LITERACY, SCIENCE, AND SCIENCE EDUCATION

by

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ABSTRACT

In examining the connections between literacy, science and science education, I laid out a number of questions. For example, what sorts of literate tools might facilitate writing to learn, and do children who are just becoming literate use these tools? I then examined the writing of children in science class in an attempt to determine if their writing can indeed facilitate their learning. The results of this research could help teachers make decisions about the use of writing in the learning of science.

The kinds of literate tools I identified as being potentially helpful were transitionals – those words or grammatical devices which demonstrate how ideas are connected. Also, I suggested that data tables, sentences and paragraphs were also useful for students to learn. I found that grade 5/6 students used a wide range of literate tools, but that they were much more competent with those tools which were both oral and literate than those which could only be used for writing (punctuation, sentences, paragraphs, and data tables).

When I attempted to determine if the children used their writing to learn, I found very little evidence that this was certainly so. However, there was some evidence that paragraphs had the potential to create a "dialogue" between student writing and thinking, so the students could make more explicit connections between science ideas.

Lastly, I noticed certain gender difference in the classroom. Because of this, I contrasted the writing of the girls with the writing of the boys. I learned the girls were generally much more capable writers than the boys. More interesting, however, was that the girls generally attempted to explain their science concepts in different ways than did the boys. The girls were more likely to rely on their own reasoning, whereas the boys were more likely to persist in using culturally created science explanations. The research findings have important implications for analyzing students' learning and for finding ways to facilitate learning for both girls and boys.

DEDICATION

I owe thanks to a number of people for supporting me through the last four and a half years. First, my family. I would not have considered doing a PhD without their encouragement, and their confidence in me. They supported me emotionally, financially, and physically. Thank you to my daughters and to Joel for cooking, and for taking me hiking and for otherwise keeping me sane and healthy. Thank you to my parents for giving up their granddaughters for four and a half years, but for always being supportive of our endeavours. The most important thing I learned during my PhD is that the only thing that really matters in life is family and friends.

Which of course brings me to the second group of people who were so helpful. We moved to Burnaby with an intention not to make friends. We were rich in friendships already, and had a close family. But the people we already knew here and the people we met were wonderful, and we were glad we did not keep to our intention. Thank you to those of you who have become like family, those who have helped us to remain sane, even if you rarely volunteered to go hiking with us.

One group who invited us to go hiking (and camping) with them was the students I had the privilege of working with. They and their teacher gave far more to me than I did to them. Although the students seemed to think they were lucky to have someone come in to teach them science, and to go on field trips with them, they cannot imagine how much I enjoyed all this. They are a great group of students, and they had a very special teacher.

Lastly, I owe thanks to my committee for their support, their conversations on various topics, and their instructions on how to write. I learned more than is revealed in this dissertation from the dialogues we had regarding the ideas. What is here is an expression of the quality of those conversations.

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER 1

RELATIONSHIPS BETWEEN LITERACY AND SCIENCE

Introduction to the Dissertation

In 1963, Eric Havelock wrote Preface to Plato, in which he outlined his thesis that the Greek alphabet was a necessary precursor to the invention of science. In 1982, Walter Ong wrote Orality and Literacy: The Technologizing of the World, arguing that it was the invention of the printing press which made the ultimate difference in changing ways of thinking from oral to literate; like Havelock, he also argued that literate ways of thinking were necessary to the invention of science. Jack Goody, in 1977, wrote The Domestication of the Savage Mind, placing the thesis regarding writing as a precursor to science within a cultural context. He argued that literacy was not a precursor to science, but that the degree of logic, abstraction, and systematic skepticism in the science way of thinking were improved by literacy. All three men seemed to believe that literacy would have a positive effect on science: Havelock that science owed its existence to alphabetic literacy (which created a generally available literacy), Ong that science owed its existence to the printing press (which created a generally available literacy), and Goody that science was improved by literacy. Then, in the 1970's, the "writing to learn" movement began in schools. It seemed that many researchers believed that writing could be helpful for individuals to learn.

There are many parallels between the cultural arguments of Havelock, Goody and Ong, and the writing to learn movement. It was the parallels that first led me from Havelock's thesis to the writing to learn movement. However there are significant differences as well. The most significant difference is that the writing to learn movement examines the effects that writing has on an *individual's* learning, whereas Havelock's, Ong's and Goody's arguments examine the effects that the development of literacy would have on *cultures*.

A second difference is one that Scribner and Cole (1981) pointed out. They claimed that, even if literacy changed cultural ways of thinking, children of literate societies were unlikely to experience the same changes as they became literate. Rather:

> The development of writing systems and the production of particular kinds of text may, indeed, have laid the basis historically for the emergence of new modes of intellectual operation, but these over time, may have lost their connection with the written word. There is no necessary connection between the modality in which new operations came into being and the modality in which they are perpetuated and transmitted in later historical epochs. (p. 73)

Thus, they argued that literacy might have changed ways of thinking in a culture, but that these ways of thinking could well be learned by children without the children learning to write.

A third difference between the two arguments is that the cultural argument takes place within the context of science; the individual approach of writing to learn takes place in the context of school. Children acquiring knowledge in school, and scientists acquiring knowledge in their profession are two very different contexts for the use of literacy. This will be discussed more in Chapter 2, when I contrast the genre of science discourse with writing in schools.

Despite Scribner and Cole's discussion, the underlying premise for the writing to learn movement is that writing can have a profound effect on individuals' ways of organizing information, as if an individual will think differently because of writing. For example, C.B. Olson (1984) argued that clear writing represented clear thinking and that writing was a "tool for promoting cognitive growth" (p. 30). Applebee (1984) noted that "it is widely accepted that good writing and careful thinking go hand in hand" (p. 577). McGinley and Tierney (1989) wrote, "A principal tenet of recent theories in the area of writing is the belief that writing actually engenders understanding by virtue of the exploration and reexamination of ideas that it affords" (p. 234). And for science, Glynn and Muth (1994) wrote, "Writing can play a powerful role in the learning of science" (p. 1065).

It is understandable that some researchers would assume writing to be strongly connected to ways of thinking, when we examine the parallels between the cultural argument and the individual argument. In the cultural argument, writing is seen as a medium for justifying knowledge. In the individual argument, writing might be seen for its justificatory nature or for its generative power. Herrington (1985) noted that one group of researchers on writing to learn looked at writing from "the perspective of a school community" (p. 404). Members of this group expected students to be engaging in thinking, and usually expected students to explore ideas in learning logs or journals.

The other group of researchers considered school writing as "a way of learning the intellectual and, in some instances, the social conventions of particular disciplinary communities" (Herrington, 1985, p. 405). Much of the writing to learn in science has been conducted from this point of view (Herrington, 1985; Keys, 1994;

Fellows, 1994; Glynn & Muth, 1994). Among this group of researchers, writing is seen as a way to justify knowledge.

The main focus for writing to learn in science, then, is to detect inadequacies in arguments. For example, Goody (1987), writing from a cultural point of view, argued that sustained skepticism would be possible in literate cultures, but not in oral cultures. With literacy, we can share information across time, and so we learn that our ideas have changed. This should make us more critical of the knowledge we ourselves are constructing. Emig (1977) wrote from the individual point of view. Although she noted that writing seemed to draw from both hemispheres of the brain, and that the right hemisphere seemed to be the one in which knowledge was generated, she went on to illustrate the importance of writing for its justificatory power. She argued that individuals would be able to critique their own written products because they could see them. This was in opposition to speech, for which there is no visual product.

Another parallel is that Havelock (making the cultural argument) believed that only with the invention of literacy could cultures develop abstract thought. Following on this, Winchester in 1985 wrote that one of the three direct consequences of Western literacy is "Western science in its systematic theoretical [abstract] and experimental or observational form: the interrogation of Nature" (p. 34). Goody (1987), on the other hand, argued that abstract thought existed in all cultures, regardless of whether the culture was oral or literate. However, with writing, he believed that connections between ideas, the abstractions, would become more obvious to the writer. Emig, from the individual argument, also argued that connections would become more clear with writing. She drew on both Vygotsky and Bruner to justify that "[t]he medium of written verbal language requires the establishment of systematic connections and relationships" (p. 126).

It is perhaps an unfortunate consequence of parallels between the cultural argument and the individual argument that some basic research has not been done in the writing to learn movement. The assumption of writing to learn is that writing will help children to learn. But what exactly do we mean by learning, and what is learning in the particular context of science? Schumacher and Nash (1991) pointed out this problem with the writing to learn research. They noted that often the researchers identified learning as accumulation of information, rather than as re-organization of what students knew. Vygotsky (1934/1986) considered learning to be the appropriation of culturally constructed concepts. He believed children appropriated these concepts by making links between their everyday experiences and abstract scientific concepts. A second question to be asked is: does writing actually help students to learn science? And, if writing does help children to learn, are there particular kinds of writing which are more conducive to children learning science than other kinds of writing? Langer and Applebee (1987), in a large scale study, examined different kinds of writing, including analytical essays, and paraphrasing text, and recording text verbatim, in an attempt to determine what students learned Not unexpectedly, different kinds of writing seemed to induce different kinds of learning. A fourth question to ask is: as well as kinds of writing, are there particular literate tools (for example, sentences, paragraphs, conjunctions, data tables) which are conducive to learning science? Goody (1977) suggested that data tables would be useful tools for helping people to re-organize their information. In this dissertation, I pose some basic questions regarding writing to learn in science, exploring different kinds of writing to choose one which is most likely to facilitate the kind of learning that I would value in a science class - making connections between ideas and/or changing conceptions. I then ask what kinds of literate tools might demonstrate that children have learned. Then I examine the children's talk and writing to determine whether they demonstrate learning in one medium and not the other, or in both. And lastly, I attempt to determine if the children are indeed learning because of their writing.

Bereiter and Scardamalia (1987b) note that it is in grade 5 or 6 that most children first become literate. Also, both Piaget and Vygotsky believed that children became much more capable of abstract reasoning as adolescents, at about the age of 12. Children in grade 5/6 are usually 11 to 13 years old. It is in the context of a grade 5/6 class that I sought answers to the questions.

Focus of the Research

This dissertation will focus on three areas of questions, each of which is oriented towards answering whether writing can be a tool for children to learn science. First, I will examine the ways in which literacy might affect an individual's ability to learn science. I will logically examine various language and literate tools, and discuss how each might contribute to children's abilities to learn in science. Then I will determine to what extent different children display those tools. In a grade 5/6 classroom, I would expect considerable variation in ability.

Second, I will examine the children's writing to determine if the children are using their writing to learn. For this, I will define learning from two perspectives, individual constructivist and socio-cultural. The students will make two drafts of their written assignments, and I will compare the first drafts to the second drafts, looking for changes in what the students seemed to believe. At the same time, I will examine data of students' talk, to compare writing as a tool for learning science versus talking as a tool for learning science.

A third area for exploration came out of the analysis of the students' writing. I learned that there were two different groups of students, roughly divided along gender lines. Generally, the girls in the study seemed to be better writers than the boys. Consequently, as well as looking at whether these children used their writing to learn, I examined their writing to see what I could learn about the different sub-cultures in this classroom.

Area 1:

What literate tools might help individuals to learn science?

What literate tools do individual students in grade 5/6 have?

Area 2:

Is there any evidence that students use their literate tools to learn science?

Is there any evidence that students use their talk to learn science?

Area 3:

Do boys and girls adopt and adapt these literate tools in different ways?

Towards Answering the Questions: The Research

Choice of Methods

I was interested in examining writing and learning, both complex phenomena, in the context of a science classroom. I was not interested in the phenomena separated from their everyday events, but rather was interested in the relationships between the writing, the learning, and the culturally constructed science knowledge which the children attempted to appropriate.

There are a number of ways of categorizing research methods. If one were to consider whether the research results could lead to generalizations or not, then research methods could be divided into quantitative and qualitative methods. If one were to consider the aim of the research, whether it be prediction, understanding, emancipation, or deconstruction, then the quantitative / qualitative division would not be sufficient. Since most methodologists initially categorize research methods as quantitative or qualitative, this seems an appropriate place to begin.

Roberts (1982), pointed out some differences between the quantitative and qualitative methods. He noted that Pepper had outlined six world views: animism, mysticism, formism, mechanism, contextualism, and organicism. Roberts considered neither animism nor mysticism to be suitable for academic knowledge building, since neither relied on evidence as the means for justifying knowledge. Of the other four, he considered formism and mechanism to be the suited to quantitative research and contextualism and organicism to be suited to qualitative research.

Roberts (1982) claimed that qualitative research fit with contextualistic and organistic world hypotheses since contextualism was:

> A system of thought that focuses on the event in its context. We have no adequate knowledge of an event, according to this world hypothesis, until we know the context in which it occurs; it is not enough to know the form of the event, or even the mechanism that is, metaphysically speaking, responsible for it. In fact, both kinds of knowledge might be totally irrelevant. (p. 279)

This definition of contextualism would seem to lead me towards choosing qualitative methods.

Lather (1992) subdivided qualitative methods, noting "alternative practices of educational research go well beyond the mere use of qualitative methods. Their focus is the overriding importance of meaning making and context in human experiencing" (p. 91). Lather went on to outline, under the heading of qualitative research, three different possible contexts for human experiencing: understanding, emancipation, and deconstruction. My research was oriented towards understanding whether children make meaning of science concepts through their writing. If they do, then what kind of meanings do they make? Consequently, my research method belonged in the category of qualitative research focused on understanding. Within this category, Lather listed interpretative, naturalistic, constructivist, phenomenological, hermeneutic, symbolic interaction, microethnography.

The particular type of research method I used – discourse analysis – does not appear in Lather's list. Mills (1997) noted that "discourse" has divergent meanings, depending on who uses the term. For example, some use the term to refer to speech acts only, others use the term to refer to anyone who speaks at length on a topic, others use the term to mean any sustained communication, written or spoken, about a topic. Some refer to discourse as being only speech, and use the term "text" for written communication. But the term "text" might be used by others to refer to unsustained engagement on a topic, with discourse being sustained; others see the difference between text and discourse as that texts have surface similarities, whereas discourse has deeper coherencies. For the purposes of this research, I will use the term "discourse" to refer to the students' speech and writing on the topic of science.

Mills also pointed out that there are different theoretical constructs for examining discourse. Cultural theorists believe that discourse is "not a disembodied collection of statements, but groupings of utterances or sentences, statements which are enacted within a social context, which are determined by that social context and which contribute to the way that social context continues its existence" (p. 11). Another group, the mainstream linguistics group, holds a different theoretical construct. Discourse is "an extended piece of text, which has some form of internal organisation, coherence or cohesion" (p. 9). Mills added that mainstream linguists believe the particular community which produces the discourse affects the form of the discourse. For example, in advertising different discourse forms are used than in science. A third group is the social psychologists or critical linguists. This group will generally fuse the two above concerns. They will look for how it is that discourse communities use linguistic structures to acquire and maintain power.

For answering the questions in the first two areas, I drew on mainstream linguists, Brown and Yule (1983) in particular. When I moved on to the question in the third area, how different groups in the class made meaning, then I moved closer to critical linguists.

Brown and Yule (1983) discuss various ways of analyzing discourse. They noted that a person could spend a lot of time transcribing tapes to record intonation, could also count the numbers of all different parts of speech in written text, etc. However, they recommended uhat a researcher should limit the analyses to answering the questions posed. They called this a pragmatic approach to discourse analysis. I will describe more regarding the choices I made for pragmatic discourse analysis in the chapter where it is used.

Issues of Validity

Issues which arise for any research method, but seemed to come to the fore only with the advent of qualitative research, are to do with representation. Recent methodologists have pointed out that accurate representation is not only difficult (maybe impossible) but perhaps not even desirable (Clifford, 1988; Guba, 1990; Lincoln, 1990; Lather, 1991). The notion that an individual can represent what is happening is perhaps dangerous. We might be led to make generalizations on the basis of what we believe are objectively determined representations of the situation.

Another problem that arises, and should arise, is that every researcher will bring a unique perspective to the study. Other researchers will have different theoretical constructs and these different theoretical constructs will influence what is seen, what is reported and how what is seen and reported is interpreted. Thus, the researcher should make her own theoretical construct as clear as possible.

My theoretical construct is that individuals and cultures affect the ways in which technologies are adopted and adapted. Consequently, I believe that writing can affect the way in which a person thinks. However, this effect will vary depending on the individual's history and culture. I will not just examine those students who wrote well and learned science, but also those students who didn't seem to learn science.

These students will not be lumped together, but will be examined individually as I seek patterns. In this way, I hope to find how individuals adopt and adapt the technologies of writing and science.

A second theoretical construct which will affect this research is that I believe that there are particular linguistic structures used by the science community to ensure that the community acquires and maintains power. Many science teachers are unaware of how the linguistic structures reinforce notions of what knowledge is of most worth. Further, they might well have learned the linguistic structures implicitly, and be unaware that they are teaching them. The children I was working with were in grade 5/6, so were unlikely to have been taught these linguistic structures by their teachers.

Although Lather noted that the researcher should make her theoretical constructs clear, this is not enough. After all, the researcher must not select only those data which will support her theoretical construct. She must carefully consider the issues and the data, checking as many different interpretations as she can. Various research theorists have suggested strategies for enabling qualitative researchers to gain a broader perspective. One method that has been suggested is to describe all that is observed in the classroom. However, there are problems inherent in this suggestion. Within the best of my ability and within the bounds of clarity, I will describe the circumstances in the classroom and my thoughts on the question of whether children use their writing to learn. However, to write so completely that every detail is reported is not only impossible, but would sacrifice clarity. My focus was on writing to learn in science. Details from outside that focus are not included in this dissertation.

The data that I collect are inevitably biased. However, there are steps I can take to reduce the bias. For example, I immersed myself in the classroom. I spent four to five hours a week in the classroom, for one school year. Then I returned the next year with informal arrangements. I visited once to teach a mini-unit, I often dropped in, but more often, I accompanied the students on field trips when extra adults were required for supervision. Two years in a row, I was able to spend a long weekend camping with the class.

For my immersion to be helpful for others, I selected a focus and sought patterns relevant to that focus. Roberts (1982) suggested that only data supporting or refuting the noticed patterns should be reported. Edwards and Westgate (1987) noted the basis for selecting data (the researcher's theoretical constructs) must be made explicit. As well, they suggested the frequency of noticed patterns should be reported.

I will use a variety of data sources, as suggested by Carspecken (1996) and Lincoln and Guba (1985). Lincoln and Guba outlined a number of other measures for reducing bias: 1) credibility (to establish that other researchers, with similar theoretical constructs, might learn something similar in the same situation), 2) transferability (to help teachers decide whether the situation described applies or could apply in their classrooms), dependability (which I will not discuss since this construct is based on the view that researchers can represent what actually happens). As well as the first two, I will add from Lather (1986) 3) theoretical constructs, to make a total of three ways in which I attempted to ensure that the data were selected in as unbiased a manner as I could. Lastly, Edwards and Westgate (1987) suggested 4) including raw data.

Credibility

According to Lincoln and Guba (1985), 1) credibility would be established by being involved with the students on a regular basis over a long period of time (prolonged engagement), by collecting data from a variety of sources (triangulation), by checking interpretations of the data with others involved in the situation (peer debriefing), and by taking the analysis of the data back to the participants for confirmation (member checks).

Prolonged engagement: I was involved with the students for two years, observing and team-teaching science and social studies for the first four months; teaching and evaluating science, and going on field trips for the next six months. During the second year, I visited the classroom occasionally, taught some lessons, and went on many field trips.

Triangulation: I videotaped the students in small groups, took copies of all their written assignments, video-taped "thinking tests" with small groups, and interviewed selected students. Most of these data were collected in the last four months of the first year.

Peer debriefs: The classroom teacher and I watched the tapes together, to interpret what the students might have meant. In most cases, his interpretations of what happened enriched my understanding of the situation. After teaching the students nearly every day for two years, he knew the students very well.

Member checks: While reading the students' writing, I wrote questions in those places where I didn't understand what they meant. During the thinking tests, a similar situation took place - I was able to ask the students what they meant almost as soon as they said it.

Transferability

To establish transferability, Lincoln and Guba (1985) suggested "thick description." The researcher should describe rich details of the classroom to help readers place themselves in the context. Teachers then would be able to determine if the situation described fit their classrooms. This, however, is a complex issue. Having too much detail might make the situation seem more real, but might obscure the research focus. Roberts (1996) warned that "thick description" can be a collection of irrelevant details. "One's observations should have a theoretical thrust," he wrote (p. 244). In other words, description, rich or otherwise, should lead to analysis. Lather (1986) argued that collecting only data that had a theoretical thrust is likely to lead to confirmation of one's theory. She suggested being sensitive to other possible interpretations. Although Roberts and Lather might seem to be arguing on different sides, both were concerned the research being credible and transferable.

I have tried to take a middle line here. I have not included in this dissertation all that I was aware of in the classroom. Choices were based on how relevant I thought the details were to the study. When I was unsure if the details were relevant, I included them. But, as with any situation, I can only include those details which I noticed.

Theoretical Constructs

Lather (1986) claimed that our research questions appear through the lens of our theoretical constructs, as do our research methods. We must find a way to determine if our data are merely confirming our theoretical constructs. She suggested researchers must have a systematized reflexivity. To help develop this reflexivity, we should examine our data through different lenses. In 1991, Lather examined her data through the four lenses of realism, feminism, critical ethnography, and deconstructivism. She suggested that researchers keep a notebook of the changes they go through regarding their theoretical constructs.

Edwards and Westgate (1987) were not so rigorous in their description of the research process, but they were concerned that the data be as unbiased as possible. They suggested the researcher spend time observing the class to become familiar with that context (prolonged engagement), make field notes in a number of lessons (this was difficult for me since I was teaching, not just observing), make as many verbatim recordings as practicable (small groups, student writing, thinking tests), and listen carefully to the recordings to determine what patterns were there. They suggested that researchers go into the situation without pre-determined analytical methods. Once patterns were discerned, they suggested that further data be collected to confirm or revise the constructs. What I did was collect far more data than was practicable to analyze in detail. However, once I noticed some patterns appearing, I was able to focus on different aspects of the data and use different analytical techniques for different sets of data.

Inclusion of Raw Data

Edwards and Westgate suggested that some transcripts be included in the final presentation of the research so that readers could determine whether selected events were representative. In Appendix B, I have included examples of the first draft of six students' Alka Seltzer™ assignments. These samples were chosen to display a range of literate abilities for both boys and girls. Transcripts of two thinking tests are included in Appendix C.

As well, excerpts of transcripts and a number of samples of students' writing have been included in the text of the dissertation. Most samples given of students' writing are complete samples. The exceptions are when the piece was very long. In those cases, only excerpts were included.

