research base that elucidates the ways in which students' experience-based knowledge and ways of thinking are sensible and useful in everyday life, science educators are exploring the usefulness of instructional models that are organized around a view of the learning process as one of conceptual change. Their efforts focus on changing instructional strategies so that students are supported in developing meaningful and genuine understandings of central science concepts.

Other efforts to help students develop more integrated understandings in science focus on changing the way in which the science curriculum is organized. The National Science Teachers Association's Scope, Sequence and Coordination Project is challenging the traditional layer cake high school science curriculum. Instead of presenting science as a four-year sequence of physical or earth science, biology, chemistry, and physics, new curriculum models are integrating each of these science disciplines into every science course. Project 2061, sponsored by the American Association for the Advancement of Science (AAAS) is defining the key concepts and ideas that all 18-year olds should understand about science. Their report, *Science for All Americans* (AAAS, 1990), emphasizes integration of traditionally separated science disciplines, integration of mathematics and technology, and integration of the social sciences and history of science into the science curriculum. A large number of educators working in a Science-Technology-Society tradition are also challenging the organization of the science curriculum around the traditional science disciplines. To enable students to connect science kn. vledge with their everyday experiences, they advocate a science curriculum that is centered around key societal problems and issues (acid rain, AIDS, genetic engineering, pollution, rainforest destruction, landfills, etc.). By studying science concepts in the context of real-world problems, students may be better supported in integrating their knowledge of science with the world around them.

A common thread across all these efforts is that "less is more." There is consensus that students will not develop integrated knowledge if we continue to try to cover so much content. Everyone seems to agree that we should teach less but teach it "for understanding" and that an important aspect of "understanding" is integrated knowledge.

Our experiences in this study point to two gaps or limitations in the science education reform efforts. First, there has been little focus in the science education research and curriculum reform on the social context of the classroom. Curriculum changes that focus on what content the teacher presents (e.g, "integrated" science vs. teaching biology) will not go very far in enabling students to develop more integrated understandings. Despite the absence of such an integrated curriculum, our students made meaningful conceptual connections that stand in contrast with the disconnected bits of knowledge that students usually take away from a science class. As discussed above, we believe that it was aspects of the social context of the classroom and the teachers' representation of scientific inquiry and knowledge in a learning-focused community that supported such meaningful learning for the students.

A second limitation of current science education research and curriculum reform is a focus only on *science* curriculum and instruction. Our fifth graders' science learning seemed to be strengthened and enriched by their experiences in social studies and writing classes that shared underlying values and pedagogical and epistemological approaches. Perhaps science educators can improve students' opportunities for learning science through more substantive, long-term interactions with educators in other disciplines. While this recommendation might seem particularly targeted to elementary education, where each teacher is responsible for multiple subject areas, there is an equally great need at the secondary level. In junior and senior high schools, where students move daily from one classroom and subject area to the next, there is a tremendous need to help students integrate their learning. Perhaps we need to stop assuming that it is a useful experience for students to adapt to very different kinds of teaching approaches and attitudes toward knowledge as they move from one teacher to the next. Instead, it may be especially important at the high school level that teachers create learning settings that share common pedagogical approaches and epistemologies, despite the differences in subject matter.

Integration Within and/or Across Disciplines: Contrasting Perspectives

There is an interesting contrast between the view of integration held by most science educators and cognitive psychologists and the thematic view of integration being explored by many elementary school teachers. While the science educators and researchers are primarily examining integration of knowledge from a disciplinary standpoint, elementary teachers are exploring much wider integration efforts across disciplinary boundaries that are traditionally considered quite disparate--science, the arts, reading, writing, history and the social sciences, physical education and dance. Reports of such integration efforts, however, generally focus on teachers' planned curriculum and do not explore the ways in which students do or do not integrate knowledge as they participate in such a curriculum. Studies of student transfer of knowledge across disciplinary boundaries makes many researchers skeptical that students will make very many of the intended connections across subject matter boundaries.

In our project, we began with similar reservations about integration across disciplinary boundaries. We thought it would be a challenging enough task to teach for integrated understanding within each of the three subject matter areas of focus (science, social studies, writing). Our study provided insights about such disciplinary integration--about how students succeeded and failed in efforts to connect their disciplinary learning with their own personal knowledge and experience, about how they succeeded and failed to make the disciplinary knowledge "their own." Unexpected results of the study concerned the interesting cross-disciplinary connections made by students. We believe that our emerging perspective about that features of the learning community that enabled such integration raises new questions about thematic teaching, about the disciplinary vs. interdisciplinary debate, and about current science curriculum reform efforts.

Learning From Students and From Colleagues

While this study has made significant contributions to our thinking about integrated teaching and learning, it has also taught us a great deal about a new approach to research in which teachers, researchers, and students learn together. In our LISSS study group, we created a learning community much like the ones in our classrooms. Table 1 can be used to describe the ways in which our interactions in this project contrasted with earlier experiences with inservice professional development opportunities and with more traditional approaches to educational research.