Outline of the Research

Confidentiality

In this study, I told the students that I wanted them to remain anonymous. The students were very trusting and told me that I could use their real names; however, I felt more comfortable with them not being identified or identifiable. The children were young, in grades 5 and 6. As a simple example of my reasons for wanting the students to remain anonymous, some of them made pragmatic decisions about the amount of work they wanted to do. If, in the future, the employment market were to be tight, I would not want an employer to judge these students by their behaviour in elementary school.

To ensure the anonymity of the students, all student names are pseudonyms. Since there were twenty six students in the study, each student pseudonym begins with a different letter. This different letter assignation made transcribing videotapes easier. In transcriptions, I can use letters instead of full names.

The students were videotaped as opposed to merely audiotaped. This helped me understand what the students were doing as they talked. The tapes will be destroyed once the dissertation has been successfully defended. The only people who watched the tapes were the classroom teacher and I.

The students' writing was photocopied and the originals returned to the students. In students' writing, in places where students referred to their peers by name, the names were changed to the pseudonyms.

The School

The school was located within commuting distance of Simon Fraser University, in the city of Burnaby, British Columbia, Canada. The school served a mixed income section of Burnaby. There was low income housing very close to the school and, nearby, there was a very expensive neighbourhood. Students ranged from upper middle class, to children whose families were on social assistance.

The students in the class were a mixed group. As I watched one of the thinking-test[1] videotapes, I realized that only one child of the three had been born in Canada, and all three spoke a different language at home than at school. This led me to examine the ethnic origins of the other students in the class. Of the twenty-six students in the study, at least twelve had been born in a country other than Canada, or shortly after their family had arrived in Canada. In this group, eight different countries of origin were represented. Approximately half the students spoke another

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[1] Groups of three students were video-taped as they attempted to solve a chemistry question.

language as well as English. In total, there were six different languages students could speak. In Canada, the difficulty of identifying cultures as having generalizable qualities, and the inaccuracy of assigning cultural characteristics to individuals of particular ethnic origins, becomes very apparent.

At Christmas, one student moved away, and four students arrived. Three of the new arrivals came from Hong Kong and spoke very little English when they arrived. These were the only three children who, on the surface, seemed to have problems understanding spoken English.

The Teaching

I chose to teach a chemistry unit. I wanted a unit where the students would have opportunities to design experiments, and describe what had happened. In this unit, I could also challenge them to explain what they had observed.

The unit was experimentally based. Each week, the students were given a set of materials and a goal, but were not told how to achieve the goal. There were other activities, other than experiments. For example, there were role plays, a set of information to learn via a "jig saw" activity[2] and, importantly, writing about what they had done, observed, and thought. Each writing assignment was done as a first draft, which I read and asked questions about, and a second draft, which I also read and made comments on. The students were required to hand in both first and second drafts. On Friday afternoons, the teacher set aside time for students to finish homework. Any student who had his/her name on the board for homework not done had to finish and hand it in before leaving. Three students still managed to hand in

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[2] Each member of a group would read a different text, then "teach" it to his/her peers.

very little writing. One student, after several months, handed in his first written assignment to one of the student teachers. She, not realizing how difficult it had been to get him to hand in anything, gave him back his paper, telling him it was inadequate. It was some time before he handed in another assignment. Students were encouraged to write a third draft, but this was not required. None did.

As well as writing, the students were videotaped in their small groups. I set the camera on a different group each day. Unfortunately, the microphone, placed on the table with the students, picked up much background noise, as well as vibrations from the table. These tapes were very difficult to transcribe. The teacher and I watched these tapes to code different student behaviours, and transcribed sections which were relevant to the research.

A third source of data was the "thinking tests." After the students had completed the unit, I met with groups of three students for about twenty minutes. In each case, I posed a problem for the students, and they attempted to solve the problem in discussion with their peers. At times, when it seemed their discussion had reached a dead end, I attempted to refocus them in a direction which I hoped would be more helpful.

In June, I collected the fourth set of data: interviews of selected students. I chose students who represented different abilities in science, but only interviewed students who had done a fair amount of writing. I asked the students about their attitudes towards writing, towards science, and towards school. Only one of the students thought the summer holidays might be as much fun as school. Most of the students felt that school was more fun than being at home. This is a direct reflection on their regular classroom teacher. The next year, most of these students had the same teacher. I overheard one student say to a friend "All the kids in the school envy us because we have so much fun."

The Students' Writing

Teachers have often told me that students don't like writing, and one science teacher told me that was the aspect of science her students disliked most. Although some of the students in the study did not like writing, many did. When I left them with some homework over the Easter weekend, I apologized, telling them I didn't like to assign homework on long weekends. One of the students volunteered that this was fun homework. His attitude was not exceptional, nor was it unanimous.

In the students' writing, I tried to encourage them to use a style that I thought would be more conducive to learning. This kind of writing was expressive and exploratory, while still describing the science content they had been learning. This is similar to what Herrington (1985) suggested - that students need to explore and make connections, but they must also learn the writing style of science. In elementary school, learning the genre is not as important as it was in Herrington's study of college students. Nonetheless, the students should learn what it is that is valued in science. To justify the kinds of questions I asked the students in their writing, and to justify the kinds of writing I asked for, I drew on Britton (1970/1993) and Barnes (1976/1992).

Barnes (1976/1992) noted that students who were preparing to present to an audience unfamiliar with a topic prepared much more thoroughly than students who prepared for an already informed audience. I wanted my students to have the advantage of preparing for an audience unfamiliar with the topic. I wanted them to think that they were, in some way, teaching their audience about their results.

Consequently, I did two things. The students designed their own experiments. They conducted these experiments in small groups. Although I moved around the class to visit small groups, my visits were snapshots of what was happening. Then, instead of asking my students to anticipate the needs of an unknown audience, the students wrote for me. They had to anticipate my needs. Since they designed their own experiments, they were in a situation where they could sometimes use expressive language, but often had to be more explicit. But they were the judges. And when I asked them to explain in more detail, it was because I was indeed confused about what they had written.

Secondly, I told the students I did not know the answer to the questions they were wrestling with. I have some problems with a teaching style which leads students to "discover" their own answers, because of its manipulative nature. On the one hand, I give the students the impression they are discovering their world through their empirical explorations. However, I am, through questions and summaries, guiding them towards culturally constructed and accepted interpretations of the empirical experiences. Students do not "discover" these ideas. In defence of having students "discover" their own answers, if I told students the scientific conceptions, past experience has shown me that most of the students would begin to rely on me to tell them the required answers, rather than struggling with the issues themselves. And, if I just leave the students to struggle on their own, without giving them some guidance towards the culturally accepted construct, there is no reason to expect the students to come up with this culturally constructed concept. And, eventually, the students will be expected to know the cultural constructions. The tension between free exploration and manipulation towards students constructing the "right" answer is always a tension for teachers.

My compromise was to tell the students that scientists had theories to explain how the world works. Their theories are well-grounded in evidence, but new evidence could show them to be wrong. Consequently, the students should attempt to find answers for themselves. Student answers sometimes are the beginning of new theories. Another thing I did was, when presenting a particular cultural construction, such as Newton's laws of motion, I would tell the students that I did not understand the laws. In this way, the students worked either to help me understand, or helped me to refute Newton's ideas. (We have not yet managed to refute Newton's laws.) I provided a fair amount of guidance to the students in the questions I asked them, and when I conducted the debriefs after the experiments. If one student or group of students seemed to have developed a good understanding, I encouraged those students to explain their ideas to the others. Sometimes, I summarized what the class had learned.

Britton classified three types of language, depending on the goal of the communicator. What he named transactional language is oriented towards an *unknown* or *any* audience. This, of course, is an ideal. It would be, if not impossible, certainly very difficult to meet the needs of any audience. Even if we all shared a common language, genre would interfere. Some audiences require communication to be brief, whereas others want details. Some readers require narrative connections, whereas others require logical connections. Further, much as recording every detail of what we noticed in a research situation would render the research meaningless, attempting to be so explicit in our writing or speech so that the needs of everyone were met would render our communication meaningless. Transactional language is the style used by scientists in their publications.

Britton also described expressive language, which was more exploratory and more visceral. Students write expressively when they write for an audience familiar with the situation. Letters and conversations are examples of expressive writing. With expressive language, the communicator assumes the audience is familiar with the context. Consequently, the communicator does not need to be explicit in details which contribute to understanding. Poetic language was his third category. Although some of the students did write for purposes other than transactional, their use of poetic language is outside the focus of this research.

I wanted the students to be able to consider their audience's needs, but their audience was me, their teacher. I had been present for some of their experiments, so they could assume I knew a certain amount of context. Consequently, I expected the students to include characteristics of expressive writing in their writing.

Barnes (1976/1992) differentiated two kinds of speech: exploratory, and final draft. He associated exploratory speech with learning. Final draft speech was designed to give the impression that the speaker had the answers, that no more exploration was necessary. In my masters research (McVittie, 1994), I focused on whether students who used exploratory language were developing ideas, and if students who used final draft language had already formed ideas which were resistant to change. I found that this was indeed the case, that the two students who used final draft language were far less likely to change their ideas than those who used exploratory language. Consequently, in this research, I encouraged students to use exploratory language in their writing. Also, I used exploratory language while discussing the issues with the students.

Outline of the Dissertation

In Chapter 2, I will outline the research that has so far been done on writing to learn, then focus on the writing to learn in science research. This will be to attempt to discern what kind of writing is most likely to lead to children learning in science class. When children use writing in science class, should they be practicing the style of writing used by scientists, or should they be using a different kind of writing? The exploration in this chapter will be a preliminary for the study of children using writing in a science classroom. This literature search helped me to choose my research and teaching strategies.

In Chapter 3, I examine two current learning theories. One theory is currently influential in science education - individual or psychological constructivism. The other theory has become important in language studies and psychology of education. This is socio-cultural theory. Both these theories are types of constructivism in that both have the basic assumption that children construct their own knowledge. Psychological constructivism seems to suggest that children in similar situations will learn similar things. Socio-cultural learning theory emphasizes the role of the culture in mediating a child's learning. Both theories will be used to interpret the empirical data.

In Chapter 4, I will discuss what literate tools might help children to learn science. Then, I will examine the writing of children in a literate society, and look to see what literate tools they already have in grade 5/6, the age at which the majority of them are just becoming competent in writing. In Chapter 4, I will attempt to answer the questions in area 1: What literate tools might help individuals learn science? and, what literate tools do individual students in grade 5/6 have?

In Chapter 5, I will examine the students' writing, looking for evidence of learning, and discuss whether this is evidence that they use their writing to learn. In Chapter 5, I attempt to answer the question in area 2: Is there any evidence that children use their literate tools to learn science?

Lastly, in Chapter 6, I will examine the students' writing from a perspective that gender might make a difference. Since the research is qualitative, no generalizations can be made from the findings. Regardless, the findings might suggest that further studies are warranted, or might have implications for teaching. In Chapter 6, I attempt to answer the sixth and last question: Do boys and girls adopt and adapt these literate tools in different ways?

In Chapter 7, I will attempt to draw it all together, by describing my intellectual journey, and by highlighting some of the implications the results of this research might have for teaching.

Implications for Teaching

Currently, there is a movement called the Writing-to-Learn movement. This movement seemed to develop in the late 1970's, and gained momentum throughout the 1980's. Much of the research has focused on student writing in English and social studies courses (Holliday, Yore & Alvermann, 1994), although there has been some exploration of writing to learn in science. More research on writing to learn in the science classroom is called for.

The question of whether and if so, how, children use their writing to learn science has specific implications for teaching and learning. If students can use their writing to learn science, then teachers should be encouraged to integrate science and writing. If particular literate structures are more helpful for learning science than others, then teachers could focus on these structures in science classes, and on others in other classes.

A second implication of the research is the particular method for analyzing students' writing and talking which I had to develop to further my own understanding of what the children meant. This method could be useful for other researchers who examine writing to learn in the science classroom.

A third and very interesting implication of the research appears in Chapter 6, in which I examine two different ways in which children made sense of their science experiences and the cultural constructs. It seemed that different children made sense in completely different ways. Different teachers are likely to value one way of learning against another. Knowing that different groups of children learn science in different ways should alert teachers to value both ways of learning. This is especially important since the two groups seemed to divide somewhat according to gender.

CHAPTER 2

WRITING TO LEARN IN SCIENCE

Writing to Learn In Science

Herrington (1985) cautioned that there are two different ways of linking writing to learning in the writing to learn movement. She noted that one group of researchers looked at writing from "the perspective of a school community" (p. 404) and these scholars argued that writing should be "used as a medium for students to engage in the *process* of thinking" (p. 404). This group of scholars encouraged students to use exploratory writing, perhaps with pre-writing assignments, perhaps with learning logs, or journals. In this group, the teacher should not take the role of examiner, because students would be less likely to explore ideas if they were going to be graded on their "mistaken" notions as they worked towards greater understanding. The creation of a dialogue between teacher and learner was important. In their 1989 study, McGinley and Tierney claimed that students, in the act of reading and writing, create their own worlds. They thought that writing could help students develop new conceptions. McGinley and Tierney fit with this first group of scholars. This group seemed generally to consider writing to be a tool to generate knowledge.

The other group of researchers considered school writing as "a way of learning the intellectual and, in some instances, the social conventions of particular disciplinary communities" (Herrington, 1985, p. 405). She noted that these scholars believed that students would learn to use the "lines of reasoning of a disciplinary forum" (p. 405) by participating in that forum. For example, both Keys (1994) and

Fellows (1994) examined ways in which writing could help students develop conceptual understandings closer to those of scientists. They, and other scholars in this group, look at ways in which writing can be used to enculture students into a particular discipline. Keys (1994) wrote that "Experience in composing investigation reports should promote the construction of reasoning skills necessary for writing in the scientific report genre" (p. 1005). Keys wanted teachers to provide an environment which would support the development of reasoning skills. She hoped that students would work together in small groups to discuss and debate their views, before having to write them. In other words, she expected the students to use their talking to change their concepts, and to use their writing to acquire the genre and to change their concepts. This group of researchers seemed to consider writing more as a method of justification.

In this dissertation, I will be using the term "genre" to refer to the ways in which scientists write, as well as the ways in which their arguments are constructed. Thus, learning the genre, in this dissertation, means becoming familiar with science vocabulary and learning a particular outline for a science report; as well, it includes learning the relationship between evidence and theory. Consequently, if a teacher wanted a student to become encultured into science, s/he would want students to learn the genre of science discourse.

The Genre of Science Discourse

The genre of science writing has changed over the centuries. Sutton (1996) quoted a section of a paper written by Robert Boyle in the 1660's. Sutton pointed out that the voice was 1) personal, 2) used figurative analogy to facilitate understanding of the issue, and 3) was speculative and tentative. The metaphors and speculation in early papers were part of a persuasive technique. Sutton believed this was typical of new theories. But, according to Sutton, as researchers gain more confidence, their writing style changes. Sutton noted:

> Writing is especially important, and it is in the writing of successively "firmer" kinds of publication that we find and (sic) a gradual obscuring of the human agency, and a change from "persuading" to "informing". (p. 9)

He noted the published language of science, especially that of text books, conveys the impression that facts are out there to be discovered. The transition takes place as other scientists quote the original work, using less and less speculative language, and leaving out more and more contextual details, until the textbooks present the research as accepted facts. The explanation assumed for why these facts are not already known is that they were previously overlooked. Sutton's ideas parallel those of Latour and Woolgar (1979), who argued that a scientist's role seems to be to convert tentative hypotheses into established facts, or to deconstruct someone else's established facts to leave a hole to be filled by their own constructions. Latour (1987) noted the way in which an argument is made affects the interpretation we have of the "facts."

Sutton (1996) noted that the particular genre of science reports became formalized in the seventeenth century. The genre, he believed, was important for controlling controversy. Writers separated those points they were willing to debate from those they thought were undebatable:

> [T]he new natural philosophers grew in confidence at setting down 'matters of fact' which could be accepted either on the authority of witnesses or on the authority of a written account which allowed vicarious 'attendance' at the experimental event. (p. 12)

So science reports became separated into methods and results sections, which were carefully separated from discussion sections. The results were apparently indisputable. The equipment and the facts spoke in these sections. The discussion, the part in which theory was invoked to explain the supposedly objectively acquired results, involved the voice of the scientist. The discussion section was the part which was debatable. This is not to say that the methods and observations are in dispute. What is in dispute are the values and metaphors which lead scientists to pose the questions and see the parts of the world they do.

Lemke (1990, p. 21) summarized the modern grammatical preferences of the language of science to be: heavy use of passive voice; abstract nouns instead of verbs; abstract relation verbs instead of action verbs (e.g.: be, have, represent). The preferred figure of speech would be analogies, and the typical rhetorical pattern is thesis-evidence-conclusion. In other words, the intent (thesis) of the research is presented first; next how the research was conducted is presented. Third, the evidence is discussed in terms of the intent (thesis).

Gilbert and Mulkay (1984) analyzed introductions of science papers. They pointed out how the writing is constructed to give the impression that there are two current theories. One theory is presented as generally accepted, but based on flimsy evidence, while the authors' theory, a novel one, is substantiated by the indisputable empirical evidence we are about to read. Although Sutton (1996) claimed that theories still controversial were presented in more tentative language than accepted theories, this would not seem to be the case in the controversy Gilbert and Mulkay examined. At the same time as making the other view seem wrong, the authors put forth their interpretation in terms of "facts." Gilbert and Mulkay showed the published language of science as being very authoritative, as if to stop discussion before it could begin.

Sutton's point regarding the tentative nature of still controversial theories can be modified. Still controversial theories are not treated as black boxes (Latour, 1987). They are still explicitly discussed - although proponents of each theory present their own theory in authoritative terms. Latour and Woolgar (1979) noted that there are different types of facts. Those facts which are still controversial are explicitly contrasted to their opponent facts. Those facts which are accepted are often implicit within other facts. For example, when fossils were first discovered, scientists acknowledged different interpretations while arguing for their own interpretations. Currently, arguments about fossils are to do with what species they represent, exactly how many millions of years old they are, etc. We no longer discuss the possibility that winds might have whimsically sculpted the shape of animal bones, nor do we argue how much time might have been available for the fossils to form.

According to Ziman (1984) and Harding (1998), the metaphors scientists use to interpret their observations are derived from their culture and their experiences within that culture. Gilbert and Mulkay (1984), and Sutton (1996) noted the interpretation of empirical evidence is supposed to be the only debatable aspect of scientific publications. Excluded from formal discourse is what Gilbert and Mulkay term the contingent repertoire, with "[o]vert references to the actions, choices and judgments of their authors being kept to a minimum" (p. 42). As described in a preceding paragraph, the thesis-evidence-conclusion style of writing does not allow much room for including choices made in the course of the experiment. The impression is thus given that all decisions are made in advance, that the individual scientist's decisions are logical, not contingent. The peculiar style, lexicon, and grammar of science writing proclaim a strong, authoritative, objective image of science. This style of writing is inconsistent with the skepticism that I learned was supposed to be part of having an "open mind." As Gilbert and Mulkay noted, science writers are:

> peculiarly able to construct accounts in which they [science writers] appear to have privileged access to the realities of the natural world: indeed, no matter what the diversity of views, each scientist manages to convey the strong impression that his voice and that of the natural world are one and the same. (p. 89)

Gilbert and Mulkay also pointed out that the method sections of science papers are supposed to be written "assuming that a library is available, for a Martian to come and do your experiment" (p. 53). The scientists in Gilbert and Mulkay's study recognized that this was impossible. Bench work, they acknowledged, involved tacit knowledge and an intuitive feel. Yet my high school science teachers told me that I was to write the method so clearly that a "man" from Mars could repeat the experiment. I was supposed to anticipate the needs of an unknown and totally unknowing audience.

According to Britton (1970/1993), children, as they are learning to write, write expressively, as if in conversation with others. They write as if context were familiar to the reader; they include personal references and emotions. Teachers, according to Barnes (1976/1992), take on the role of acting as a stranger to the child while reading the child's writing, thus encouraging the child to include details of context which are necessary for understanding. However, if students are expected to anticipate the needs of their audience, and their audience is their teacher, then teachers should not be asking their students to include details of which the teacher is aware. If the teacher does ask students to include details of which s/he is aware, then students are not learning so much to anticipate the needs of their audience as to anticipate the vagaries of their teachers.

The style of writing is one thing. The other aspect of science genre is how knowledge is warranted. What counts as evidence in a science paper? An important aspect of science is that it is foundationalist. That is, in science, certain facts have greater value than other facts. The facts with greater value are those based on empirical observations. Other facts are logically or causally derived from these greater value facts. However, the logic must not be based on mystical nor animistic warrants[3]. Warrants for science knowledge are expected to come at least somewhat from empirical evidence. The questions posed are ones which scientists think can be answered by reference to empirical evidence.

A significant aspect of the use of literacy in science is that scientists write to convince others of their arguments. The context of use for literacy in science is different than the context of use in the science classroom.

Writing to Learn in Science Class

The context for using literacy in science class is the context of school. In school, children are often expected to appropriate cultural knowledge. Rarely are they expected to create original knowledge. When children write, they usually write

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[3] Roberts (1982) pointed out that of the six world views, neither mystical nor animistic world views were suited to the creation of academic knowledge because they did not rely on evidence. Yet there is

to convince their teachers, not of their arguments, but rather that they do know the material the teacher has presented to them. Children might be encouraged to construct their own interpretations of cultural knowledge, and to explore ideas. Or, teachers might expect that students become encultured into a particular discourse community.

Herrington, however, argued that both writing to learn by using an exploratory style in a relatively non-judgmental environment, and learning the genre, were important. She examined the writing of college science students. The study I carried out was in an elementary classroom, a very different context than college. College students usually have chosen a discipline in which they wish to spend some time. One of the aspects of studying that discipline is learning the writing style so they can read and write for their chosen community. Elementary school students should be learning how science arguments are constructed. However, elementary students have not yet chosen a discipline, and, besides, are still learning the basics of writing and grammar. Further, elementary students might be better served if they were to focus their learning on acquiring culturally created science concepts, and the methods for warranting knowledge, rather than learning the specific writing style. Also, the possibility exists that writing styles other than that of science might be more useful for learning these other aspects of the genre of science.

I agree with Herrington, that, ultimately, both learning patterns of argument and learning writing style are important. However, I believe that in elementary

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evidence for both mystical and animistic explanations. However, the connections between the evidence and explanations rely on non-empirical connections.

school, learning the style is less important than exploration of ideas. Consequently, I did not focus my teaching on science writing style.