Our collaborative teaching and study enabled insights we would never have seen had we been working in the more traditional isolated teaching and research roles. Through our interactions together in weekly study group meetings across three years, we examined issues of teaching for understanding in these three different subject matter areas. As we started conducting research on our own efforts to teach for understanding, we brought our data to study group sessions to ask for feedback, reflections, and support.

Over time, we have come to see students as our research and learning collaborators rather than our "subjects." In our weekly study group we as adult educators were learning from each other, but our students soon called our attention to the fact that we could be learning equally valuable lessons from *them*. The students had to practically hit us over the head with their unique ways of integrating knowledge in order for us to pay attention. These students have opened our eyes to new ways of thinking about integrated learning and have raised our standards of what is possible. It now seems possible not only to help students understand within subject areas but also across.

Each of us began this project with different ways of thinking about curriculum integration. We had read much of the theoretical and research literature addressing the importance of integration within subject matters (especially in science) and the potential value of the integration of writing and discourse in subject matter learning. The integration of writing and discourse in writing to learn was the area we chose to explore together. Through our collaborative study and review of the research literature, we became convinced that it is very difficult for students in classrooms to develop knowledge that is well integrated with their personal beliefs and experiences, knowledge that is integrated conceptually within a disciplinary area, and knowledge that represents an integrated understanding of the relationship between content and process knowledge in the disciplines. The research literature enticed us to explore whether different kinds of classroom discourse and writing could support such difficult integrateed learning in science, in social studies, and in writing instruction. We took on what we considered to be a very challenging task--trying to help students develop well-integrated and genuine understandings within each of these three subject areas. We thought integration of certain kinds of writing and discourse could be helpful tools in accomplishing this goal.

We started this project with the intuitive feeling that there was something important missing from the typical theme-teaching approach to integration that is popular in many elementary school classrooms. We now believe we can identify important gaps in traditional theme-teaching approaches. Theme teaching often focuses, we now see, primarily on one aspect of knowledge and learning--the content, the topic--usually not even at the concept level. Although theme teaching focuses on content, that content is rarely focused on the big ideas or concepts that organize the disciplines. And many times the concepts selected are only marginally related to each other or are not very powerful concepts in terms of helping learners describe and explain their world. The selected concepts chosen may be too specific to be useful or may be too large and abstract to be useful. Concepts get chosen more for how well they fit with the theme rather than how important and useful the ideas are within the discipline, how powerful the ideas might be for students, how well they might connect with children's knowledge and experience, and whether they are ideas that can be represented in meaningful ways to children (appropriate pedagogy). Theme teaching also does not usually consider integration at the level of epistemologies (attitudes toward knowledge) and learning community pedagogy. It was this kind of integration that we believe enabled so many students to make such interesting connections across content areas even when the particular topics and concepts taught in science, social studies, and writing seemed so separate and distinct.

We have developed these insights through a research strategy that is new for us and that we have found to be particularly powerful. Acting as a group of collaborating teacher/researchers is an approach that has both the advantages of research done by outsiders and the advantages of insider research. As insiders in these classrooms, we draw from a much richer, more multifaceted understanding of the context, the learners, and the teachers. But we also serve as outsiders for each other. We have seen in this study how critical those outside lenses are. Working in isolation as teacher/researchers in our own classrooms, we would have been able to contribute significant insights to the education community, but our isolation would have blinded us to many critical integration issues. Just as students pointed out to us that their learning is enriched by interactions with peers bringing multiple perspectives, we have found the same to be true in our teacher/researcher collaboration. For the three of us writing this paper, the cross-disciplinary nature of our group removed blinders that never would have been removed if we had followed any one of several accepted research paradigms in science education. We would never have come across these cross-disciplinary connections if we had maintained our focus only on science and science learning. Our research and learning was enhanced by regular interactions with experts in other subject matter areas; like our students we are integrating ideas across subject areas in ways we find both personally meaningful and educationally important.

Our collaboration is also enhanced by the amount of time and effort we put into creating a genuine learning community for ourselves in which each of us felt safe to share our ideas and to publicly revise our thinking in the face of new evidence. We have now been meeting together weekly for almost three years, and we have spent significant time planning and teaching together at the elementary school and at the university. The level of collaboration has been intense and filled with the emotional ups and downs that go with the territory of creating and maintaining productive, cooperative relationships. This latest phase of our collaboration made visible to us the importance of looking to our students as research partners. Because the students got so involved in the research process and had so much to teach us, we are eager to push our teacher-researcher model even a bit further and explore in the future the possibilities of a teacher/researcher/learner model.