There is a third group of scholars with a third conception of learning, a conception which Herrington did not comment on. Schumacher and Nash (1991) noticed that, in much of the research conducted on writing to learn, the final "measures of learning emphasize the amount of knowledge the individual has rather than whether the writer has come to a new understanding or conceptualization of the topic" (pp. 70-71). In other words, some seem to believe that writing is a way to increase the rote accumulation of facts.

In this dissertation, I will not be examining the effect of writing on retention of details. I am interested in the effect of writing on ways of thinking. I am interested in whether students use their writing in the ways that Goody (1977) suggested - whether they can use their writing to notice contradictions and to make links between ideas.

According to Goody, writing is a way in which a person can visualize his/her thoughts - put them on paper and move them around by physical means. According to Fondacaro and Higgins (1985), this should allow greater capacity for classification. Fondacaro and Higgins claimed three expected differences between speaking and writing. The first is that speaking should be faster because more muscle co-ordination is involved in writing. Second, writing should be easier to review and hence more concise. Third, the syntax of writing should be more accurate, deliberate and elaborate, because the audience is unknown and the context must be created on the page. Bazerman (1994), similar to Fondacaro and Higgins, described writing as difficult because of the great number of factors bearing on the writing task. He included in his analysis motives for writing, attitude towards the audience, and expertise with the resources, among others. All these factors would have a bearing on how willing individuals will be to focus on their writing - on whether they will attempt to use writing as a way of learning.

Kinds of Writing

Britton (1970/1993) differentiated three categories of communication according to the goal of the communicator, regardless of whether this communicator chose the oral or literate mode. The three categories were: transactional, poetic, and expressive. The goal of expressive communication is to establish interpersonal relationships. Expressive communication is personal, emotional, and evaluative. It is told as a running commentary, or as if the audience were there at the time. Expressive communication takes place among people who share or have shared an experience, so the context is not described in words. A letter responding to a friend's concerns, or conversation, are forms of expressive communication. When young children write a description of what they did in an experiment, knowing that the teacher knows what they did, the writing contains characteristics of expressive communication. The other two of Britton's categories, poetic and transactional, are attempts to communicate with any or an unknown audience. Poetic communication is the result of a communicator's goal to establish a feeling or mood. Once the work is finished, the work will be interpreted differently depending on the audience; however, it is unusual for a work to be retracted and reworked. In transactional communication, the communicator is considered to be saying what s/he means. What the person says can be challenged on the basis of truth or logic; however, individual readers should be getting much the same message from the text. The text may be corrected and re-expressed. This is the kind of writing found in science journals. (This is the kind of writing I am engaging in right now, trying to ensure that "any" audience will understand what I have written in much the way that I meant it.)

Barnes (1976/1992) cited research (p. 93) which showed that students were more likely to organize information if they were doing this for an uninformed audience than for an audience which "knew" the answer. When a teacher set him/herself up as an expert, the students tended to use what Barnes called "final draft" language. The final draft language was authoritative in tone, and the students who used this language did not explore ideas, but accepted trivial solutions. Solomon (1991) showed similar results with students who worked together on worksheets. "The list of questions encouraged those students who thought they had 'finished' to cut short the others' talk by going on to the next question" (p. 261).

In Gilbert and Mulkay's 1984 study, oral discourse seemed to show more of the uncertainty of science than published written language. Is oral discourse any better at demonstrating the uncertainty of facts? Solomon (1983) examined conversation among school children. She found that the need for consensus was strong. Children tended to accept contradictory conclusions and to hold these conclusions simultaneously, rather than to continue an argument. In my master's research (McVittie, 1994), I found that one student held two different conceptions of why the results of a chemical reaction occurred the way it did. She used whichever explanation was convenient for answering a particular question. Barnes (1976/1992) found that students were more likely to explore ideas when they had a clear understanding of the task, had sufficient background knowledge, and when the social relationships in the group were friendly. Although all these characteristics were present for the students I worked with for my master's research, one of the students described a complex well-synthesized version of equilibrium *and* believed her lab partner's simple version. She saw no conflict between the two explanations.

Writing in Schools

The research on writing to learn shows that children are not generally expected to engage in exploratory writing. Bereiter and Scardamalia (1987a) described two models for teaching literacy, one which focused on students telling knowledge (similar to Barnes' 1976/1992 final draft language), the other which focused on students transforming knowledge (similar to Barnes' exploratory language). Newell and Winograd (1989) complained that "writing is rarely used to help students explore and extend content-area information" (p. 213). Applebee (1984), referring to the National Study of Writing in the Secondary School, noted that, although 43 % of student time in school is spent writing, most of this writing is for mere recording of responses. Only 3 % of student time in class and for homework was spent on writing of paragraph length or longer. (In other words, most of student writing is at the level of word or sentence!) Nearly all the extended writing was oriented towards giving back information, not for exploring connections between ideas. All this research implies that children are not being taught, or even asked to use, their writing for making connections between ideas.

Since the National Study of Writing in the Secondary School was completed, there has been more research conducted on writing to learn. Although Rivard (1994) and Holliday, Yore et al. (1994) noted that most of the writing to learn research was conducted in experimental situations, in English courses, and with college students, some research has been conducted in elementary and secondary science classrooms. Holliday, Yore & Alverman (1994) noted: "Unfortunately, most writing to learn research has concentrated on communicating ideas rather than facilitating understanding" (p. 885). They noted that writing in science classrooms is usually limited to displaying knowledge for evaluation purposes, which limits students' ability to learn from their writing.

For Glynn and Muth (1994), meaningful learning involved students creating relationships between ideas. They noted that some of the conceptual relationships that students in science should learn are: "hierarchical, enumerative, exemplifying, sequential, comparative, contrasting, causal, temporal, additive, adversative, and problem solving" (p. 1060). They claimed good science writing should include all these kinds of relationships. They concluded that writing forced students to be more clear about what they had observed and done, helped them organize their ideas, and allowed them to see the holes in their knowledge.

Fellows (1994) noticed three patterns in the students' conceptual changes in science: accretion (additive accumulation of facts), conceptual schema became more organized, and schema became more like those accepted by scientists. Post-tests showed the concepts to have reverted to become less complex. Importantly, those aspects of the students' concepts which they retained were those focused on in earlier explanations and those "most salient" in their observations (p. 995). This would lead me to conclude that earlier explanations are more resistant to change, unless the students have direct empirical experiences to the contrary.

Learning Theories

By examining the writing-to-learn research, in both science classrooms and other classrooms, I noted that those studies which had an evident learning theory drew more on psychological constructivism theory than socio-culturalist theory. For example, the patterns of conceptual change which Fellows identified come from Posner, Strike, Hewson & Gertzog (1982) and have since been re-addressed in Schumacher and Nash (1991). Cobern (1993) provided a cautionary note about psychological constructivist conceptual change theory. He noted that explanations would be acceptable or not, depending on the assumptions and forms of argument inherent to a particular community. He pointed out that:

> conceptual change theory argues that students learn science when they see that the scientific explanation is superior to the untutored, common-sense beliefs they brought with them to the classroom. However, that only works when students share the plausibility structure of the science teacher and the science textbook. The documented difficulty in bringing about conceptual change plus the socio-cultural diversity of most classrooms is evidence that many students do not share this plausibility structure. (p. 58)

Thus, when we teach students how to write science (Herrington's second group of scholars, those who focus on the learning of a particular genre which includes a particular writing style), we do not teach them reasoning skills which would fit any discipline, any context. Rather, we attempt to enculture them into a particular community; we attempt to teach them to accept the same plausibility structures as the community.

Research on writing to learn should examine both what literate tools the students have, and whether they use them to demonstrate learning. Further, research on writing to learn should consider those students who do *not* seem to learn in science class. Can different groups be identified according to their literacy tools and do the literate tools tell us anything about how children learn in science? The class in which I conducted the research was too culturally diverse to determine if different cultures can be identified. However, there were enough boys and girls to look for differences in these sub-cultures.

Summary

The genre of science includes both the writing style and the way in which science arguments are constructed. Students, whether they are in elementary school or college, should be learning how science arguments are constructed. The writing style of science, with its authoritative voice, and condensation of complex ideas into simple terms might or might not be an effective way for elementary school students to learn how science arguments are constructed.

A survey of the writing to learn research has shown that writing is potentially a useful tool for examining our knowledge. Much of the research that has been done on writing to learn has been done in contrived situations, or in English or social studies classrooms (Holliday et al., 1994), or with college level students. Holliday et al. also pointed out that much of the writing expected of students has been transactional, rather than exploratory. Yet Barnes (1976/1992) argued that exploratory writing was more conducive to learning than final draft writing. His description of final draft writing seemed to match with Britton's (1970/1993) transactional writing. According to both Barnes and Britton, children are more likely to learn if they are encouraged to use exploratory writing in science.

Constructivism is a very common theory regarding children's learning in science. Constructivism is a term used in a variety of ways, and a variety of fields, including the epistemology of science (Phillips, 1995), research in the social sciences (Guba, 1990), and science education (Driver & Bell, 1986). In the next chapter, I examine two different versions of constructivism in science education, psychological (radical or individual) constructivism and socio-culturalism. The main difference between these two theories is the emphasis each places on language. Psychological constructivists suggest that the empirical world is most important for children's learning, and language plays a secondary role. Socio-culturalists argue the reverse. They postulate that language is a tool which mediates our understanding of the empirical world.

A consideration of the two learning theories is integral to this dissertation. In this dissertation, I am considering the possibility that a particular language medium, that of writing, might facilitate children's learning in science. Thus, the role that language plays in learning is an important consideration. Consequently, in Chapter 3, I will examine the two learning theories. I will attempt to use both in examining the classroom data in Chapters 4, 5, and 6.

CHAPTER 3

LANGUAGE AND LEARNING THEORIES

Introduction

Two learning theories have dominated the Western world for most of the twentieth century. They are constructivism (developing from Piaget's theories) and behaviorism (developing from Watson's theories). Constructivism has offered, and continues to offer, much towards understanding how children make sense of their worlds. The theory focuses on personal construction of knowledge. In other words, the learner is active in his/her own learning. Behaviorism, on the other hand, focused on stimulus-response as the way in which human children would learn. The problem with behaviorism is that learning of such things as language and science is probably much more complex than the conditioned response of, for example, salivating.

The end of the twentieth century has seen the introduction to the Western world of two more learning theories. One of these theories, socio-culturalism, came from the Soviet Union. Socio-culturalism developed at the same time as Piaget's theories; however the ideas were suppressed by Stalin in the Soviet Union. The other theory, situated learning (Lave & Wenger, 1991), developed in the late 1980's. Although Piaget's theories, socio-culturalism, and situated learning are very different theories, they could all be considered types of constructivism.

Constructivism has become prominent in science and math education in the 1990's (Matthews, 1997). But the noun "constructivism" cannot be used to label a coherent set of beliefs. Many educators and educational researchers claim to be constructivists, yet their teaching and research practices are disparate. Cobb (1994a) noted that "[a]s a theory, constructivism is often reduced to the mantra-like slogan that 'students construct their own knowledge'" (p. 4). Phillips (1995) argued that, in a loose sense, we might all be considered constructivists. He justified his point by claiming that "we" do not believe that children are born with knowledge or even schemata for fitting knowledge into. Nor do "we" believe that knowledge comes simply from direct perception. In this sense, "we" must believe that individuals are agents, actively involved in the construction of knowledge.

I am not sure if we are all constructivists, but even limiting the membership to those who accept Cobb's and Phillips' definitions, constructivists are diverse. Driver, Asoko, Leach, Mortimer and Scott (1994) categorized constructivists into three separate groups:

> One tradition focuses on personal construction of meanings and the many informal theories that individuals develop about natural phenomena ... as resulting from learners' personal interactions with physical events in their daily lives... A different tradition portrays the knowledge-construction process as coming about through learners being encultured into scientific discourses... Yet others see it as involving apprenticeship into scientific practices. (p. 5)

These three traditions have been named psychological constructivism (Cobb, 1994a), socio-culturalism (Cobb, 1994b), and situated learning (Lave & Wenger, 1991). Psychological constructivism views the individual as the site where knowledge is constructed. Socio-culturalism and situated cognition see the culture as the site where knowledge is constructed. Despite that socio-culturalists assume that knowledge is constructed in the culture, they often focus their research on individuals - examining how individuals acquire cultural knowledge. In this case, the social aspect of socio-culturalism comes from language. Language is a socially created product. Vygotsky (1934/1986) noted that children learn by acquiring words, and then gradually appropriating the meanings of the words.

Situated learning theorists focus on how learning takes place in apprenticeship situations. Their theories would lead to setting up school science laboratories to be as similar to actual science research situations as possible. If the students were to be working as scientists, they would be expected to write in the style expected of scientists. The context of use for literacy would be science. This theory did not suit the purposes of this study, where the context of use for literacy was the classroom. As well as the students learning some of what was valued in science, I wanted them to explore ideas with their writing. The exploration of ideas was more important to me than that students learn the genre of science. Consequently, I chose socio-culturalism over situated cognition. The two learning theories I will contrast are psychological constructivism and socio-culturalism.

Psychological Constructivism

Psychological constructivists draw from the work of Piaget, with many authors referring specifically to Piaget's theories (Bodner, 1986; Fosnot, 1989; Gunstone, 1988; Richardson, 1997; von Glasersfeld, 1989). According to Piaget, when children meet new situations, they must somehow fit the new experiences coherently with their current understandings of how the world works. Piaget named the need for coherency "equilibration." The new experiences might fit easily with what children expect. If so, the new information is assimilated. However, if the new information does not fit well with prior conceptions, the child experiences a lack of coherency. The child must somehow adjust his/her prior concepts to fit the new information. Having to adjust the prior concepts is called accommodation. For assimilation to occur, the students can adjust their perceptions of the external information. For accommodation to occur, the students must adjust their internally held concepts.

An important point about Piaget's theory is the assumption that development precedes learning. The child's brain must mature first before the child will be capable of a new stage of learning. According to Piaget, a child's thinking develops through definite stages, from concrete to formal operational. As each new stage is reached, the child becomes capable of a different kind of thinking. Formal operations is the ultimate stage of thinking, in which individuals become capable of abstract, logical, mathematical reasoning. Most children enter this stage about the age of adolescence, sometime between 10 and 15 years old. They become capable of this thinking because their minds develop, and no amount of teaching will accelerate the development. (Piaget, in his later work, acknowledged that children could enter the stage of formal operations earlier if they were exposed to a greater variety of experiences. However, children had to develop the ability for abstract, logical, mathematical thinking before they could learn at this level.)

Psychological constructivism draws on Piaget's learning theories, but adds tenets of its own. Much research has focused not on stages of learning, but on specific misconceptions that children have prior to teaching. Some psychological constructivists (Osborne & Freyberg, 1985) claim that children's misconceptions cannot be put into different stages, and are not age-related. According to Driver and

Bell (1986), the tenets of psychological constructivist learning are: 1) Students' prior learning affects what they will learn in class (affecting whether students will assimilate or accommodate new information). 2) Learning involves constructing meanings, not deriving knowledge directly from sensory experiences. 3) The construction of meaning is continuous. 4) After further consideration, students may reject their own new constructions. 5) Learners are ultimately responsible for the meanings they construct; in other words, learning is individual, and the teacher can only create opportunities for change to occur, but cannot change a child's beliefs. 6) Some meanings are shared across age groups and cultures.

To facilitate conceptual change in the classroom, much research has been done on students' prior conceptions. Gunstone (1988) pointed out that students' prior beliefs "are frequently at odds with the ideas of science and can be held to tenaciously by students" (p. 73). Interestingly, (concurring with Driver & Bell, 1986; Driver et al. 1994; Osborne & Freyberg, 1985, and von Glasersfeld, 1989) particular misconceptions can be common across age groups and nationalities.

A second important consideration for teachers is evidence that students can hold both the scientists' conceptions and their own conceptions at the same time, using the one called for in the particular situation. In other words, they can use the science community's conception on the exams, and continue to use their own conceptions in their everyday lives. This is contrary to Piaget's theory about the need for equilibrium. Children can apparently have two different explanations for the same phenomenon. In an examination of this problem, Posner et al. (1982) described a theory of conceptual change. They argued that for conceptual change to occur, students must first be dissatisfied with their prior concepts, and that the new concepts must be intelligible, plausible, and fruitful. If any of these conditions are not met, students will neither assimilate nor accommodate the new information. Rather, they will ignore the new, conflicting, information, not counting it as serious enough to warrant changing. However, if they have extrinsic reasons for acquiring the concepts, for example, marks on an exam, they can display the concept temporarily, as if they understand and accept it. As soon as the extrinsic reason is gone, the students will retain only their original conception.

Twice I have mentioned that children of different ages and different nationalities will often have the same prior conceptions. Psychological constructivist writers claimed this is because conceptions must be viable - they must work. As Bodner explained (1986, p. 875), "[c]onstruction is a process in which knowledge is both built and continually *tested.* Individuals are not free to construct any knowledge, their knowledge must be viable, it must 'work.'" Children learn by interactions with the world. According to psychological constructivists, they learn by trial and error (random trials) at first, then they begin hypothesis testing, in self-directed trials. When they reach the developmental stage of being able to reason abstractly, they can develop their conceptions to be much more like those of scientists. There is almost no discussion of the effect that other people might have on how children interact with the world.

A major difference between von Glasersfeld's version of psychological constructivism and socio-culturalists' is the role each group assigns to society (von Glasersfeld, 1993). For von Glasersfeld, society is not an ontological given, just as the "real" world is not a given. All a person has access to is his/her sensory experiences, whether these be experiences of the non-social or of the social world. Language, he claimed, is not taught, but is learned just as a child learns from the non-social world.

> You cannot teach language to a two year old or a three year old. You may occasionally be able to show them the use of a new word, but even this often does not work too well. Later, specific interaction can focus on specific linguistic difficulties. That is why teaching language at a later stage by correcting what children say is enormously important. (1993, p. 30).

According to von Glasersfeld, words are received as sounds which a student will then have to fit to a particular, already existing, concept. Children develop an understanding of sounds and their relationship to the world by having adults say, for example, the word "cup" while holding a cup. The child gradually learns to differentiate a cup from a glass and from the drink within it. In other words, we learn language by associating sounds with objects. If no concept exists for the word, the student will either ignore the verbal signal, fit the signal to a pre-existing concept (assimilation), or attempt to create a new concept (accommodation). Von Glasersfeld (1989) argued that "the basic elements out of which an individual's conceptual structures are composed and the relations by means of which they are held together cannot be transferred from one language user to another, let alone from a proficient speaker to an infant" (p. 132). Understanding only occurs if listeners have the same conceptual structures as speakers. Von Glasersfeld (1993) wrote that the point of talking or lecturing to students was to encourage them to recombine concepts, but that by talking he could not "give people any new concepts" (p. 32). For him, conceptual structures are built by association between sounds and objects or events.

Von Glasersfeld, after describing the "very simple inductive procedure" (1993, p. 31) by which children acquired language, proposed:

> You hang on to the schemes, the gambits, and the methods that have worked in the past. We all do this, not only in the area of language, but in all areas of learning. This principle has an important corollary that I have often mentioned: We have no reason whatsoever to change what we are doing so long as it produces the desired result. This assertion links with the notice of misconceptions in physics and in other teachings. If these conceptions have satisfied what the students demanded of them up to now, the students have no earthly reason to change. The love of truth will not make them change. You have to show them that their conceptions have limitations and that there are situations where those conceptions do not work. (p. 31)

Von Glasersfeld's individuals are isolated, separated from the external world which includes other individuals. Nonetheless, he argued that social interactions are important to what a child learns, postulating that social interactions were the main source of 'perturbations' for students, so dialogue with peers or with teachers was integral for developing concepts.

Psychological constructivism has been and continues to be a useful theory for learning. However, it leaves out an in depth examination of language and culture. It is as if, once children are exposed to tools appropriate for their development, they will adopt them and become different as a result. Fosnot used the word "discover" as if information were out there in the world, waiting to be found, as if everyone who stumbled over the information would give the same meaning to it. Further, an implicit assumption of many psychological constructivists seems to be that the empirical world constrains us enough that we will all eventually construct the same knowledge. Harding (1998) argued that the word "constructivism," while useful for showing that knowledge is created rather than discovered, is inappropriate because it does not show the effect that culture would have on the constructed knowledge. She suggested we use the term "co-constructed" instead, to show that knowledge is constructed by individuals *within a culture*.

I am not suggesting that the world does not constrain what we will learn from it. There are some things that we will all learn; otherwise, we will die. And there are some explanations that just do not fit with the world. But what and with what methods a society chooses to investigate are integral to the knowledge that will be co-constructed.

Bruner (1990) pointed to a problem with the psychological constructivists' notion of learning. Bruner noted that his theories from the early 1960's of how children learn were still good, still would work. However, significant numbers of students remained unaffected when these theories were implemented in classrooms. Bruner decided the reason was that children have very different out-of-school experiences. If all children were from the same culture, and if they were all affected in the same way by the culture, psychological constructivist learning theory would perhaps be the only theory needed. But children are not all from the same culture, and they are differentially affected by their cultures. We all make meanings in unique ways, and the most significant aspect of how we make meaning is our engagement with other people. And the most common way for engaging with other people is through language. Merely by using language, we are involved in the social construction of meaning. For example, someone might tell me a word. Then, on my own, I might find myself in situations where the meaning becomes more clear to me. Usually the meaning will only become more clear in a social situation. The situation might be social in the sense that someone else has set it up for me, or it might become more clear through dialogue - written or spoken - with another person.

Another criticism of psychological constructivism came from Vygotsky (1978, p. 19), and was directed at the behaviorists. Note how von Glasersfeld pointed to simple mechanisms for children's acquisition of language. Vygotsky, in his criticism of behaviourists, argued that reductionist means were not useful for studying complex, unique, human behaviour. Language is complex, and seems to be unique to humans. Von Glasersfeld (1993) argued that language was learned by association. Vygotsky argued that words were external representations of complex and internal meanings. The meanings were culturally created. The child, while trying out words in different contexts appropriated the cultural meaning of the word. Von Glasersfeld's description of learning language seems to apply only to concrete objects, not to the abstract meanings that Vygotsky called scientific concepts.

This brings me to a discussion of socio-culturalism.

Socio-Culturalism

Socio-culturalist research is varied. Wertsch et al. (1995) noted that the term "sociocultural" has been used by numerous authors from various disciplines. Those who use the term will often not cite one another. Some use the term, but don't cite Vygotsky. Still others cite Vygotsky, but use a term other than socio-cultural, perhaps socio-historical. I will be referring to those socio-culturalists who draw on Vygotsky.

Some of Vygotsky's beliefs about learning and development are in direct opposition to those of the psychological constructivists. Learning itself is different according to Vygotsky contrasted with Piaget. For Vygotsky, a child becomes more able to interpret the world when s/he has cultural tools available. Learning was the "appropriation" (the adoption and adaptation) of cultural tools. For Piaget, learning meant adjusting one's personal theories to fit with perceptual evidence. For Piaget, the child developed new ways of thinking, then became able to evaluate the evidence in new ways. Development preceded learning. For Vygotsky, learning preceded development. The child learned (appropriated) the tools, then became more able to look at the world in a new way. A child would develop abstract logical thought because of learning how to use cultural tools which would enable thinking in this way, not because s/he had reached that level of maturity.

Howe (1996) pointed out that this is a radical view of learning, that learning is not dependent on development (as Piaget claimed), nor that development and learning are interdependent. Rather, Vygotsky argued that development, within certain limitations, is dependent on learning. Learning preceded development. This is significant to the thesis that writing was necessary for the development of abstract thought. Vygotsky believed the psychological tool of language (and by extension, writing) was important to a child's way of thinking; however, he also believed the child needed to participate in a context where the child could appropriate the tool.

Despite that Wertsch (1978) believed that Vygotsky actually meant all kinds of communication systems when describing his learning theory, Vygotsky only examined language. For Vygotsky (1978, 1934/1986), the ability to use language as a psychological tool was what developed children's thinking. Children learned how to use language by interacting with others and because they wanted to understand what others meant. This is another major difference between socio-culturalists and psychological constructivists. For von Glasersfeld (1989), language was learned by association of sounds with empirical objects; social interactions were no more important than interactions with the non-social world. Vygotsky (1978) argued that words are necessary for helping children to focus on aspects of their worlds. Importantly, also, Vygotsky argued that language was sequential. Thus, as a child learned to speak, the child became capable of organizing his/her thoughts in sequence. Thoughts might be iconic and holistic. Words force one to create or discern sequences.

Vygotsky (1934/1986) postulated the existence of two kinds of concepts: "scientific" and "spontaneous." Vygotsky's description of scientific concepts is that they are abstractions which have been culturally and thoughtfully created. Thus, collectives rather than individuals create scientific concepts. Vygotsky's examples of scientific concepts are drawn from many different disciplines, including art, history and the social sciences. I think that a more appropriate term would be "scholarly concepts," rather than "scientific concepts," but since I am writing about science education, I will use the commonly accepted term. Spontaneous concepts are those concepts which arise from the lives of the children. They are implicit, and unexamined. Some socio-culturalist researchers prefer to call these concepts "everyday concepts" (Howe, 1996). The main difference between spontaneous and scientific concepts is that scientific concepts are explicit systematic abstractions from everyday occurrences; spontaneous concepts are not explicitly organized (Howe, 1996). Vygotsky considered spontaneous concepts to be largely experiential, whereas scientific concepts are culturally created abstractions.

To illustrate the two kinds of concepts, I will refer to an activity the students in the study carried out. During the chemistry unit, the students mixed six different chemicals with purple cabbage water. I asked the students to categorize the kinds of reactions that occurred. Perhaps because I knew the scientific concepts of acid and base and other, I expected the students to notice that there were three different kinds of reactions. However, the students saw five different kinds of reactions. One chemical turned the purple cabbage water aqua (or turquoise, or green-blue), and another turned it blue, (or blue-green or teal). One turned the purple cabbage water hot pink and one turned it light pink. Two other chemicals only slightly affected the purple cabbage water, seeming just to dilute the colour. The students' experiences were spontaneous concepts: the concepts involved sensory experiences (in this case, the chemicals and reactions had odours, colours, sounds), the concepts were specific, and ungeneralized. The scientific concepts of acids and bases and other did not occur to the students. In the activity, the students had two other reactions to do with their chemicals: to dip turmeric stained coffee filters in them, and to mix all possible pairs of the chemicals. Even with the bases changing the colour of the filter paper from yellow to brown, orange, or red, and the acids and others not affecting the yellow colour, the students did not generalize. It was only through me expressly requesting the students to make three categories that they even considered the possibility that they could generalize blue reactions together and pink reactions together, and then notice that those chemicals which turned the cabbage water bluish were the same that changed the colour of the turmeric.

Vygotsky (1934/1986, p. 162) argued that the manner of learning the two kinds of concepts will be different. Spontaneous concepts arise from the child's experiences. (Remember, however, that Vygotsky noted that children will focus on those aspects of their experiences that they have words for. The words come from people they associate with. Thus, even the spontaneous concepts will be affected by children's relationships with others.) Scientific concepts, on the other hand, are abstractions created by the culture, through discussion and generalization. Vygotsky wanted children to have opportunities to explore their spontaneous concepts. He felt the teacher should encourage children to make explicit their spontaneous concepts, to put words to them. As children put words to spontaneous concepts, they begin to increase understanding of their concepts and begin to organize them into systems. The teacher, at the same time, introduces children to particular scientific concepts. Children, in their struggles to make meaning, test the scientific concepts in their everyday lives, and gradually learn what the adults mean by the concept. Introducing a scientific concept to a child, no matter how well the teacher explains it, does not mean the child will know it. The introduction is only the beginning of a long, complex learning process. But the child is unlikely to abstract from spontaneous concepts *without being taught*. Teaching is done through signifying certain aspects of phenomena. The most common way to signify is through language. Thus, for Vygotsky, words are integral to learning.

Vygotsky noticed children developing towards scientific concepts by, at first, clustering together experiences which happened perhaps at the same time. They might then move on to clustering together those things which have one quality in common, and the cluster will gradually evolve. For example, the child might put a red triangle and a blue triangle together as being the same, putting a yellow square out of the group. Then the child might add a blue circle to the cluster, since it has the same colour as the last added triangle, and then perhaps a blue square. Vygotsky suggested that eventually, with the help of adults, the child will begin always to select the same abstract quality (shape or colour) for clustering. At this point, the child has developed a concept. When a child can cluster all squares together and call them squares, the child has the very early beginnings of a concept. But Vygotsky considered this stage to be a pseudo-concept. When the child knows that all squares have equal length sides and right angle corners, when the child knows the abstract reasons for classifying squares, then the child actually knows the scientific concept.

Vygotsky's ideas addressed learning, and his idea of what constituted learning was different than Piaget's. Piaget's learning theory has been called an epsitemology. But Vygotsky's theory does not constitute a formal epistemology *per se*. He did not discuss how it was that scientific concepts arose in the first place. Rather, he addressed how children learn those scientific concepts. I would like to take the liberty of suggesting how scientific concepts could develop within a culture, in an attempt to justify why culture and history would be so important to this theory. As an example, suppose that I have had an experience, a spontaneous concept, and describe this experience to a friend. She has had a very different experience, but she finds my story somehow reminds her of her story. As the two of us explore what is the same about the two situations, we abstract our particular qualities which neither of us would have focused on by ourselves. Perhaps I had been walking alone, heard footsteps behind me, and wanted to run away. Perhaps she had been watching a movie, and wanted to leave the cinema. We discuss the similarities, and come up with the concept of fear. We can now use the concept of fear to examine other spontaneous concepts, attempting to determine what is similar in each case when we want to escape a situation. We might find the sweaty armpits and jittery feeling occurs sometimes when we don't want to run, but want to know something. So we might develop another concept, separating anxiety from fear. The understanding of fear and anxiety would not likely develop unless two or more people explored the issue together. For me, the experience of walking in the dark and the experience of being at the cinema are contextually rich. There are too many data for me to be able to remove an abstract quality from either situation. The two of us together, as we attempt to understand one another, are able to remove ourselves just enough from our own situations to abstract qualities which are similar.

The situation in the creation of science knowledge might be similar. A person in England noted that larks fly high in the sky, then drop suddenly towards the ground. It might have been in conversation with other people that other important data about this situation were noticed. Many larks performed this trick, and the larks which did it were males. These males performed in the spring, in mating season. The term "larking" was invented, referring to daredevil stunts that male larks engage in to attract female larks. When I heard about this, I remembered seeing a red-tailed hawk on the Canadian prairies performing in similar fashion in mating season. I generalized in a way I could not have on my own. I assumed the particular red-tailed hawk was a male, and was performing a mating ritual. In formal science knowledge, one further step is expected. The person in England and I would have to publish our findings to submit them to the scrutiny of the science community.

Solomon (1992) categorized three different kinds of knowledge, two of which show similarities to Vygotsky's kinds of concepts. The first kind of knowledge Solomon described was general or common knowledge. She noted that general knowledge is not general (not accepted by all), but we assume it is. Assuming that it is commonly accepted means that we change our understanding of what we are discussing moment by moment as we attempt to establish rapport with our conversational partners. There is no internal logic for tying the different aspects of general knowledge together. Justification is made through a call to what many of us name common sense. People are unaware of their general knowledge until there is a need for it. To solve problems related to general knowledge, we must become conscious of it; we must make it explicit. The most common means of making knowledge explicit is through language. But the need for inter-personal rapport interferes with our ability to articulate our ideas. If a friend or conversational partner makes a statement about his/her general knowledge, we can modify what our knowledge was without even having been aware of what we were thinking. This might be a momentary change. Regardless, there seems to be no reason for logical consistency in our general knowledge.

Solomon named her second way of knowing personal knowing. In personal knowing, children have reasons for believing what they believe. They can articulate what they believe, and why they believe it. They might even go to the effort to verify their beliefs through further observations or through experiments. There is a logical basis to personal knowing. Children are willing to argue in support of their personal knowledge, and can be convinced that their personal knowledge is wrong, or become further convinced of its correctness. As with general knowledge, however, the need for consensus can interfere with full discussion of the issue. But, unlike general knowledge, agreement might only appear to have occurred; the child could well remain firm in his/her belief. Solomon (1992, p. 63) cautioned against believing agreement has taken place just because someone quit the argument.

General knowing could develop to become personal knowing. As general knowledge concepts become articulated in a social setting, individuals might not accept the statements and might push for further elaboration. One way in which teachers can push children to examine their general knowledge is to have them hypothesize what will happen in a particular event before the event occurs. The children are more likely to notice discrepancies when they have been forced to put words to their expectations.

Science knowing, Solomon's third category, is the kind of knowledge which is most logically justified. Science knowing is similar to personal knowing in that it has a logical basis, but is different from personal knowing in that it has been communally tested and constructed. Science facts and concepts become "scientific" by being accepted by the science community (Ziman, 1984). Thus, science knowledge is not personal. Science knowledge is always communally constructed, although the community is limited to the community of scientists.

Solomon's science knowledge is similar to Vygotsky's scientific concepts. A community has participated in developing knowledge which is systematically organized, and, as much as possible, internally consistent, and externally consistent with other scholarly knowledge. Solomon's personal knowing is similar to Vygotsky's spontaneous concepts, which develop as children struggle with their experiences of the world. Vygotsky did not describe anything similar to Solomon's general knowledge.

Spontaneous concepts are very different from the misconceptions which psychological constructivists worry about. Spontaneous concepts are experiential. There is no question of them being right or wrong. The problem with a person's spontaneous concept is that it is limited as an explanatory tool, or that it has been inappropriately generalized. Misconceptions arise when students have somehow (perhaps sometimes from hearing adults discuss issues involving general knowledge) got an idea that is very different from that of the science community. Often misconceptions are like spontaneous concepts - the students have had an experience which they remember, but their interpretation of the experience is limited as an explanatory tool. But sometimes, students have misperceived what happened. A person might have something happen in a particular way once, and infer that this will always happen. Despite evidence to the contrary, the person might well continue to believe the first experience is the only way that event could happen. A third sort of misconception might be the result of language. For example, children will often argue that humans are not animals. There are good reasons for them to believe this. Signs on the doors of malls indicate that animals are not allowed, yet people go in and out. Children learn the everyday sense of the word "animal," which creates problems for them in biology class. This kind of misconception comes directly from language.

Educators from both socio-culturalist and psychological constructivist camps assume that children want to understand their worlds. In attempts to explain how children learn, many researchers have discussed the trial and error approach, and the association of words with objects (von Glasersfeld being a good example of this extant belief). But this was not enough for Vygotsky. For Vygotsky (1934/1986, p. 99), words are integral to learning. Words are symbols of cultural meaning. The word, according to Wertsch et al. (1995) both helps us focus our attention on certain things and constrains us from noticing other things. Thus, the word is the mediator of learning.

Vygotsky (1934/1986) noted that before a child learns that words are symbols for cultural meaning, s/he might seem to understand a concept. Vygotsky pointed out that "words take over the function of concepts and may serve as means of communication long before they reach the level of concepts characteristic of fully developed thought" (p. 101). People are adept at using language to achieve what they need. Consequently, our students can show in many ways that they understand scientific concepts, but actually have what Vygotsky called pseudo-concepts. Consequently, teachers should probe to find out what students actually mean by particular words.

Pseudo-concepts might well be an essential stage for children to go through as they adopt scientific concepts, attempting to relate scientific concepts to their spontaneous concepts. The child learns the word, and tries it out in different situations. Through dialogue, the child's understanding of the concept changes to be more like that of science. (Pseudo-concepts might well be compared to drafts of papers - better to have a draft to work on than nothing at all. In the same way, pseudo-concepts give the learner a starting point for revision.) A number of socio-culturalist researchers claim the child learns in dialogue with teachers or more competent peers. This claim, to me, would seem to make the learning of word meanings similar to that described by von Glasersfeld. It is as if the child is gently and gradually being pushed towards the appropriate use of the word. Yet, I learn from my students, and they learn from less competent peers, because of the interaction among us all. It is not that I, the teacher, do not teach scientific concepts to my students. Rather it is that we are all always at some stage of pseudo-concept. We are always learning more, and the knowledge is being co-constructed, not just "discovered." When students ask me a question about the scientific concept I have just presented to them, I think about it, and often adjust my understanding of the concept. As I make more and more abstract connections between my ideas, my concept approaches what Vygotsky described as a scientific concept.

Socio-culturalists, as with psychological constructivists, argue that students should be learning in activities. Both groups believe that dialogue between teacher and student is important. However, the senses of activity and dialogue are different between the two kinds of constructivism. The role of dialogue for psychological constructivists is to attempt to determine what the child's misconceptions are, and to challenge them to re-organize their ideas. The role of dialogue for Vygotsky was to have the students make explicit their rationale for their pseudo-concepts. He believed that once students were aware of what they believed, they were more able to build on this, or to change this. Vygotsky wanted teachers also to introduce cultural constructions(to children in conversation with them, and these cultural constructions should help the children to understand their experiences. Thus, the kind of activities that socio-culturalists consider to be most beneficial are human interaction activities.

I doubt, however, if an interested viewer of a psychological constructivist and a socio-cultural classroom could tell which was which by the activities and dialogue taking place. I do not think the teaching practices are different enough.

For psychological constructivists, the activities are largely empirical, working with objects. For the socio-culturalists, such as Davydov (1995), Wertsch (1978), and Howe (1996), it is in activities that children learn cultural tools, language and otherwise. In science class, cultural tools include such mundane objects as graduated cylinders and chemicals, as well as ways of categorizing and observing. In a socio-cultural classroom, ways of thinking are tools and are integral parts of the activity. Cultural tools both constrain and focus the child's learning. Wertsch et al. (1995) believed that the Soviet interpretation of activity (from activity theory, an offshoot of Vygotsky's socio-cultural theory) implied that students would learn only one way to proceed. They expressed a broader view of activity, in which more than one way of proceeding could develop. Either way, Vygotsky (1934/1986) wanted these activities to be such that children could express and further develop their spontaneous concepts, as well as learning scientific concepts. Again, though, I doubt that an interested viewer could tell the difference between the two types of classrooms just by examining the kinds of activities that took place. One would have to interview the teacher about his/her rationale to be able to tell the difference.

Definition of Learning

The definition I will use of learning is based both on psychological constructivist and socio-cultural learning theory. Driver (1988), writing from the perspective of a psychological constructivist, noted that learning meant changing. By this, she meant that we change our perceptions and interpretations of events as we learn. In her article, she described a number of ways in which change could be prompted, and these ways involved making connections between empirical experiences and explanations. Vygotsky (1934/1986) believed that children had to learn to "grow" their spontaneous (everyday) concepts up to the culturally produced scientific concepts, and they had also to "grow" their scientific concepts down to their spontaneous concepts. His students were learning as they made connections between ideas. They should have made connections among spontaneous concepts as they learned to generalize as their culture did, and they should have made connections between scientific concepts and their own experiences.

Thus, what is common between these two theories is that students will make connections between their concepts. They will, in some cases, reject the generalizations they have made because they cannot connect two ideas. For example, students commonly connect the thickness of vegetable oil with the notion of density.

They have connected two ideas inappropriately. Until they make this connection explicit, it is very difficult for the teacher to have them focus on this issue. Once the students make the connection obvious, the teacher can then present other situations, such as that vegetable oil floats on water. Water is less thick and therefore seems less dense. In attempting to connect the three ideas: the observation of relative thickness of vegetable oil and water, the observation that oil floats on water, and the original belief that thickness was density, the students will (we hope) make new connections. Making connections between ideas is integral to the development of science concepts. The development of science concepts is learning in science.

Implications for Research

Vygotsky focused on individual children, how each child appropriated cultural tools. At the same time, he emphasized the importance of culture, particularly the role of language. For Vygotsky, language was the most important cultural tool, the tool which signified aspects of the child's experience, helped the child to focus on particular events, and constrained the child from noticing other events. Language also forced the child to sequentialize thoughts. In these senses, words mediated between the child's experiences and the meanings derived from them. Not all students will have the same cultural tools. Different children in the class will come from different cultures; even if all the children had been born in the same country, different children have variable access to these cultural tools. Consequently, in socio-cultural research, we should be looking for the presence of and the degree of expertise each child has in the use of cultural tools. The particular focus of this research, on writing and science education, meant that I would look for literate tools and children's learning of scientific concepts.

I needed to establish which literate tools would be most likely to enhance a child's ability to acquire concepts in science. Also, I needed to determine the tools different students had acquired, and the uses the children made of these tools. Further, I was hoping to be able to tell if students used literate tools to facilitate development of scientific ways of thinking. This last question is of most interest, but most difficult to ascertain. We cannot know what children really know, only what they make explicit. In this case, I was seeking what they made explicit through language.

To help me ascertain if children were appropriating scientific concepts, I used Vygotsky's taxonomy of concepts, looking for how students used their spontaneous concepts in their literacy and how they used them in their science. As the children struggled to "grow" their spontaneous concepts up to their scientific concepts, how did they do this? Vygotsky argued that children should have opportunities both to work from their spontaneous concepts to their scientific ones, and vice verse. Consequently, I also looked for how children displayed their understanding of scientific concepts.

Vygotsky argued that words are external representations of word meanings. Word meanings are abstractions. Children hear words, and then try out the words in different situations. The word begins as a pseudo-concept, used appropriately, but lacking the abstractions associated with the meaning. Children, of course, learn to use the words appropriately only through trying out the words in social situations.

However, merely by using the word, they are engaging with a socially constructed concept. The word meaning developed in social situations, whether the child was present at the time or not. By learning the meaning of the word, children "grow" scientific concepts down to their spontaneous concepts. Children also do the reverse. They attempt to describe their experiences, and as they do, they sequentialize and abstract. Hence, they "grow" their spontaneous concepts up to scientific concepts.

To facilitate my examination of the children's thinking, I encouraged children to make their reasoning explicit. Presumably, this helped the students to make associations between spontaneous concepts and scientific concepts, and showed the kinds of pseudo-concepts children were using. Further, it helped me to examine the process - how the children were learning. To have the children answer the questions as honestly as possible, I had to assume a very non-judgmental posture. I did not give greater rewards to children for using scientific concepts or to children who used spontaneous concepts. Instead, I asked students to make their reasoning clear, and to put words to why they reached the conclusions they did. I treated all concepts as pseudo-concepts, including my own.

The implications for teaching were that I had to engage in dialogue with my students. The teacher is important in the socio-cultural classroom. The teacher's concepts are pseudo-concepts; regardless, the teacher should be able to challenge the students. The teacher's pseudo-concepts are more abstract and more generalizable than most of the students' pseudo-concepts. Since dialogue was important, the empirical activities were not considered enough for student learning. After each activity, we discussed what each different group had learned. Then, when individual students wrote what they had done and learned, I responded to them with questions and corrections. The students were expected to reply to my comments.

Student - teacher dialogue was important in the "thinking tests." In the thinking tests, I met with a group of three students, demonstrated a particular phenomenon that was related to the unit of work we had done, and asked the students to attempt to explain what had happened. As the students made suggestions, I asked them to make their reasoning clear, both so the other students in the group would be able to understand their suggestions, and so that I could better tell what exactly the student's pseudo-concept was.

Thus, it was from socio-cultural learning theory that the dialogic nature of the writing and thinking tests was derived. In dialogue, I would more easily discern what the children were thinking, how they were relating different concepts, and how their pseudo-concepts were developing.

However, I also addressed the research questions through a psychological constructivist view of learning. Socio-culturalists seem to consider learning to be the appropriation of cultural tools. Psychological constructivists consider learning to be a change from a mis- or pre-conception to the scientific conception. The ideas of Schumacher and Nash (1991) seem to fit with a psychological constructivist view of learning. Schumacher and Nash classified three kinds of learning: one is that learners add new material to what they already know (accretion); another is that they adjust their concepts to fit into new situations(tuning); and third, they might reject old concepts and replace them with different concepts (shifting).

In the next three chapters, I will address the issues of individual students' writing and learning in a grade 5/6 science classroom.

CHAPTER 4

CHILDREN'S LITERATE TOOLS APPLIED TO SCIENCE

Introduction

Literacy is a technology composed of smaller tools. To describe literate tools in socio-cultural terms, they are scientific concepts (culturally created concepts) which children might acquire through interactions with their culture. Examples of literate tools are paragraphs, headings, data tables. Paragraphs serve to organize information so that more related bits will be found together. When a person is asked to write in paragraphs, presumably that person will have to organize his/her ideas into more closely related details. Headings are ways of indicating that one part of a written product is all about the particular topic. With headings, the author perhaps can pay closer attention to what ideas relate to one another, and also to having balance in the overall product. Data tables are tools for organizing and visualizing information. With data tables, students could perhaps re-organize the information so that patterns become more apparent.

The reason for examining particular literate tools is that these tools might facilitate children making connections between ideas. Sometimes, the student will have to reject previous connections to be able to make new connections. This making connections would be considered learning. In this chapter, I examine what literate tools might be useful for students learning in science, and I examine what literate tools these particular grade 5/6 students had.