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Appendix

Timeline of Key Concepts Taught Concurrently in Science, Social Studies, and Writers' Workshop

Dates	Social Studies	Science	Writer's Workshop
September	**Historical Inquiry:** What is an historian? Where do they get their information? Primary/secondary sources artifacts oral history	**Nature of Science and Scientific Inquiry/ Adaptations:** ***Do you think there are more species of organisms in the desert or here in Michigan?*** scientist nature of scientists' work, scientific inquiry stereotypes evidence organism desert organisms structure function adaptation species diversity of desert adaptations water	**All About Me:** Overview of writing process (one complete cycle): leads word choice use of details focus revision publish
October	**Elliott History:** **Becoming an Historain** perspective research data collection strategies interviews collaboration in writing the history of Elliott primary and secondary sources		**Animalia:** Collaboration through cooperative groups; public sharing and revision of ideas; ownership, commitment, shared responsibility, learning is celebrated Use of quality literature as model Writing process

Oct 15		**Food for Plants:** ***How do plants get their food? (Why do they need water?)*** photosynthesis food energy light, sunlight water air seed embryo cotyledon changes in matter structures of plants functions of plant parts diversity of plants but universality of photosynthesis adaptations comparison of plants and animals evidence research scientific argument hypotheses models scientists as writers and talkers scientists in history experimentation	**Descriptive Writing:** Practicing the writer's craft - revision techniques to create better description through use of 5 senses, exaggeration Use of literature as models Use of evidence and developing shared expertise
November			**Establishing a Writer's Workshop:** Getting topic ideas, reponding to each other's writing, authors' day, visit from an author; focus on how to work together as a community of writers - use patterns established to support and develop capacity to help each other

December	**Social Issues and Social Conflicts: Throughout History** empathy discrimination prejudice rights duties justice equality racism sexism ageism ableism democracy exploitation social conflict		

January	**Colonization: Bringing the invisible to the foreground - Women, Africans, Native Americans, Hispanics** New England colonies Mid-Atlantic colonies Southern colonies primary/secondary sources perspective slavery, discrimination empathy racism equality social conflict prejudice exploitation sexism critical reading of textbook and other sources social conflicts persisting today	**Human Body Systems: Why do you need to eat and breathe? (What happens to the food you eat? to the air you breathe?)** evidence research scientific argument hypotheses changing knowledge models scientists as writers and talkers experimentation historical experiments systems- digestive, circulatory, respiratory interactions structures of human body systems functions of human body cells, organs, systems cells energy - food energy, light energy energy changes (food energy to usable energy) cell respiration - how each cell gets food and oxygen to release energy from food chemical change comparison of plants and animals (both do cell respiration, only plants do photosynthesis)	**Poetry in Writer's Workshop:** Learn about aspects of poetry that can be used in own writing: simile, personification, line breaks, color poems, poetic license Use writing process to create poetry or other forms of writing. Author's day and Literature share day as pattern to encourage collaboration and sharing

February			**Author's Design:** Understand aspects of author's design - author's purpose, topic knowledge, choice of form, audience Author's design as framework for deciding what to write and in what form Focus on inquiry, asking questions in addition to usual focus on collaboration, public sharing and revision of ideas through author's day and literature day.
March		**Use of animals in research:** ***Should we do the the "pig pluck" dissection recommended in the Michigan Model Health Curriculum?:*** use of animals in research dissection research experimentation animal rights? discrimination? alternatives to animal testing	**Transition to Next Unit:** Continue writer's workshop format and sharing of writing with emphasis on reflection and portfolio selection for middle school folder.

April	**Westward Expansion: Focus on the Trail of Tears** critical reading of text and other sources perspective oppression social conflicts Native Americans White settlers discrimination racism justice democracy invisible groups in history exploitation empathy prejudice land ownership Jacksonian democracy **Justice and Equality in Society Today:** Hussein and Iraqi War Gender Issues Today Political Campaigns and Women		**Author's Exploration:** Use of biographical material and book sets to explore: Where do authors get ideas? What do authors do to improve their writing? Explore forms of writing: fiction, biography, subject matter book sets Study author's biographies and book sets to get ideas for writing and to experiment with different forms Develop focus question for finding out more about fiction, biography, or subject matter sets Study own "All About Me" piece from viewpoint of memoir Collaborate with others to explore differnt book sets and develop focus question

April-May	**Civil War/ Civil Rights:** ***What social conflicts continued to fester after colonization which helped contribute to the outbreak of the Civil War and erupted once again in the Civil Rights Era?*** civil war civil rights duties democracy perspective discrimination slavery racism sexism social conflict prejudice justice equality primary/secondary sources critical reading of text and other sources	**History of Life on Earth/Geological Time:** ***What problems or difficulties would a scientist have learning about dinosaurs? How has scientific thinking about the history of life on earth changed?*** geologic, "deep" time scientific inquiry unanswered questions changing theories evidence geologic time periods relative times lived on earth by plants, dinosaurs, humans adaptations structure function organisms time line, models questions about life in the past paleontologist stereotypes	
June		**Sound:** One-week unit taught by prospective teacher as part of methods course requirement **Sex Education:** One-week unit What changes happen to your body as you grow from a girl to a woman? What things are you wondering about your body and its reproductive system?	