Cautionary Notes

In Chapter 2, I briefly summarized some of the research from the writing-to-learn movement, attempting to focus on the research from science education. Some researchers in the writing to learn movement seem to believe that writing and thinking are so closely related that one can be counted the same as the other (C.B. Olson, 1984). A more common belief is that writing allows re-organization of thoughts. Not all the writing to learn researchers make both these assumptions, and some make neither. Regardless, there is a need to examine these assumptions.

First, it is important to note that students might think far more clearly than they express. We access their thinking through their language. A metaphor used by Fellows (1994) was that writing can be a window to students' thinking. We must keep in mind that windows only show part of what is inside, and often those windows are muddy and take the internal world out of focus. What I examine in the next three chapters are those ideas that students explicitly made accessible to their peers and me through their talking and writing. Perhaps, but not certainly, as they expressed their thoughts, they made these ideas accessible to themselves as well.

Second, there are complications which interfere with our ability to discern if students can use their writing to re-organize (learn) science concepts. One complication is that we can never be sure of what exactly a person is thinking, even if that person is really trying to demonstrate what s/he is thinking. Indeed, I am often unsure of what I am thinking myself, since my thinking seems to take place at many levels, and only that which is put into words is easily accessible. If I am unsure of what I know, that ignorance can only be greater when I attempt to determine what a child knows. When a child has trouble expressing a scientific idea, I do not know if that child lacks the ability to communicate, or if s/he does not understand the science. Thus one problem is that a student might learn how to state his/her ideas more clearly, but not have changed those ideas. Another problem is that, even at those times when a student writes an entirely different statement, was it the writing which brought about the change? It could be the student learned by discussing the ideas with someone else.

To detect if a change did take place, all writing was necessarily done as first draft and second draft. Between the two drafts, I wrote comments about the students' ideas. In this way, I could at least detect if the student changed his/her articulation of the conception between first and second draft. If the student completely changed his/her explanation between drafts, I considered this to be actual learning in science, rather than just an improved ability to articulate. However, I could not be sure if it were writing that brought about the change. The changes that took place might be only spuriously connected to the students' writing. I might have been more effective by conversing with the students.

Outline of the Chapter

Regardless of these complications, I will attempt to answer the question of the connection between writing and learning in the science classroom. In this chapter, I will address: What literate tools might help individuals to learn science? and, what literate tools do individual grade 5/6 students have? To answer the second question, I examine how some of the students used literate tools in their writing, and whether they used these tools to connect ideas. Then, I look at the writing of all the students to determine how many of the students used which literate tools. In Chapter 5, I go on to address specifically the question of whether students used their writing to learn science concepts.

The reason for working with grade 5/6 students is that this group of students is just becoming capable of expressing themselves in writing. Wells (1986) pointed out that children acquire their spoken languages through informal interactions with others. By the time children start school, they are orally proficient in their first language. At school, they acquire literate technologies, but the acquisition process is much more formal than the acquisition of oral language. One of the first problems children face with writing is mastering the mechanics. Bereiter and Scardamalia (1987b) noted that the majority of children in the class would not be proficient writers until grade 5 or 6. We know, though, that children's literary proficiency varies considerably, with some children becoming very capable readers and writers, and others having great difficulty.

Some of the writing to learn research has focused on science. Several of these researchers argued that writing in science style might facilitate the development of scientific reasoning skills (Herrington, 1985; Glynn & Muth, 1994; Keys, 1994). Consequently, an issue I will be sensitive to in this analysis of the data is: does writing in the style of science help students make connections between science ideas?

Initially, in this chapter, I outline the particular kind of discourse analysis methods I used. I draw on Brown and Yule (1983) who described pragmatic discourse analysis. Next, I note what literate tools I believe would be helpful for students making and demonstrating connections between ideas. Next, I examine samples of writing of a selected group of students. These students were selected because they represented extreme ends of the different dimensions I wished to examine. Ruth was one of the most competent writers in the class, and seemed to understand science. Viola, despite her grammatical difficulties, enjoyed writing, but did not attempt to explain the science phenomena we were studying. Thomas wrote competently but didn't like to write; however, in his talk, he demonstrated considerable science interest and understanding. I examined the competency each of these three students displayed in each of the literate tools I identified at the beginning of the chapter.

After analyzing Ruth's, Viola's, and Thomas' writing in depth, I peruse samples of writing from the other twenty-three students in the study to determine if the tools the three used were common to the rest of the class.

Analysis of Language

Transitionals: Oral and/or Literate, Types, Roles

In this section, I use the term "transitionals" as an all-encompassing term to refer to those parts of language with which we demonstrate relationships between ideas. Glynn and Muth (1994) argued that learning involved the creation of relationships between ideas, including: "hierarchical, enumerative, exemplifying, sequential, comparative, contrasting, causal, temporal, additive, adversative, and problem solving" (p. 1060). Thus, transitionals - those grammatical and lexical devices which demonstrate relationships between ideas - would be important indicators of learning.

The best way to notice if a transitional exists is as a member of the audience. Was I, as a reader, able to understand connections between idea units? In attempting to answer this question I chose punctuation, headings, paragraphs, implicit rules, and announcements as transitionals. Conjunctions are named markers by Halliday (Brown & Yule, 1983), and are considered ways to relate ideas chronologically and logically by Hildyard and Hidi (1985) and Chafe (1985). Headings were pointed out by Goody (1977) as a way of lumping similar ideas together. Implicit rules were pointed out by Brown and Yule (1983) as a way in which writers indicate how ideas sequence. An example of an implicit rule is that, in a narrative, earlier events are described earlier in the story than later events.

I use Halliday's definition for markers as the definition for transitionals: transitionals show relationships between ideas. Transitionals can show how one idea follows from the previous. This is similar to Halliday's term "markers" (Brown & Yule, 1983). My term "transitionals" also encompasses those parts of speech which alert our audience to what is about to come. Consequently, I use the term "transitional" to refer to any word, phrase, punctuation form, etc. which alerts audiences to relationships among ideas.

I classify transitionals in three different ways. First to be discussed is that some transitionals (punctuation, headings) are only available in literate form, whereas others are both literate and oral (conjunctions). Since transitionals which are only oral (intonation, etc.) are not the focus of this dissertation, I have not included intonation in transcriptions of tapes.

Second is that transitionals can be different parts of speech. For example, transitionals can be conjunctions, punctuation, headings, etc. Some of these, such as conjunctions, connect two ideas, and the particular conjunction shows the type of connection. Others, such as headings, can be thought of as meta-transitionals, preparing the audience for a set of idea units on the same topic, but the topic is different than the topic prior to the heading. For example, the heading "Observations" prepares the audience to read a set of descriptions related to the event under study.

Third, transitionals play different roles, or, in other words, indicate different sorts of relationships between idea units. For example, the conjunction "therefore" indicates to the audience that the next idea is logically linked to the previous ideas. The heading "Observations" indicates to the audience that a whole set of empirical data is about to follow.

Transitionals: Literate and/or Oral

As mentioned previously, some transitionals are only available in writing. These would include punctuation, headings, and paragraphs. Other transitionals are available both in speech and writing, such as conjunctions, adverb phrases, etc. Other transitionals, such as intonation, pauses, and physical context, are only available in speech. But, in this dissertation, I am more interested in the students' writing than their speech. I will be using their speech only as a comparison to their writing. Consequently, I will examine literate transitionals, and only those oral transitionals which are also literate transitionals.

Transitionals: Forms

Conjunctions.

The way in which students link ideas together is important for examining what students are thinking. According to Chafe (1985), subordinate conjunctions are much more commonly used in writing than in speaking. Hildyard and Hidi (1985) noted that children in grade 6 did not use as many conjunctions in written work as in speech. They concluded that children of this age were not yet taking advantage of writing - they were still learning how they could relate ideas differently in writing than in speech. Note that both subordinate and co-ordinate conjunctions are important for demonstrating how ideas link together. But writers, according to Chafe, are able to link ideas more densely without adding too many more words. They do this by subordinating some ideas to others.

I might use the conjunction "therefore" to show that the clauses before lead logically to the clause I am about to state. Thus, the conjunction "therefore" is not just linking the clauses together. It is also preparing my audience for what I am about to say.

Punctuation.

One way in which writers can alert their audiences is with punctuation. Writers can use periods to indicate that one idea unit (see discussion in the next section) has ended and another is about to begin. They use commas to show more idea units are about to be added. They use parentheses to show that one idea unit is subsidiary to the main one. Punctuation is unavailable to speakers, although some speakers are very adept, and almost seem to speak in paragraphs. These kinds of speakers are rare, and none of the grade 5/6 students I worked with "spoke in paragraphs."

Implicit rules.

An important indicator to audiences of how ideas relate to one another is the order of the ideas. One "rule" of discourse is that, in narrative, unless stated otherwise, earlier described events are considered to have taken place earlier in time (Brown & Yule, 1983, p. 125). Audiences do not need "and then's" to explain sequencing. In logic, two ideas which are more closely placed together should be more closely linked than two ideas which are farther apart. Order and proximity are implicit ways in which relationships between ideas are displayed.

Another implicit transitional is a style disjunct which prepares the audience for something different (p. 98). If a communicator has been using one type of transitional or has consistently used transitionals, and suddenly uses a different type of transitional or leaves a transitional out, the audience should suspect something different is about to happen.

Headings, paragraphs, announcements.

Headings, paragraphs, and announcements are all meta-transitionals, indicating a series of idea units are all related to one another and distinct from the previous idea units. Goody (1977) noted that headings are a useful development in writing for organizing ideas. Headings can be used to help the audience anticipate the change which is about to take place. Sutton (1996) argued that the particular genre of science writing developed so scientists could separate those areas which they did not consider available for discussion (methods and observations) from those which they considered human interpretations (discussion of the results in light of theory). In other words, the thesis, evidence, and conclusion sections[4] of a science paper would be separated under different headings[5]. Since headings let the audience know what will be discussed in the next set of ideas, headings are meta-transitionals.

Another type of meta-transitional is a paragraph change. When a writer makes a new paragraph, s/he indicates that a new topic is about to be addressed. Subsequent ideas in the same paragraph illustrate the main idea.

Something I noticed that students did to indicate a change in what they were writing about was the announcement. Students often started sentences with announcements such as "What I observed was," then followed with a series of idea units, all of which were observations.

Transitionals: Roles

Halliday invented the term "marker" to be a word which demonstrated the relationship between two ideas (Brown & Yule, 1983, p. 191). He classified four kinds of markers depending on the roles they played - the type of relationship they demonstrated: additive (such as "and," "or," etc.); adversative (such as "but," "however," etc.); causal (such as "so," "therefore," etc.); and temporal (such as "then," "after that," etc.) All these examples are conjunctions. Brown and Yule caution that not all communicators use markers to link ideas. Further, Brown and Yule cautioned that, when analyzing discourse, one must look for the role each marker plays rather than assuming the form of the marker matches the function. For example, in the

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[4] Lemke (1990) pointed out the typical writing style of a science paper is thesis, evidence, conclusion.

above classification, "and" is considered an additive marker; sometimes, however, it is temporal.

I have used the four roles that Halliday defined for markers, and examined transitionals to determine if they play the same roles. The heading "Observations" can be considered an additive transitional, since it prepares the audience for a list of empirical data. The heading "Procedure" can be considered a temporal transitional, because it prepares the audience for a time sequenced list of actions. Punctuation lets the audience know whether one idea is less important than another. For example, a comma setting off an adjective clause lets the audience know that the idea unit inside the comma is not integral to the flow of the sentence. It might show a subsidiary relationship between the main idea in the sentence and the idea in the clause. Thus, I have added "subsidiary" to Halliday's list of roles.

In science writing, we should expect to see all the roles for transitionals which Halliday defined for markers: additive when details are cumulative, adversative (which can also be for comparing ideas, so I will call them "comparative") when two phenomena or ideas are compared or contrasted, causal when logical connections are being made (but since not all logical connections are causal, I will call this kind of marker "logical"), and temporal when a sequence of events is being described. I added one further role - that of "subsidiary" when one phenomenon or idea unit is displayed as being less important than another.

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[5] One would expect the language style used in the different sections of a paper to be different. Although a different style of language, from reporting to speculating, is not here considered a transitional, it will be interesting to note whether students do use different styles of language.

Transitionals: Summary

I defined transitionals to be those parts of speech which indicate relationships between ideas. Transitionals might indicate a logical relationship between ideas, or might be a literate signal of what is about to come. To determine if a transitional was being used, I asked myself if the particular part of speech was demonstrating a connection between idea units. If it was, then I had to consider it as a potential transitional.

I classified transitionals in three different ways: by whether they are oral and/or literate, by their types and by the roles they play. First, some transitionals (conjunctions, phrases, chronological order, style disjuncts) can be used in both oral and written communication. Some (punctuation and headings) are only used in written communication. I would expect students to be more capable with the former, those which they would use or hear in speech, than with the latter. For those students whose writing I examine most closely in this chapter, I will also examine their speaking, to determine if they use the oral-literate transitionals in their speech as well as they do in their writing.

Second, I examined the different forms of transitionals. I identified conjunctions, punctuation, implicit rules, headings, paragraphs and punctuation as different forms of transitionals.

I found that a weakness in looking just for one form of transitional is that communicators can use different forms of transitionals to perform the same roles. Consequently, it was important also to examine the roles that transitionals played. For this, I used the roles Halliday defined for markers, but I changed the names of some of them, and added one. Since not all explanation is causal, I called those transitionals which Halliday referred to as "causal" as "logical." And, since not all comparisons are adversative, I called these transitionals "comparative." Comparative transitionals might point out similarities or differences. The other two roles which Halliday named were additive and temporal. I added the role of "subsidiary" for those transitionals which show one idea to be less important than another. The five roles that transitionals can play are additive, temporal, logical, comparative, and subsidiary.

Idea Units

In this dissertation, I wanted to determine how students were connected different concepts. I could only examine those concepts which they were making explicit. To facilitate my analysis of the explicit meanings which students were connecting, it was necessary to define an idea unit. This was not an easy task.

According to the Oxford Dictionary of Current English (Allen, 1984), an idea is "a plan or scheme formed by thinking; mental impression or conception" (p. 363). Thus, a single word can be an idea. However, treating individual words as separate ideas would not indicate what students were attempting to communicate with these individual words. Ultimately, I was attempting to determine the meanings students communicated and how they did this. Although words have meanings, without other words or events associated with them, their meanings are limited.

A sentence could be considered an idea. The Oxford Dictionary defines a sentence to be "set of words (or occas[sionally] one word) containing or implying a subject and a predicate and expressing a statement, question, exclamation, or command" (p. 681). There were three problems with using sentences as idea units. One was that sentences do not exist in speech. We must guess where one sentence ends and another begins. Secondly, children in grade 5/6 often have troubles writing sentences. Some children avoided the problem of punctuation by not using any, and wrote their assignments as one long sentence. Yet they were expressing many different ideas. Thirdly, the word "implying" in the definition of a sentence was a problem, since I wished to examine what students made explicit. Something usually larger than a word and often smaller than a sentence was the definition I needed.

I considered the possibility that any word/s in association with an action could be an idea unit. But in science writing, often abstract nouns replace action verbs.[6]

After wrestling with the purpose of my analysis, which was to examine what ideas students were making explicit, I decided to select the first subject and predicate as a complete idea unit. If other objects followed in a list after the first mentioned, I decided that the student had already explicitly stated the verb, so I considered each separate object as a separate idea unit. On the other hand, I considered adjective and adverb phrases to be part of the idea unit they modified, as long as any predicates involved were not explicitly stated. This definition is consistent with Chafe's (1985) definition.

Chafe noted that idea units (as he defined it) are a feature of speech. His definition was "it is a clause - that is, it contains one verb phrase along with whatever noun phrases, prepositional phrases, adverbs, and so on are appropriate" (p. 106). He noted that spoken idea units are about seven words long, whereas written ideas units are about eleven words long. Importantly, he pointed out that sometimes idea units cannot be discerned - a problem more common in written than spoken language. However, writers who used idea units, he claimed, were much easier to understand than those who didn't.

When children just gaining literacy write, they often write sentence fragments. As long as the fragment fit my definition of an idea unit, it was treated as one idea unit. I did the same in the transcriptions of the students' talk.

To summarize my definition of idea units, I treated a subject and predicate as an idea unit. If other objects were linked to the first object in the predicate, they were considered as separate idea units. This was because the subject and verb for the object had been explicitly mentioned. Since the subjects and verbs of adjective and adverb phrases are not explicit, these phrases were considered part of the idea unit they modified. I could have broken down idea units into much smaller parts than I chose, such as treating a subject as being a separate idea unit from the predicate, or adjective phrases as separate idea units. My rationale for the size of idea unit was that I wanted to show what students were making explicit, and how they were linking their ideas together.

To illustrate the use of my definition of idea units, consider the following examples. In each example, I have placed superscript numbers in front of each idea unit. First, from Viola's writing, we see the use of an abstract noun, but it is part of a predicate.

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[6] Lemke(1990) used the example of "pressure." Does the word "pressure" automatically imply an action?

> [1]The Alka Sletzer bubled up so high [2]you can feel the presure [3]when the air goes up.

I counted these as three separate idea units because there were three separate subjects and predicates.

For the following example, I have done something different with idea units (but still following my rule of counting idea units as explicitly stated subjects and predicates). Here, I have taken the first part of Thomas' sentence, which has subject, verb, and object, as one idea unit. He added other objects after the first one. I treated these as distinct idea units.

> [1]First I got one Alka selster tablet, [2]one jar with water in it, [3]and one tube that measured by mL. [4]Then I took the Alka-selster, [5]put it into the tube, filled with water [6]and put it in the jar with the top down.

The first idea unit includes subject, verb and object, so is easy to distinguish as a complete idea unit. In the second and third, the subject and verb have been explicitly stated in the first idea unit. Idea unit 2 is an object (with an earlier mentioned subject and verb). In idea unit 3, the phrase "that measured by mL" is an adjective phrase, modifying "tube," so I did not consider it a separate idea unit. This is similar to the second idea unit; the part "with water in it" is not a separate idea unit because there is no explicit action. The same holds for "with the top down" in the sixth idea unit.

But let's examine the idea units I marked as 4 and 5. "[4]Then I took the Alka-selster, [5]put it into the tube, filled with water." Thomas seems to have separated unit 5 into two separate units by using a comma between "tube" and "filled with water." If Thomas had first put the Alka Seltzer™ tablet in the graduated cylinder, then filled the graduated cylinder with water, I would have treated these as two separate idea units. However, Thomas put the tablet into the graduated cylinder which was already filled with water. Hence, "filled with water" was an adjective phrase, rather than an action. "Filled" is an adjective participle, rather than an action. It leads an adjective phrase. The comma was used inappropriately, and I considered the two phrases to be part of the same idea unit. This decision of mine might seem rather arbitrary. If Thomas had described his actions in chronological order, he could have written at least two idea units here: he filled the graduated cylinder with water, and he dropped the tablet in the cylinder. The definitional reason for counting "filled with water" as part of a larger idea unit is because "he" as the subject of the action was not explicitly mentioned. "[F]illed" was definitely an adjective participle rather than a verb.

I have taken great pains to justify my reasoning in this case. This is because I wish to point out later the problem with using the genre of science writing as a way for children to use writing to develop science ideas. Scientists describe their actions as briefly as they can, making many actions appear as a single event, and have a tendency to refer to themselves implicitly - usually through the use of the passive voice. I will point out later the problem with condensing idea units.

I made similar decisions regarding the categorization of idea units in speech.[7] Here is a section of talk from Viola:

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[4] Coding of transcripts is described in Appendix C. However, I present the system here.
The letter in front of the speech is the student's initial. If a J appears, it is I who spoke. Three dots indicates a noticeable pause of less than one second duration. Longer pauses are indicated by two sets of three dots, and even longer ones have the time indicated in square brackets.
I made no attempt to indicate students' accents by misspelling the words.
When one student overlapped speech with another student, a square bracket was drawn to connect the overlapping speech. Sometimes two speeches did not overlap, but the new speaker started speaking so quickly that I had the impression the first speaker had not finished. In these cases, there is no period at the end of the first speaker's talk. If the first speaker continued to speak after the second stopped, I indicated this by the placement on the line - the second speaker's speech began positionally on the page after the first speaker's talk, then the first speaker's began after the second finished.
If I could not understand what a student had said, I put a question mark in square brackets.

V [1]Well the ... um ... the baking soda ... um like ... was a little powdery so and um ... a little stiff [2]so it just floated down to the bottom [3]and stayed there [4]and the baking baking powder um was .. a little soft [5]so it started to float [6]and then it started going fizzy and bubbly?

Here, I have put the whole description of the baking soda as powdery and stiff in the same idea unit. Again, though, I have considered adjectives and adjective phrases to be part of the same idea unit as the noun they modified.

In summary, my definition for idea units was that subjects and predicates stated explicitly were idea units. Separate objects were separate idea units, if the subjects and verbs had previously been explicitly stated. Adjective and adverb phrases without explicit subjects and verbs were considered part of the idea unit they modified rather than as separate idea units.

Lists and Data Tables

As mentioned earlier, Goody (1977) believed that data tables were a significant literate development, a way to help us organize and re-organize information. By changing the way in which we tabulate our data, different patterns can be discerned. An example of the usefulness of data tables is from the acids and bases activity which I asked the students to do. Each group of students had six different chemicals to test, and two different indicators to test them with. The indicators were turmeric stained paper and purple cabbage water. The only time I have ever found that grade 5/6 students were able to discern a pattern in the way the chemicals reacted with the indicators was when they tabulated the information. After tabulating the information, I asked the students to group the chemicals into three different groups depending on how the chemicals had reacted with the indicators. This was very difficult for all the students; only two groups out of eight were able to discern a pattern. However, this was two groups more than were able to in other classes who carried out the activity without the specific suggestion of re-organizing the information in the data table.

The second experiment the students did in class was a complex one involving mixing all possible combinations of six different chemicals. We discussed how they would know what all the possible pairs were. The groups figured out, on paper, techniques for creating all possible combinations of two different chemicals. The result was that almost every group of students constructed, spontaneously, a type of data table. The results of this will be discussed later.

Summary

In this chapter, I will analyze the students' writing using each of the three categories described above: how students demonstrated the relationships between ideas using transitionals, how they elaborated or collapsed idea units, and the effect of data tables on their writing. I will also examine their talk, to determine if students use more transitionals and idea units in writing than in speech.

The literate tools of transitionals I believe are useful for students to display relationships between ideas. Familiarity with the tools, however, could mean some students appear to know more than their peers, where their peers are making just as many connections between ideas, but are unable to demonstrate them. The literate tools of data tables and lists seem logically to enable students to visualize relationships between ideas. Idea units are a construct useful for examining how students connect and represent their science concepts.

At the same time as I search for the literate tools the students use, I will be sensitive to any possible effects their literate tools might have had on the development of their science concepts, as evidenced by changes from their first to their second drafts. I will also compare whether they were more likely to demonstrate re-organization of ideas in speech or in writing. This analysis will be more thoroughly discussed in Chapter 5.

Students' Writing

Transitionals and Idea Units

By examining idea units and transitionals, I was able to analyze how students displayed their understanding. I looked for evidence that the students changed the amount of information that was explicit from first draft to second draft, or how they changed their writing over the course of the unit. The data regarding changes over the course of the unit should be taken lightly. Trends cannot be considered to be occurring over six assignments, unless a student was shown how to use a particular transitional and ever after consistently used that transitional.

A good example of the increase in explicit material came from Thomas' first and second drafts of the Alka Seltzer™ experiment. In that experiment, students were given graduated cylinders, jars, access to water, and Alka Seltzer™ tablets. The stated purpose of the activity was for the students to attempt to measure the amount of gas given off by the tablet. However, we had just discussed what the signs of a chemical reaction would be, and I wanted them to observe one. Thomas' first draft of his experiment follows. I have numbered the separate idea units with superscripts, and highlighted the transitionals.

> Exparament
>
> [1]**First** I got one Alka selster tablet, [2]one jar with water in it, [3]**and** one tube that measured by mL. [4]**Then** I took the Alka-selster, [5]put it into the tube, filled with water [6]**and** put it in the jar with the top down.
>
> [7]**My hypothisis is** the gases from the alka selster went up to the top of the tube. [8]**Therefore** the water in the tube is pushed down by the gas presrer. [9]**Therefore** the water around the tube in the jar is pushed up. [10]**Were the water and the gas meet** is how much gas there is in the tube. [11]One alka selster tablet produses 45 ml of gas.

My first impression of Thomas' writing was that it seemed terse. I think this was because he had called me over to his group during the activity to point out a number of observations which he did not record. I was expecting him to include these in his writing. Rather, his writing only addressed the stated purpose of the experiment - to determine the amount of gas produced by one tablet.

Some important characteristics of his writing are that he laid out his description of what he did in clear chronological order, saving his analysis for later. His use of chronology and his separation of two very different parts of his experiment (what he did from what he thought) are wordless transitionals. Further, Thomas connected nearly every idea unit to the previous idea unit with a transitional. Each transitional demonstrated the relationship between the last idea and the subsequent idea. Note that in the first sentence, Thomas used commas, and "and" as additive transitionals, but in the second sentence, used these as temporal transitionals, indicating subsequent actions. Here is an example of the problem Brown and Yule (1983) pointed out with Halliday's taxonomy - according to them, Halliday had classified "and" as an additive marker, yet it can also serve temporally.

Thomas' second paragraph began "My hypothesis is." Both starting a new paragraph and announcing it as his hypothesis alert the reader to a change: we have moved from his description of what he did to his explanation. The paragraph change is a transitional. Even without the paragraph change, the announcement of "my hypothesis is" tells us what he intends to do. At this point, Thomas did not just link two idea units. Rather, he differentiated two separate sections of his writing - the description of what he did and his explanation for the results.

The next transitionals, consistent with his intent to explain, are all logical - "therefore," and "where" (misspelled). His final idea unit lacked a transitional. Because this is the only time that Thomas did not use a transitional, this can be considered a style disjunct. The reader should be alerted that something different is about to appear. The final idea unit is the conclusion, the answer to the question posed at the beginning of the activity. His final idea unit was indeed something different.

Note that in the first paragraph, Thomas used only temporal and additive transitionals. His idea units are presented as unproblematic descriptions of what he did. These statements are not available for dispute. In his second paragraph, he has switched to discussion. His transitionals are logical. He is laying out his thinking for us, and we could, presumably, challenge him on one of his logical steps. His conclusion is a statement, a description of his observation; again, it is authoritative and unproblematic.

Since Thomas was one of the few students in the class to use logical transitionals on this first assignment, I read his write-up out loud to the rest of the class. I pointed out how he had used the word "therefore," and that it was helpful to use words such as these to show how ideas relate to one another.

My written comments on his first draft pointed out spelling errors, with the correct spelling in the margin. I also circled the word "therefore" and wrote "Great connecting word" in the margin. My summary comment on the first draft was:

> Great Thomas. You have answered the challenge I posed to you - to find how much gas one Alka Seltzer tablet would produce.
>
> You have explained your reasoning for why you measured the gas the way you did. Your reasoning is convincing.
>
> Did you do any other experiments with the tablets? Did you learn anything else about chemical reactions?

The first paragraph of his second draft was basically a copy of the first, with none of the spelling corrected. Indeed, he misspelled a word in the second draft which he had spelled correctly in the first draft. However, he changed the last paragraph from (first draft):

> [7]**My hypothisis is** the gases from the alka selster went up to the top of the tube. [8]**Therefore** the water in the tube is pushed down by the gas presrer. [9]**Therefore** the water around the tube in the jar is pushed up. [10]**Were the water and the gas meet** is how much gas there is in the tube. [11]One alka selster tablet produses 45 ml of gas.

to (second draft):

> [7]**My hypotesis is** the gas from the alka selstester tablet went up. [8]**Therefore** the gas is lighter than the water. [9]**Because of that** the water in the tube is forced to go down. [10]**Therefore**, the water outside the tube is forced up [11]**because** more water is going in the jar [12]**and** less water is inside the tube. [13]One alka setster tablet produse 45 ml of gas.

The logical connections in Thomas' thinking were more elaborated in the second draft, and he included another logical transitional, "because," which showed another relationship between two idea units. The "of that" which followed the "because" is a transitional, indicating that the "gas is lighter than water" is to be connected by the "because" to the subsequent idea unit.

Thomas' greater elaboration of ideas brings up an interesting point about whether writing can be used to develop science concepts. According to many researchers, writers tend to link their ideas more densely than speakers. They tend to subordinate ideas, string adjectives together, etc. (Chafe, 1985; Emig, 1977, Fondacaro & Higgins, 1985; Hildyard & Hidi, 1985). Further, by using special terms (much as Lemke, 1990, noted scientists will), writers will make their connections between ideas less explicit. But it was when Thomas separated two idea units (the term gas pressure buried some of his logical connections) that he made explicit one of his inferences. He had assumed the gas was lighter than water, and he now explained this assumption and the evidence he used for it - he had noticed the gas rose up through the water.

One of the advantages of having students write is that, in the students' writing, a teacher is able to engage individually with each student and perhaps encourage each one to do a little more than s/he is already doing. One way of describing this would be to say it is in a student's writing that teachers can engage with each student in that student's zone of proximal development (Vygotsky, 1978). But, as Schaffer (1992) pointed out, the student will choose whether or not to pick up on what the teacher suggests. It is interesting that in Thomas' changes from first draft to second, he did not respond to my comments, but made his own choice about what part of his assignment needed further elaboration. One possible explanation for Thomas' choice to ignore my comments was that he was not ready to consider them. Schaffer suggested this as a reason why children might not pick up on suggestions from their parents. However, I will suggest two other possibilities for Thomas. Thomas did change his second draft, making his reasoning more explicit. And from conversations with him, I would guess that the experiment was well within his intellectual ability. Indeed, he was suggesting explanations which were beyond what had been asked of him. Thomas might not have responded by describing more details of his Alka Seltzer™ experiment because he did not really like to write. Consequently, he answered the narrow question posed rather than deviate and describe other issues which had appeared during his experiment. There is a third possibility. Thomas was the only student in the class who considered himself my intellectual equal. This did not mean that he was disrespectful, rather that he believed he was just as capable of figuring out what was happening as I was. Thus, he would not consider my suggestions with any more weight than he would consider his own.

Thomas used transitionals and idea units effectively in his writing. The transitionals he used were the chronological order of events, the separation of his description of actions from explanation, conjunctions, style disjuncts, and punctuation. At the time of the study, he was still having problems with punctuation, a strictly literary transitional. He rarely used paragraphs and did not use headings, two other strictly literary transitionals.

The question arises as to whether he used transitionals and idea units as effectively in his speech as he did in his writing. To determine this, I examine Thomas' thinking test. The thinking tests were situations I set up for groups of three students to work with me on a particular challenge. Barnes (1976/1992) and Solomon

(1991) noted that students will sometimes come to consensus rather than exploring contradictory explanations. I had noticed that many of these students did not attempt to explain their empirical observations. I hoped that I would be able to prompt them to explore contradictions and to attempt explanations. The thinking tests thus were more like the dialogue I could engage in with the students in their first draft - second draft writing experiences.

The question posed to Thomas' group was "What is the difference between baking soda and baking powder?" Thomas' group included Priscilla, a girl who sometimes volunteered to speak in whole class discussions, and Henry, a quiet student who attended school only about half the time. He had been labeled as learning disabled.

The first suggestion the group made was that baking powder might have had pure sodium in it, whereas sodium bicarbonate was a molecule. Thomas reminded me that I had told them that the element sodium (pure sodium) reacted with water. Consequently, baking powder, if it contained pure sodium, would react with water. (For the full transcription of this group's thinking test, see Appendix C.) In the following section of transcript, Thomas struggled with a suggestion Priscilla posed, that perhaps the essential difference between baking soda and baking powder was due to their densities. This section of the transcript begins with Priscilla responding to me when I asked her to continue her line of thought. In Thomas' sustained speech at the end, I have put each unique example of transitional in bold.

P Could you come back. I just need a little time. I was going to say something. Oh yeah. I have a question. Is sodium heavier or is it light?

J Sodium?

T *Heavier than water? I would think it is obviously lighter than water because there is there's only one atom.

P Is this one that bubbled up or that one bubbled up?

T And.

J This is the sodium uh this is the baking powder and this one is the uh baking soda.

T [1]**Just like** um I'd say **if** water it's has three molecules joined together [2]**and** it will stay [3]and there's like one specific weight [4]**and then** everything bounces [5]**so** there's some space [6]**but** with sodium there's more space [7]and just a little bit and a little bit of molecules? [8]**'Cause** with sodium of ah atoms they bounce around [9]and there's some space [10]but in the water H_2O there's thuh .. it's got more joined together [11]and so it's you can so it's gonna have equal amount of space around it [12]but there's gonna be more space in the middle [13]so it's probably will have a little bit more.

An interesting point is that at *, Thomas interrupted me to question Priscilla about her question, then took over from me to answer her. As mentioned previously, Thomas considered himself my intellectual equal. I believe that this was an important factor in his complete engagement to find explanations. He knew that to find answers he had to think through the problem rather than rely on me.

Thomas' last speech was 107 words long, a full minute. This speech was as long as many of his written assignments, longer than some.

There is one difference between his talking and his writing that should be noted. In this speech, there were 107 words for thirteen idea units (an average of 8.2 words per idea unit); in the Alka Seltzer™ writing, there were 111 words for eleven idea units (an average of 10 words per idea unit). Chafe (1985), with a similar definition for idea unit, pointed out that written language tends to have more words per idea unit than spoken language. Chafe's findings, in this case, seem consistent with mine. What is interesting is that Chafe was studying adult language, and I am studying children's. Hildyard and Hidi (1985) did not find that children were adept at using literate tools.

In his speech, Thomas used transitionals, just as he did in his writing. He used transitionals to indicate a number of different relationships between ideas: temporal, comparative, and logical. "Just like" is an adverb phrase which demonstrated Thomas' intention to link the construction of water molecules to his earlier description of sodium atoms. This transitional is comparative. Thomas' other transitionals are: "And then" (temporal relating "everything bounces" and the earlier description of structure of molecules); "but" (comparative showing that he will now contrast something to water); "so" (logical showing that "everything bounces" is the cause of "there's some space"); and "'cause" (logical showing that he will now justify his earlier statement.) After the "'cause," Thomas added six ideas, explaining about water and sodium molecules being different sizes, attempting to justify why water molecules should have more space around them. Thomas seemed as effective at demonstrating relationships between idea units in talk as in writing.

Further, Thomas demonstrated he was as capable of displaying his reasoning in talk as he was in writing. He did not seem to need writing to develop his science concepts. He was quite capable of drawing on his thoughts without putting them in visible form on paper. Also, with talk, he was able to draw on ideas from his peers and from me. Although Scardamalia and Bereiter (1985) suggested that students be taught to use their writing in a dialogic fashion, using cards with questions written on them, and, eventually, internalizing these questions, Thomas showed that he would profit more from engaging in dialogue with his peers and teachers. This is not an argument on my part that any students should not be expected to write in grade 5. Rather it is to suggest that students should be encouraged but not expected to use their writing to develop their science concepts. Since students at this age are much more fluent in spoken language, talking should not be dismissed as a medium for learning in science classroom.

Viola contrasted with Thomas, in that she was a student who focused almost entirely on the empirical description of events. She found the physical involvement in the empirical activities exciting (as did Thomas), enjoyed writing about them (unlike Thomas), but did not accept my challenge to attempt to explain. Her group, for the Alka Seltzer™ experiment, tried pressing their hands over the graduated cylinder to capture the gas. They worked on the floor in the hall. Every time I went into the hall, they excitedly called me over to show what they were learning: how the gas was pressing against their hands to escape; how some bubbles remained in the water; how the popped bubbles left a track on the plastic of the graduated cylinders.

Viola, perhaps because of her enthusiasm for writing, did not write very neatly. In her first drafts, words were not clearly separated, and her spelling was non-traditional. Her assignment was hand-written, so I am unsure if she was intending to separate her words but didn't leave enough space, or if she didn't know how to separate her writing into words. In my translation of her first draft, I have made spaces between her words, so that I could count her words to compare her speaking to her writing. The complete write up of her experiment follows. In this version, I have highlighted the transitionals she used. A discussion of her use of transitionals follows her writing.

AlkaSeltzer Experiment
[1]**Fist** we put it on 50 [2]it gose up to 65 [3]the gas pushed the air [4]it end by when the fazz disapert [5]it wend down by 15 m [6]**that** epeals 65 min [7]**When** you put your hand on it [8]it gose Hot brued [9]**fist** we will put the water in the gaitshepe [10]**and** put the Alkaseltzer in the Jar [11]put it on 75 [12]it went on to 100 [13]the fizz and buelbe it is rieseing [14?]your hand pushe the pest it [15]the air pusseh it to the top abouhe ml 107 [16]The alkaseltzer brud up so high [17]you can fell the puesp when the air gose up. [18]**Fist** we broke the Alkaseltzer [19]**and** put it in the gitger clender shpe [20]it work [21]it was pusheing the air up [22]you could hear the sould [23]**and** suff [24]We all had to pushe are hand on the girlplth cleid [25]**and** it was so great to do the experament [26]I like the suff [27]**so** it was kind of fun to be a sicent [28]pernt to be a great sicent [29]I had a hole buleb of fun.
Viola

Notice that her ideas do not seem ordered, either chronologically or logically. Although I had some idea of what the experiment was about, I had great difficulty interpreting what her group had been doing. Until I marked the idea units and moved later details back to where I believe they should have first been stated, I couldn't tell what the original measurements of water were, what the final measurements of water were, what different experiments the group had tried or why. In the table below (Figure 1), I have inserted in italics any information which I believe was necessary to understand what Viola was writing, but which she left unstated.

Figure 1: Viola's Actual Writing and a Possible Translation

Viola's Writing	Translation
[1]Fist we put it on 50	We *filled the graduated cylinder* to the 50 *mL mark, with water.*
[2]it gose up to 65	*When the tablet was added,* the fizz (mentioned later) went up to the 65 *mL mark.*
[3]the gas pushed the air	The gas *(produced by the tablet)* pushed the air up against our hands (mentioned later).
[4]it end by when the fazz disapert	It *(the reaction?)* finished when the fizz disappeared.
[5]it wend down by 15 m	It (the volume) then dropped by 15 mL.
[6]that epeals 65 min	The mark the fizz reached equals 65 mL.

Note that Viola's very first idea unit described what they did. A reader could not possibly understand what she had done, without more information being made explicit. I have added the minimum of information, in italics, that should have been in this idea unit for a reader to make some sense of what she wrote.

Interestingly, Viola has been more explicit in her description of what she observed and of her calculations than of what her group did. This surprised me, because I thought her actions would be the easiest part for her to write about. She knew what she had done. Then I thought of Britton's (1970/1993) finding that students who are just acquiring writing write expressively, as if for an audience who was present. Viola described her actions for her teacher. I had been present for some of the experiment; regardless, I was an audience whose needs she had to make guesses about. Perhaps she wrote more explicitly in her observations and calculations because she wrote for her own understanding, to elucidate for herself what she thought happened.

In an examination of her transitionals, I noticed that all are temporal. The word "fist" translates to "first;" unfortunately, because she used the word three times, it lost its usefulness as a transitional unless I concurrently analyzed idea units. With an analysis of separate idea units I realized that "first" referred to the first step in a set of actions, not a first experiment. In each case when she wrote "first," I believe that she was marking that a new experiment had begun. She needed a meta-transitional, such as a heading, to alert her reader to the way in which she was using "first."

In the seventh and eighth idea units: "[7]When you put your hand on it [8]it gose Hot brued," the word "when" might have been a logical transitional, showing a cause and effect relationship between Viola putting her hand on the cylinder and the gas becoming hot. I didn't even consider that she had meant this when I first read her writing. Rather, I assumed that she used "when" as a temporal transitional, to describe that she could feel the gas was hot when she put her hand on it.

To enable myself to comment to Viola on her writing, I rewrote her assignment. I gave her back her version and the rewritten version, with the spelling corrected in those places where I could interpret a word. I circled those words I couldn't recognize. I commented on her observation of the heat of the bubbles, that this was an interesting observation. I asked her questions in many places where missing information made understanding difficult. For example, I asked her after her second sentence, "Did it go up after you dropped the Alka Seltzer tablet in?" My summary comment at the end was:

> Viola: You have written a wonderful story about your experiment. I certainly enjoyed reading it! (I had some trouble reading your writing. You must have been writing very fast!)
>
> To give me more room to ask you questions, I rewrote your words, with spaces between, so I could put questions right there.
>
> I am glad you enjoyed this experiment. I hope the next few experiments will be as much fun for you!

In her second draft, she attempted to answer the questions and problems I had posed. However, she had a long way to go towards anticipating the needs of her audience.

An important problem in Viola's writing was the lack of the implicit transitional of chronological organization. My difficulty interpreting her writing illustrated either the importance of this transitional, or illustrated how culturally bound I am to it. Second, the lack of punctuation made separating idea units unusually difficult. Third, her lack of conjunctions made the relationships between idea units difficult to tease out. If I were to take Viola's writing as the sole measure of the clarity of her thinking, I would conclude she was not very bright. But that conclusion would be based on using her ability to express what she knew at one particular evaluative moment with one particular evaluative tool as a measure of her intelligence. The conclusion would also be based on the assumption that she wrote for me as her audience. But in the translation in the table, I pointed out that Viola spent far less effort making her actions explicit than she did in making her reasoning explicit. Perhaps Viola wrote to make her reasoning clear for herself, rather than to demonstrate her understanding for me. This would be ideal for a student who was using writing to develop her ideas.

Viola never attempted to explain her experiments in her writing. Perhaps Viola did not understand the need in science for explanation. Thomas, in many senses, was a scientist. The notion of explanation drove his questioning of me, and encouraged him to try different experiments. Several times in his writing, he attempted to use scientific concepts. Perhaps Viola needed more assistance from her teacher in helping her "cross the border" (Aikenhead & Huntley, 1998) into a country with a different culture.

In the last experiment, the students were given six chemicals to test with acid/base indicators. The two indicators were purple cabbage water and turmeric stained coffee filters. Unfortunately, the students did not yet have a clear idea of how to construct data tables. (Most of them had recorded the results of their second experiment in data tables, but this had been disastrous for their writing. This will be discussed in the section on data tables.) However, the effectiveness of this experiment for the students finding a particular answer is not the focus of this next analysis. Rather, it is to show how Viola's expression of ideas had improved.

> Cabbage juice and base.
> [1]**My gourp** Priscilla and Joni and Darlene. [2]**We got** the cabbage juice [3]**and** yellow coffee filter [4]**and** baking soda [5]ammonia [6]hydrogen peroxde [7]**and** acetic acid [8]rubbing alcohol. [9]**I did a experiment** [10]I used a yellow coffee filter and ammonia [11]it make it trun red [12]**and** put rubbing alcohol actice acid [13]it made it trun yellow [14]**then** I put baking soda [15]it got all smokey and bubble and a big lump of baking soda.
> [16]**That the end** Bye Viola

Viola used three temporal transitionals in this draft: "and," "then," and "That's the end." But even without the temporal transitionals, she wrote the story of the experiment in chronological order, a significant improvement over the first assignment. She ran idea units 10 and 11 together without punctuation. But there is good reason for this. 10 is what she did and 11 is the result. The same happened with idea units 12 and 13 and idea units 14 and 15. She linked these ideas by their proximity to one another. She showed a temporal relationship between the pairs by describing the action first, and the result of that action second. Three months made a great difference in her ability to express herself in writing.

Viola has organized her writing in other ways as well. She marked that she was going to tell me who she was working with, instead of treating as a given that the students she mentioned later were in her group. She marked a change when she went on to the next stage of her writing, telling me what materials she used. For her ninth idea unit, she used a sentence to mark a change from describing the materials to describing the actual experiment. This is similar to what Thomas did in his first experiment write-up, when he switched from describing what he had done to explanation.

Although Viola demonstrated great difficulty in communicating what she was doing, and did not attempt to explain her empirical observations, throughout the chemistry unit she read the comments I wrote on her assignments. She made changes based on my feedback. She wanted to learn. As demonstrated by her final assignment, she improved considerably in her expression of ideas. Her grammar, spelling, and, more importantly, ability to tell the experiment in a fashion which made sense to her audience, vastly improved, despite that my comments were limited to asking questions where I was confused. The most significant improvement in her writing was probably her narrative clarity. By the last two experiments, I found it much easier to understand what she had done, and what she had observed in her experiments. With all her practice and teacher's feedback in writing, she seemed to be acquiring the ways of literacy.

I am not sure if Viola was concurrently acquiring the ways of science. This last experiment was to help students understand the importance of categories and, specifically, the categories of acids and bases. Viola did not differentiate acids from bases. She only described how some of the chemicals reacted with turmeric stained coffee filters. Viola still was not taking me up on my request for explanations.

Thomas, however, distinguished acids from bases. His writing follows:

> Acid and bases
> [1]**When** I mixed amonia (Base) on the yellow coffee filter (Acid) [2]it made red. [3]**To make** green [4]you mix amonia (Base) and cabbage juice (Acid [5]?green (acid) and hydrogen poroxide (Base) makes yellow. [6]**To make** Blue [7]you mix sodium bicarbornate (Base) cabbage juice.

Thomas put two idea units in the first sentence, what he did and the effect of his action. In the second sentence, Thomas organized cause and effect differently, by announcing his intention to tell us how to make green at the beginning of the sentence. Again, there were two idea units, the cause and the effect. There is a change in idea unit 5, and his writing was confusing for me. I think that the second sentence ended with a parenthetical "Acid," and the "green (acid)" started the next idea unit. If this interpretation is correct, Thomas collapsed cause and effect into one idea unit in this, his third sentence. This fifth idea unit left out the agent. It is not Thomas, nor is it the mysterious "you" who has mixed the chemicals. Rather, the chemicals mix themselves, a very common thing for chemicals to do in science writing (Lemke, 1990; Gilbert & Mulkay, 1984).

In Chapter 2, I discussed the qualities of science writing. Thomas' collapsing of ideas, and his ability to make the agent disappear, are qualities consistent with science writing (Lemke, 1990; Gilbert & Mulkay, 1984). However, with this collapse, I can no longer see his reasoning. Sutton (1996) argued that the style of science writing was a development to separate what was offered for dispute (the discussion) from that which was not to be disputed (the methods and the empirical observations). Thus, scientists would write themselves out of their experimental procedures and observations. It would seem that Thomas knew how to do this, demonstrating familiarity with the science genre. But there are unfortunate consequences for this. In his first experiment write-up, Thomas displayed his reasoning. In this last assignment, his reasoning was obscure. This made my job of responding to what he was thinking much more difficult.

As with Thomas, the question must be asked of Viola's development of science concepts - how does her talking compare to her writing as a tool for her to re-evaluate her ideas?

Viola worked on her thinking test with Steven and Frank. Steven was a vociferous student, one of the boys who tended to dominate whole class discussions. In tapes of him in small groups, I noticed that he tended to take charge. Frank was reticent, one of the boys who never volunteered information in the whole class discussion. In this transcript, Frank rarely offered information. In this transcript, I took as many turns talking as the students. At first, I thought this might have been because this was the seventh (and last) group of the morning, and I was too tired to stop myself from taking over. However, when I checked the tape of the group just before this one, there was no trend apparent; I participated no more than I had with the first group of the morning. I believe now that Steven knew how to get me to tell the answers. At one point, when I refused to answer his question he challenged me with "You're a chemistry teacher." He was determined that I would show them the path to the answers.

The following section of transcript occurred immediately after I put baking soda in water and baking powder in water. The students noticed that the baking powder reacted with water, but the baking soda didn't. I asked them to try to explain what the difference between the two chemicals was. Much of the explanation focused on empirical description. In this section of transcript, I have put the first example of a particular transitional in bold.

S And the baking powder was all more powdery so it floated maybe more a little more clumped so it floated (?) I don't know.

J OK. OK. That's fine. Viola?

V [1]Well the ... um ... the baking soda ... um like ... was a little powdery so [2]**and** um ... a little stiff [3]**so** it just floated down to the bottom [4]**and** stayed there [5]and the baking baking powder um was .. a little soft [6]**so** it started to float [7]and then it started going fizzy and bubbly?

J OK And what does that mean? Fizzy and bubbly. It started going fizzy and bubbly.

V Um.

J Can you think of that in terms of chemistry? Does it mean anything to you?

V Hm. I don't know.

Despite my solicitation of a deeper explanation, Viola did not attempt to move beyond the strictly empirical description of what had happened.

The speech with the connecting words in bold was the longest sustained talk from Viola for the whole tape - forty-three seconds in all, fifty words not counting the "um's" and "like." In these fifty words, she has seven idea units and has used four different conjunctions as transitionals. Of her transitionals, "and" is additive; "so" is logical; the second bolded "and" is temporal; and "and then" is temporal.

In an attempt to compare Viola's talk to Thomas', I have added the only other speech longer than a single phrase. This speech was fourteen seconds long:

J Steven you said there wasn't a chemical reaction. Viola you said there is a little bit. What did you see that made you think there might be a bit of a reaction.

V Um ... Kay ... [1]**when** it like floated a little bit [2]and then it fell to the ground [3]and then it started making little bubbles.

She has used one more different transitional, "when" and, as with the earlier use of "and" and "and then," it was temporal. In the limited examples of sustained talk I have from Viola, she did not use a variety of different kinds of transitionals. However, she used more total different conjunctional transitionals in her talk than in her writing. All her points were connected with transitionals. Two of her conjunctions showed chronological relationships which had been the greatest improvement in her writing - her ability to sequence her descriptions so they made chronological sense. One of her transitionals showed a logical relationship, an attempt at explanation, something which she had not yet displayed in her writing.

I would have to conclude that Viola was not learning science by writing. Rather, her ability to sequence her writing was improving; further, her ability to show chronological relationships in her speech was in advance of her ability in writing. She was also attempting to explain in speech, something which she had not displayed in her writing.

The student who was most adept at the use of transitionals was Ruth. As will be discussed in Chapter 6, she wrote a lot. The girls wrote much more than the boys, Ruth wrote the second most of all the girls. Consequently, for the most part, only excerpts of her assignments will be discussed. Following are interesting portions of her first draft of the Alka Seltzer™ assignment. I have put three dots (…) where I have left out sections of her writing.

> **MATERIALS USED:**
> Alka Seltzer tablets
> Water
> Graduated cylinder
> Jar
>
> **WHAT WE DID THE 1ST TIME:**
> We filled up the graduated cylinder with 52 ml. of water. **Then** we dropped 1 alka seltze tablet **and** covered the top of the graduated cylinder with a jar. The level of the bubbles went up to 74 ml. The actual level of gas was 22 ml. **if** the gas is the bubbles **(which** I think it is).
> **WHAT WE DID THE 2ND TIME:**
> …
> **OBSERVATIONS:**
> **When** the bubbles rose as far as they were going to go they started popping **and** the level of water ended up at the **same** level **as** I started with.
> **When** we put a jar on top of the cylinder there wasn't as much gas.

When we put no jar on top of the cylinder the gas level went all the way to the top of the cylinder.
Experiment done by Ruth, Brad, Zoe, Wally, & Quentin

Notice that Ruth started her writing with a list. This is, according to Goody (1977), a precursor to data tables. Lists are available orally as well as in writing, but can be used more effectively in writing than orally for organizing ideas. Ruth also used headings, another literate tool Goody (1977) suggested could be useful for organizing ideas. Ruth laid out her experiment in a format that is more like those expected of science students. She separated the "materials," the methods ("what we did the 1st time" etc.) and the "observations." Despite the separation of methods from observations, she included quantitative measurements in the methods section. In her section called "observations," she included her qualitative observations. Here, she also included generalizations about her data.

Sutton (1996) argued that the separation of science writing into different sections was to separate what was on the table for discussion from what wasn't. Ruth seems to have taken advantage of this in some respects. Yet, in her methods section, she noted the inferences she made about the bubbles being the gas. In her observation section, she no longer pointed this out to her audience. According to Sutton (1996), the subtle change from pointing out inferences to assuming them, right within one section of writing, is a style more associated with science text books than published papers. It would seem that Ruth implicitly developed her science writing style from text book style writing. This is not surprising. A grade 5 student is unlikely to have read very many actual science papers.

Ruth did not use nearly as many conjunctions as transitionals as did Thomas. She did not need as many conjunctions because, first, she used very clear chronological order, and second, she separated ideas into different sections. I earlier described headings as meta-transitionals, because they substitute for many individual word transitionals. This is what Ruth was doing with the different sections of her report. A third reason why Ruth did not need as many conjunctions was because of her use of punctuation. She used a colon after her headings, showing that a list of information would follow. I especially noticed the use of parentheses. Inside her parentheses, she included a different sort of information, speculations. The more predominant use of speculation is one of the differences between boys' writing and girls' writing which will be discussed in Chapter 6.

In my comments to Ruth on her first draft, I commented favourably on her organization and noted that her separation of inference from observation was important. I then asked Ruth what she had learned. Her second draft included a section:

> WHAT I LEARNED:
> I learned that the bubbles are the gas (at least I think they are).
> I also learned that the pressure of the gas pushes up your hand from the cylinder (even though I didn't do that.

And she added a very interesting comment at the very end "Iterperation of the experiment done by: Ruth." In her early separation of observation from inference, she seemed to be aware that she was making some assumptions. Is she suggesting that perhaps all observations are interpretations?

Ruth's writing showed from the beginning a degree of skill which only one of the other students had. She used a much greater variety of tools, including punctuation, lists, and headings. I would consider the three I mentioned to be advanced tools for two reasons, one logical and one normative: one, the tools are all strictly literate transitionals; two, only some of the students used these tools, whereas a greater number used the oral-literate transitionals. Since only some of the students were using these tools, I guessed that they were more difficult to acquire, so, in this sense, more advanced. As well as transitionals, Ruth organized her ideas clearly into both chronological and logical units. In her writing, she attempted to differentiate between empirical observations and inferences. Thomas also attempted to separate inferences from the rest of his experiment, by noting a shift to explanation with "my hypothesis is." The attempt to separate empirical observations from inferences is a feature of the Western scientific way of thinking.

I examined the tape of Ruth in her thinking experiment. She spoke very little, and then in concert with the other two participants. They described what they saw happening, and quickly decided that baking soda did not react with water, but that baking powder had some chemical in it which would react with water. In other tapes of Ruth at work in small groups, she rarely spoke. She focused on recording the results of the experiment. It would seem that if a person were going to be better at writing than talking to develop science concepts that student would be Ruth.

So far, I have examined the writing of three students and the talking of two. All three of the students were adept at using oral/literate transitionals. Thomas and Viola were more adept at using oral/literate transitionals in their talk than in their writing. The data are difficult to determine for Ruth. Viola was the least adept at the use of transitionals, using less variety in the sense of the roles transitionals could play, and less variety in the forms of transitionals she used. Ruth was the most adept at using transitionals, using them to indicate all five relationships: temporal, logical, comparative, additive, and subsidiary. She also used meta-transitionals such as headings. I had very few difficulties understanding her writing. Ruth was also the most adept at using those transitionals that are only possible in writing. Neither Viola nor Thomas was as adept at using literate transitionals in the beginning, but both improved in their ability to use them during the term.

Interestingly, Viola and Thomas used just as many, or more, logical transitionals in their speech as they did in their writing. Viola used a logical transitional in her speech yet used none in her writing. This is contrary to Chafe's (1985) findings that people use more subordinate conjunctions in writing than in speech. This difference could be because Chafe based his findings on a comparison of academic papers to dinner conversation. Hildyard and Hidi (1985) quoted research regarding comparisons of written and oral discourse when the context for the two kinds of discourse was similar. Their research suggested that written and oral language were very similar for similar contexts. Thus, the differences that Chafe noticed might well have been because of different contexts of use. In my study, students' talk and writing were for the same contexts - science problems. The difference between my findings and Chafe's could also be because I only analyzed sustained talk from the students. I only counted talk when I was certain which child "had the floor." It seems when the same sort of topic is addressed, and the speech is sustained, people might be just as capable of developing a logical argument in speech as in writing.

But so far, I have only looked at three of the students. How did the rest of the students compare? I went through all the students' written assignments to determine if the three students whose writings I analyzed in depth represented the full range of the grade 5/6 class. I checked to see if other students used the same variety of transitionals, and used them as effectively.

Examples of meta-transitionals are headings and paragraphs. I did not teach the students how to use headings. I taught the students to use paragraphs, but, in the following count, I only counted paragraph use if students used them on their first drafts before I indicated where good locations for paragraph changes might be. Nine of the twenty-six students used headings, and twelve of the twenty-six students used paragraphs. Of the nine students who used headings, three of them used them only in their home experiment. It is possible that they adopted the heading format from books they took their activities from.

Another sort of meta-transitional is an announcement. Thomas did this when he wrote "My hypothesis is." By this phrase, he indicated that the next few idea units would be explanations. Far more students used announcements than used the strictly literate tools of paragraphs and headings. Twenty-one of the twenty-six students used announcements to indicate the next set of idea units would all be similar in a particular way.

Almost all the students used periods at what they determined to be the ends of sentences. There were many run-on sentences, and many sentence fragments, so the periods were not yet being used in expected literate ways. About half the students used commas, and seven of the twenty-six students used other forms of punctuation, including (in order of frequency) parentheses, colons, exclamation marks, and question marks.

Twenty-four of the twenty-six students wrote their final assignments in chronological order. Both the students who didn't write in chronological order recognized the proper order of the events, but didn't bother to organize their writing. One student would write "Oh yeah, I forgot to tell you that..." as if we were in conversation.

It would seem that students rapidly master the narrative, the ability to sequence a story. They tell stories in chronological order, and use appropriate transitionals to show temporal relationships between phenomena. As pointed out, Viola had trouble with this aspect of her writing in the beginning of the study (February), but was much better at it by the end (May).

All twenty-six of the students used additive and temporal transitionals. Only nine students used comparative transitionals, thirteen used logical transitionals, and five used subsidiary transitionals. Since all these roles can be played by oral-literate tools, I think the lack of use is not due to a lack of familiarity with the tools. Indeed, Hildyard and Hidi (1985) found that children of the same age used more "adversative conjunctions" than logical. Their study was of students writing stories rather than science experiments. Therefore, I would guess grade 5/6 students are familiar with comparative transitionals, but perhaps this group had not been taught they could use them to compare science phenomena. Further, the particular experiments required temporal relationships in the description of what the students did, additive when they described what they did and what they observed, and logical when they attempted to explain their results. The students could have compared their observations, but this was not specifically asked of them. Thus, considering the context of use, temporal, additive, and logical transitionals should have been the most common, as they were.

By the middle of the next year, when I asked students to compare a penny to an apple, Viola used comparative transitionals very well. Perhaps this was because the activity specifically requested that she compare. On the other hand, the students might have been taught how to compare and contrast. That more students in this study used logical transitionals than comparative transitionals would almost certainly be because of the context of use. The students were asked for explanations after every first draft. As will be discussed in Chapters 6 and 7, some students did, others did not, attempt explanations.

Figure 2: Summary of Types of Transitionals Students Used

Students	Punctuation			Meta-Transitionals			Implicit
	periods	commas	Other	Para-graphs	headings	Announ-cements	Chronol-ogy
26	26	13	7	12	9	21	24

Figure 3: Summary of Roles for Students' Transitionals

Students	Additive	Temporal	Comparative	Logical	Subisidiary
26	26	26	9	13	5

Lists and Data Tables

Data tables, as mentioned by Goody (1977), are only literate, not oral, and are a useful way to organize, observe, and re-organize ideas. They are a cultural tool, and they help us to organize information and help us to search for patterns. As an example of how useful data tables could be, consider Adam's Alka Seltzer™ experiment:

> The Alka Seltzer experiment
> [1]**When** we put the tablet into the water, [2]it started bubbling [3]**and** it rises up around 25 ml. [4]**first** we put the water at 50 ml, [5]we dropped in the tablet [6]**and** it went up to 74 ml. [7]**The next time** we put the water at 25 ml [8]**and** it went up to about 49 ml. [9]**After** our group decided to try it a couple of more times [10]**and** the first time we put it in 75 ml [11]**and** it went up to 107 ml [12]**and** the second time we tried it at 50 again [13]**and** it went up to 68 ml. [14]**Next time** our group should cover it tightly [15]**and** be more careful. [16]**I think** the average of the volume in the tablet is about 25 ml.

The information would have been effectively communicated with just a few sentences and a data table. An example follows.

Figure 4: Hypothetical Data Table for Adam's Alka Seltzer™ Experiment

Table: Volume of Bubbles Produced When Alka Seltzer is Added to Water

Trial	Original Volume of water (mL)	Final Volume of Water and Bubbles (mL)	Volume of Bubbles (mL)
1	50	74	24
2	25	49	24
3	75	107	32
4	50	68	18
Average			24.5

Consider what Adam's narrative told me which his data table wouldn't have. First, he mentioned that when the tablet was dropped in to water, it started bubbling, and second, he thought his group should be more careful about covering the top tightly. Adam did not say that he thought some of the gas might have been escaping from their measurements, but the implication is there. On the other hand, consider what he might have noticed if he had used the data table I constructed from his writing. If he did think that the average was about 25 mL, could he also have thought that some of the gas was escaping? The numbers average to 24.5, so only a small amount of the gas would have escaped, if he trusted his average. He has attempted to account for the variation in his data, but when he calculated his average, he did not think of this. When I laid his numbers out in the data table, the problem with his data became immediately apparent to me, and might have become apparent to him. Data tables can be useful for helping us to visualize patterns in our observations.

The experiment which followed the Alka Seltzer™ was complicated, and the students had to keep track of many different observations. If the need for data tables was going to arise, it would have arisen in this experiment. Sure enough, many of the students recorded their observations in data tables. Unfortunately, they only recorded information which would fit in the table, not any other interesting information. Data tables, then, are a tricky item to teach. Teachers must both teach the use of data tables and ensure that students do not forget what else must be recorded.

Comparing Katie's first draft of the Acid-Base experiment to her second draft illustrates quite well the weakness of data tables, versus the strengths of narrative writing. Her first draft was an elementary data table. In the margin, she indicated her "explanation" by writing a capital "B" beside her first entry, a capital "A" beside her second, etc.

Base and Acid
B Hydrogen peroxide and cabbage juice; The cabbage took over nothing happened with the coffe filter.
A Lemon juice and cabbage. It formed a layer of pink and red the coffe filter got pink.
B Soap and cabbage juice It made a layer of white and blue the coffe filter got blue.
A Water, baking soda, cabbage it got dark blue on the top, light blue and light green and dark green and white in the bottom the coffe filter got brown.
...

I guessed the "A" and "B" represented acids or bases, but had no clue about which chemical she meant was an acid or base. I called her aside to ask her what her observations meant, and to tell her that I couldn't tell from her list of reactions what she had done. In the following extract from her second draft, I have put in bold her elaboration on the letters "A" and "B":

> Chemistry: Base and acids expariment
>
> First we got hydrogen per oxide and cabbage juice took over and nothing happened. **We Also thought it was a base.**
>
> Then we got lemon jice and cabbage juice and we mixed it together and saw that it formed a layer. Red was on the top and pink was on the bottom. It made a chemical reaction. Then we dipped a coffee filter paper and the coffee filter turned pink. **Also I thought it was an acid because the lemon jice had acetic acid in it.**
>
> Then we mixed liqued soap and cabbage juice. We saw that it formed a layer of white on top and dark blue on the bottom and then we dipped a coffee filter paper and it turned blue. **Then we thought it was a base because liqued soap is not an acid.**
>
> ...

In this draft, Katie has described what she and her partners did, what they observed. In the bolded sections, the written elaboration of what the letters "A" and "B" meant is, in the first case, merely telling me that she actually meant "base" for the letter "B." However, in the second and third cases, she explained her reasoning for her decision. It was interesting to me to learn that her identification of acids and bases had nothing to do with the chemical reactions with the cabbage water and the turmeric.

Only twice did students place data tables in the text of their narratives. Nathan, who usually chose science fiction for his writing genre, wrote a lovely story about the stained fabric experiment. The premise was that he was writing a newspaper report on the most effective stain remover. The other example was Levine, a recent immigrant from Hong Kong, recording her results of the acid/base tests. Her table indicated the different colours which she could make.

Acids/Bass Experiment

This experiment is a funny one in al the experiment. And this experiment we can use the chemicals to make the beautiful colours. This is a table for colour.

Liquid	+	The other chemical	Colour
Cabbage juice	+	Amonia	Green
Cabbage juice		Vinager	Lighter purple
Cabbage juice	+ vinegar	+ Rubbing Alcohol	Light Pink
Light pupple	+ Green	=	Dark Blue
Light pupple	+ Green + Vinegar	+ Baking Soda	= Dark Purple
Baking soda	+ Cabbage juice	+ Vinegar	= Blue
Green	+ Hydrogen	Peroxide	= Yellow
Yellow	+ Rubbing	Alcohol	= Dark Yellow

In this experiment I learn is how to share the idea to make colour and what we are doing.

And we are very careless, to put the green on the paper so we use vinagar to clear it. That work. That is really cool for me.

The purpose for the experiment for Levine was to make different interesting colours with the chemicals she was given. She made no attempt to categorize the chemicals according to whether they were acids or bases. Her data table lays out a fairly clear set of instructions for the kinds of chemicals to mix to get the colour in the end column. It could have been improved by including the amounts of chemicals that were mixed in each case.

My conclusion about data tables is that, although the students spontaneously organized some of their information in a style which resembled data tables, they did this to avoid writing. They needed much more intensive teaching on how to use data tables as tools for making connections between science concepts. One thing I could (should) have done was to ask the students to attempt to reproduce their results from their experiment write-ups. They would have noticed the importance of recording the amounts of chemicals they mixed. If, at the same time, I was teaching them about listing amounts in their data tables (something else I should have done), they might have gained a greater understanding of the usefulness of this tool.

Summary

In this chapter, I attempted to do three things. From a review of literature on discourse, and by thinking about what the students in the study were writing, I identified a number of literate tools I thought would be useful for students for demonstrating the links between science ideas. Second, by examining the students' writing, I attempted to determine what tools the students actually used. There was quite a range in this grade 5/6 classroom. Third, I was sensitive to whether the students were developing science concepts through their writing. This last is the most interesting question to me, but also the hardest to answer. As noted in the beginning of the chapter, it is very difficult to tell if students who express ideas more clearly are more fluent in language, or are thinking more clearly. Further, it is difficult to determine if the connections students make are a result of their writing, or of some other factors, such as talking, or responding to feedback from me, or possibly just thinking further on the issue.

As answer to the first question, I identified transitionals and data tables as tools which might be useful for demonstrating connections between ideas. Some transitionals are used in both speaking and writing, whereas others I examined were strictly literate. Transitionals also take different forms, such as conjunctions, punctuation, paragraphs, headings, announcements, and implicit rules. Lastly, transitionals played different roles, linking ideas in different relationships. Some transitionals might link ideas logically, others might link them temporally, others additively, or comparatively, or in subsidiary relationships. To help in my analysis of how students linked ideas together or alerted their audiences to what they would be discussing, I also separated their language into idea units which had both a subject and predicate explicitly stated. Thus, adjective and adverb phrases were not separate idea units, but a second object for a predicate was.

Using idea units as the fundamental component of ideas, I could examine how students linked ideas together. Importantly, but not surprisingly, I found these students were more adept at using transitionals which are available in both spoken and written language. Interestingly, as far as just literate tools go, students had great trouble with punctuation, demonstrated especially in their inability to delimit sentences. Further, many students were not familiar with paragraph structure. Some students quickly acquired the literate tool once I explained the purpose of paragraphs. A more common tool was the oral/literate one of announcements. The announcement was something I defined as a form of transitional because I noticed the students using it.

Generally, I found that all students used periods, although they used many sentence fragments and had many run-on sentences. Only about half used commas, and very few used other kinds of punctuation. Nearly all the students used announcements, yet only about half used paragraphs. Nearly all the students organized their writing in clear chronologic fashion. Those two who did not write chronologically showed that they understood the chronology, and even seemed to understand that it was important. However, they did not bother to refine their writing to chronological order, instead adding details when these returned to memory.

All the students showed additive and temporal relationships with their transitionals. About half the students showed logical relationships with their transitionals, and even less demonstrated comparative and subsidiary relationships. I would guess that students saw their experiment write-ups as story-telling, and so used the additive and temporal transitionals. Also, story-telling is a familiar format to grade 5/6 students. Although I encouraged the students to attempt to explain their results in their write-ups, only some of the students accepted this challenge. Without attempting to explain, there would be little reason to use logical transitionals. Students were not specifically asked to compare or to indicate relative importance of ideas. This is possibly why so few students used comparative and subsidiary transitionals.

An interesting finding is the one regarding whether the style of science writing facilitates learning in science. In the genre of science, writing is dense, much is implicit (Lemke, 1990; Gilbert & Mulkay, 1984; Sutton, 1996). However, when I examined students' explanations, I learned more about where they might have gone wrong when they wrote less densely, when they made more of their thinking explicit. It would seem then that writing in a science style would not help the students to develop science concepts if that development were associated with a teacher making comments on their writing. Also, I found that Viola's writing about her reasoning for her calculations was more explicit than her description of what she did and observed. She seemed to be using her writing to clarify her own thinking, rather than to communicate what had happened. Although I wanted Viola to communicate what had happened, and encouraged her to do this, I should perhaps have had a format for students to write for their own understanding - something which would not have been read by me and certainly not evaluated.

Writing is a useful tool in that the students' writing was a location for me to encourage each student to go beyond what s/he was already doing. I could give individuals advice about particular writing and science problems. I asked individuals to clarify those aspects of their descriptions and explanations which were unclear. And I encouraged all students to attempt to explain their results. Some of the students accepted the challenges, others didn't.

I found that students generally demonstrated the use of language tools in their talking before they did in their writing. Not surprisingly, students used more language tools that were both literate and oral than those which were just literate. Also, they displayed the tools required for the context. In other words, it was perhaps because the students were asked to explain that far more used logical transitionals than used comparative or subsidiary transitionals.

I found this group of students to be contrary to some other research on the differences between writing and talking. Chafe (1985) noted that writers link ideas with more subordinate conjunctions than do speakers. But I found the students used as many of the transitionals that are available to both speakers and writers in speech as they did in their writing. This was consistent with Hildyard and Hidi's (1985) findings that children in grades 3, 5, and 6 were not yet expressing all the advantages of writing. Further, Viola used a logical transitional in her speech, something she did not do in her writing. I concluded that Viola was not developing science concepts by writing, but rather using her science as an opportunity to improve her writing. Her ability to show chronological and logical relationships in her speech was in advance of her ability in her writing.

All the students organized some of their information in a style which resembled data tables, but they seemed to do this to avoid writing. When they used lists or tables, they tended to leave out important information. They needed much more teaching about how to use data tables effectively.

In this chapter, I pointed out some of the literate tools that children might use n science writing, and then examined the students' writing to determine if the students generally used these tools. In the classroom, there was a wide range of literate abilities. I found that the genre of science writing is not a useful genre for learning, since the style is dense, and it is more difficult for the teacher to respond to the child's thoughts. I also found that students need more formal teaching on the use of data tables for them to be an effective tool for students to re-organize information. In Chapter 5, I will specifically look for examples of student learning of science concepts.

CHAPTER 5

WRITING AND LEARNING

Introduction

The question I will address in this chapter is whether students in this class used their writing to learn. In Chapter 3, I defined learning in science to be a change in the way we perceive the world. An indicator that we are changing the way we perceive the world is when we make connections between science ideas. When we connect ideas, we see relationships between the ideas, and that could be considered a change in perception. When we use those connections to challenge our earlier conceptions, learning of some kind will take place. Later in this section, I will discuss different kinds of learning.

Conceptions seem to have a theoretical basis. There are many things to observe in the world, and we can focus only on some. When we observe one thing over another, it is usually because what we observe fits with our theories of how the world works. For example, Kuhn (1962/1970) described an experiment in which people were to identify playing cards which were flashed at them. Some of the cards were anomalous, such as a black four of hearts. The subjects in the experiment, however, identified the cards as either a card of the right colour or the right suit. Kuhn argued "it was immediately fitted to one of the conceptual categories prepared by prior experience" (p. 63).

When I read the students' first drafts of their experiments, I could not tell if the students had the kind of implicit theories that Kuhn described. It is difficult enough to discern my own implicit theories. Consequently, the research in this dissertation was not designed to determine students' implicit preconceptions. Rather, since I believe that explicit explanation is important in science, I encouraged the students to try to explain what they were observing in their science activities. The easiest way for me to look for changes in conceptions was to look for changes in their explanations.

Driver (1988) argued that learning meant changing. Schumacher and Nash (1991) pointed to three different kinds of learning; one kind involves accumulating more details, one involves articulating one's theories to fit with the world (making connections between ideas we have constructed and the world as we see it now), and one involves rejecting earlier conceptions and replacing them with other conceptions. Vygotsky (1934/1986) argued that children should make connections between their spontaneous (everyday) concepts and scientific[8] (scholarly) concepts.

Some theorists from the writing to learn movement have suggested that in writing, students are more likely to see contradictions in their ideas (Emig, 1977; Goody, 1977, 1987; Fondacarro & Higgins, 1985). When students see their contradictions, we would hope that they would work to resolve them, and thus further develop their science concepts.

The writing the students did in this study was done as first draft, then second draft. I was hoping with this format students would have more opportunity to use their writing to develop their science concepts, and I would have opportunity to observe this development - by watching for changes. Consequently, what I look for in this analysis is first, if students changed their explanations from their first drafts to their second drafts, and, second, whether they contradicted themselves within one draft.

Note, however, that it will not be possible to make a direct link between students changing conceptions and their writing. If I see that a student has changed perceptions, that might be because of further thinking on the topic, and might have nothing to do with the writing. In a search for further evidence that learning might have taken place because of writing, I made two other analyses. Drawing on the results of Chapter 4, I looked to see if the literate tools the students used could possibly (logically) have brought about students' changes in conceptions. And, I compared the students' writing and talking. This comparison was to attempt to determine if students demonstrated more learning in their writing than in their talking.

To help me determine if learning was taking place, I used Schumacher and Nash's (1991) taxonomy of learning. Schumacher and Nash noticed that, in much of the writing to learn research, the final "measures of learning emphasize the amount of knowledge the individual has rather than whether the writer has come to a new understanding or conceptualization of the topic" (pp. 70-71). Then they presented a taxonomy of learning, one which included three dimensions.

The first dimension which Schumacher and Nash described was "accretion," or accumulation of detail. This is not the kind of learning addressed in this dissertation. The second dimension is "tuning," in which students modify what they have learned to apply in novel situations. The third dimension Schumacher and Nash

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[8] When I refer to Vygotsky's concepts, I will use the term commonly associated with him: "scientific

referred to was "theoretical shifts," which represent significant changes in the meaning of concepts and events. In the first paragraph in this section, I mentioned that the work the students engage in might cause them to challenge their earlier conceptions. If their earlier conceptions survive the challenge, that would be an example of tuning. Tuning would be apparent if they adjusted their earlier conception to address the challenge. If they reject their earlier conceptions and replace them with new ones, that would be an example of shifting. Tuning and shifting would be most apparent in students' explanations for their experiments.

I draw on Schumacher and Nash's notions of "tuning" and "theoretical shifts" to examine the kinds of developments that students demonstrated in their writing and talking. However, Vygotsky noted that children should connect their spontaneous concepts to scientific concepts. Consequently, as I was analyzing the kinds of learning that took place according to Schumacher and Nash, I also watched for how or if students made connections between their spontaneous concepts and scientific concepts.

I would like to emphasize one more time that the evidence of learning is not conclusive. The writing and talking that students do are merely windows into the children's thinking - and those windows do not allow clear focus. Students might not have been learning science; rather they might have been learning how to be better translators of their thoughts for me, their audience. However, in some cases, the evidence suggests that the students were indeed learning science; when students shifted from one explanation to another, that would suggest that they had indeed

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concepts." When I refer to ideas that children get in science class, I will call them science concepts.

undergone changes in science understanding. Nevertheless, conclusions in this regard can only be tentative.

Besides the question of whether learning was taking place, the other question that cannot be decisively answered is whether the learning taking place resulted from writing. It is far easier to decide if students learned than to decide if they learned due to their writing.

In the analysis, I will first seek what kinds of learning were taking place, either tuning on shifting. In this analysis, I will compare student talk and writing. I am hoping by this method to be able to make some inferences about whether writing was an effective learning tool. Next, I will look at the students' writing, looking to see if any literate tools seemed to contribute to students' development of conceptions. I will also examine the students' writing to determine if students who contradicted themselves in their writing detected these contradictions.

Analysis of Learning

Evidence of Tuning

Schumacher and Nash described tuning as a modification of what students already know, so as to apply it in other situations. At times, I introduced the students to scientific concepts regarding the chemistry unit. When students began to apply scientific concepts to their everyday experiences, I considered this to be an example of tuning. In Vygotsky's terms, students were "growing" their scientific concepts down to their spontaneous concepts.

An example of a student using a scientific concept to make sense of an event occurred when Thomas noticed that baking powder reacted with water, but baking soda did not. He remembered from class that baking soda is sodium bicarbonate. But, I had told them that sodium bicarbonate is a chemical compound with different properties from those of the element sodium. He reminded me that I had told the class that sodium reacted with water. He guessed that baking powder had sodium in it; he guessed that, unlike the sodium in baking soda which was unavailable to behave like pure sodium, the sodium in baking powder was available for reacting. Thus, he had taken his knowledge from class, a scientific concept, and applied it to explain the difference between baking soda and baking powder. Thomas had a pseudo-concept, but he was attempting to use the scientific concept in an appropriate context.

A second kind of tuning might be when students make their explanations more clear, displaying their reasoning. Although I have many examples of students better articulating what happened, or better articulating their understanding, between first and second draft, it is not possible to tell if the students have learned. It is possible they have merely articulated their ideas more clearly. To illustrate, I use an example from Joan's procedural description. In the excerpts of Joan's writing, I put the transitionals in bold and number the idea units. In her first draft, Joan described what her group did for their Alka Seltzer™ experiment:

> [1]**First** we got 1 alka-seltezer tablet [2]**and** put 100 ml into the graduated cylinder [3]**and** turned the graduated cylinder into the jar [4]**and** all the was came out in 58 seconds.

I commented that I didn't understand what they had actually done, and asked a specific question: "Did you put the tablet in the graduated cylinder and then add 100 mL of water?" Joan's second draft was much more clearly described:

> [1]**First**, we got 1 alka seltzer tablet [2]**and** filled the graduated cylinder with 100 ml of water. [3]**Then** the alka seltzer tablet was put in the cylinder. [4]**Then** we turned the cylinder into the jar [5]**and** all the water came out of the cylinder and into the jar in approximately 58 second.

Joan has made her writing much more clear by adding several words, and one transitional and one idea unit. The idea unit she added described dropping the Alka Seltzer™ tablet into the graduated cylinder. The few words and the one idea unit helped me understand better what her group had done. However, I am sure that Joan understood what her group had done all along. What changed was her elaboration of the details. Thus, I don't consider her better description to be an example of learning in science. What I believe Joan learned is anticipation of the needs of her audience. She learned how to be a better writer.

The following is an example of a student, Steven, tuning an explanation. Because this example examines explanation rather than description, there is a question of whether Steven understood the second draft articulated details when he wrote his first draft. Although I cannot be sure if Steven learned, or merely articulated his ideas more clearly, the articulation increased the potential for learning because I became more aware of what he was thinking, so I could address discrepancies between his concepts and those of science.

Steven's home experiment involved putting a balloon on a bottle, and putting the bottle in the freezer. The balloon ended up inside the bottle. In the following excerpts of his writing, I have bolded the transitionals, and numbered the idea units. His first explanation was succinct: "[1]**The reason for this** is that [2]cold air contracts." He then put the bottle in hot water, and noticed the balloon "blew itself up," and gave the reverse explanation. I wasn't satisfied with such a succinct explanation, so commented "Why would something get smaller just because it got colder and then get bigger because it got warmer?" He explained the shrinking balloon more explicitly in his second draft:

> While it was in the freezer it started to get smaller I left it in the freezer for 1/2 hour and the balloon went into the bottle.
> [1]**Because**: [2]In cold air the molicules move slow, [3]**therfor** there is little space inbetween each molicule [4]**so** the **colder** it gets [5]the **less** space.

Steven used five transitionals instead of the one he used in his first explanation. He increased the number of idea units from two to five. Most importantly, Steven more clearly articulated the mechanism for why the air would contract when it got colder.

As with the sample of Joan's writing, perhaps he already understood the details in his first draft, but hadn't expressed them. I cannot be sure if he has actually learned more science or if he has just explained what he knew more clearly. But with the clarity of the second explanation, I was able to recognize the accepted science explanation for the change in volume of air with change in temperature.

Schumacher and Nash suggested an example of tuning would be when students began using their new skill or knowledge in more tacit, less explicit, ways. Although I agree that this would be an example of students becoming more adept with their knowledge, I cannot use this in my study. Once students no longer made their knowledge explicit, I was no longer sure of its existence. Further, part of what I was encouraging the students to do in this unit was to make their knowledge more explicit.

Evidence of Theoretical Shifts

Schumacher and Nash noted there were different degrees of theoretical shifts. In this research, students were just beginning their study of one particular domain of science - chemistry. Thus, the major kinds of theoretical shifts (changes in world views) were not likely to occur for these students. These students did not know much about chemistry, so had not connected, for example, the kinetic molecular theory to their everyday notions of how the world works. Thus, I was seeking evidence of minor theoretical shifts, where students rejected one theory or hypothesis to replace it with another.

At times, I introduced the students to scientific concepts. The students also invented their own explanations. Ziman (1984) described a range of intellectual activities scientists engage in, only some of which can count as explanations. Scientists collect primary information about the world, which, Ziman noted (p. 14) is "essentially descriptive." Since an accumulation of detailed descriptions of particular objects and events would not be manageable, the descriptions are, as much as possible, turned into generalized statements. Also, scientists attempt to find classes of events about which generalized statements can be made. I do not consider description to be explanation, simply because we do not explicitly state the basis for selecting the details we used to describe. However, once we turn these descriptions into generalized statements, there is an implicit rationale for choosing the characteristics that are important to abstract out of the empirical situation. Thus, generalized statements could be considered proto-explanations. I called these generalizations "summaries".

According to Ziman (1984), within taxonomies of information, we seek patterns of invariant associations, which are natural laws. With natural laws, the basis for selecting details is a little more explicit than it is in description. Natural laws could be considered a proto-explanation. None of the students attempted to create their own natural laws.

In the actual category of scientific explanation, Ziman noted "the characteristic form of a scientific explanation is a rational argument linking an assembly of empirical facts with a general conceptual scheme" (p. 24). Ziman noted that any explanation should explain more broadly than that which it set out to explain. A specific example of a natural law might be explained by the general law. For example, the reason lemon juice and baking soda react could be explained through the natural law that acids react with bases. The more an explanation explains, the "stronger" it is. Using a natural law to explain a particular case of the law is a weak explanation. Stronger explanations tend to rely on postulated entities.

Ziman noted that "[I]deally, the explanatory relationship should be strictly logical" (p. 25). What he did not add, but Pepper (Roberts, 1982) did was that mystical and animistic connections are considered illogical in science. Causal relationships are considered logically connected, but what cause do we want to know? Does vegetable oil float on vinegar because someone poured the two together? Or does it float because it is less dense, or because of the arrangement of vegetable oil molecules versus the arrangement of vinegar molecules? The cause which explains the most would be considered the strongest explanation.

Ziman noted that many explanations are dependent on analogies. Postulated entities have been created, and these entities explain more than just the density difference of the two substances. Models are analogies or metaphors, helping us to visualize postulated entities.

Lastly, Ziman described theories, which are "ordering principles that explain general classes of observational and experimental facts, including the taxonomies, "laws," causal chains and other empirical regularities that are discovered about such facts" (p. 28). Schwab (1961) pointed out that theories determine the kind of data we seek. We select from a plethora of experiences the primary descriptive information which our theories direct us towards.

Some of the cultural tools that scientists use, then, are 1) primary descriptions, 2) summaries of primary descriptions, 3) patterns leading to the creation of classes of phenomena, 4) more or less invariant relationships between phenomena (natural laws), 5) causal connections between events, 6) logical connections between ideas, 7) analogies and metaphors, 8) models, and 9) theories. Primary descriptions are not explanations. 2, 3, and 4 could be considered proto-explanations. There is some attempt to make explicit the connections the researcher has chosen as important. The last five can all be considered explanations. The connections between phenomena are made explicit.

In this study, I encouraged the students to explain their experimental results. Sometimes students did this by generalizing or summaring what had occurred. I considered this to be a proto-explanations. Students also sometimes attempted to make logical or causal connections between events. And lastly, students sometimes drew upon postulated entities, what Vygotsky (1934/1986) considered to be scientific concepts. As I sought changes in what students were learning, I watched for differences in students' explanations between their first and second drafts. I also examined their thinking tests[9] to see if and how they changed their explanations within the twenty to thirty minute discussion.

Examples of theoretical shifts would be when students decided that their preconceptions were wrong, or if they had attempted a particular explanation, then changed to a different explanation which they could justify more completely than the earlier one. Mary's home experiment involved sprinkling pepper on water, then dipping her soap covered finger into the water. The pepper scattered away from her finger. As with Steven's writing, I have bolded Mary's transitionals, and numbered her idea units. In her first draft, she wrote:

> **Why I think it happens:**
> [1]**I think** [2]the soap breakes the surface tention of the water. [3]The water at the edges of the dish pull away, [4]the pepper flows with the water.

I wrote back, asking her what surface tension was, and suggested she try some related activities to learn more about surface tension. She adjusted the experiment by adding a new test, trying the same activity without soap on her finger. She noticed that without soap, the pepper did not scatter. This time she no longer used the surface tension explanation. Instead, she related what had happened to what she knew about chemical reactions. In her second draft, she wrote:

> **Why:**
> [1]**I think** [2]that some thing like a chemical reaction happened [3]**because when** I was waiting for the peper to calm down, [4]I saw the pepper giving a sort of oil texture [5]**and I think** [6]that that texture reacted with the soap! [7]I tried without the soap on my finger [8]**and** nothing happened!

---

[9] The thinking tests were videotaped discussions about a particular phenomenon. Each test involved three students and myself. They are the main source of data for student talk.

Mary increased the number of idea units from four to eight. Two of the idea units described the other test she tried, but they were integral to her explanation. She wanted to illustrate that a chemical reaction had taken place. She also increased the number of transitionals, using "I think" in both the explanations, indicating that she was about to speculate. But in the second explanation, she added a logical transitional which did not appear in the first. This might demonstrate that she was more clearly aware of attempting to convince me, or it might demonstrate that she had become more aware of the connections between her ideas.

However, the number of idea units and transitionals are not the main point of this example. The main point is that Mary rejected her original theory and suggested a second one. I guessed that she changed her explanation to put it into terms that made sense to her. The surface tension explanation is the accepted explanation for this phenomenon, but without understanding what surface tension is, Mary would have had only the word, not the meaning. She had a term, but not a scientific concept. Mary did not attempt to "grow" this scientific concept down to her spontaneous concepts. I consider the change that Mary made to be an example of learning in science, even though what she learned was not the accepted explanation for the particular phenomenon.

<u>Contradictions</u>

As well as looking for examples of shifting and tuning, I looked at the students' writing for examples of them contradicting themselves. When I noted contradictions in the first draft, I could point them out to the students, but some of the researchers on writing believe that writers should notice these contradictions themselves (Goody, 1977; Fondacaro & Higgins, 1985).

An example of a student contradicting himself in his writing comes from Emile's writing for his Alka Seltzer™ experiment. In his second draft, Emile made his explanation more explicit in response to my comments. With the greater detail he added, I detected a contradiction. But Emile obviously didn't detect this problem. (I was a critical reader of Emile's writing, yet it was on the third reading of his report that I noticed the contradiction. I can understand why students would not notice contradictions in their thinking with only writing as a tool.) In the following example, I have bolded sections to illustrate the contradiction.

> Our group took the millilitre measurer and poured 20 mL of water.
> **We poured one tablet of alka-selser to the 20 mL of water, it started bubbling to the full capacity of 75 mL.**
> Then we measure **again 20 mL of water**, this time we dropped the **alka-selser by quarters**.
> We discovered that **each quarter of alka-selser would raise the level by 5 mL which tells me that the molecuelar energy of the alka-selser is about 20 mL.**

I will discuss this sample of Emile's writing in the sections on tuning and literate tools, as well as in the section on contradictions. For now, I will focus just on the contradiction. In the first bolded section, Emile recorded that one whole tablet raised the water level from 20 mL to 75 mL. In the second bolded section he described the procedure for the second test, where his group decided to break the tablet into quarters. In the third bolded section, he recorded that each quarter raised the level by 5 mL, and calculated the total that one tablet would raise the water level. There is a contradiction between the results of the first test and the second test. In one, a whole tablet raised the water level by 55 mL, and in the second, a whole tablet was calculated to raise the water level by 20 mL. Neither writing, nor the mathematical manipulation of the numbers, seem to have pointed out this anomaly to Emile. Thus, in this case, writing was not helping Emile to learn.

Literate Tools

In some cases, I looked for changes in the literate tools that a student used in the first draft to the second draft. Then I looked for evidence that the student had learned. The possibility exists (but not the certainty) that the student learned because of using the literate tool. In the last chapter, I gave the example of the data tables that students used and pointed out how these tables did not help the students to compare observations. The data tables might have helped the students to find patterns, but, unfortunately, I did not teach them how to use data tables in this way.

However, there were also the literate tools of transitionals. I will look for examples of such things as punctuation, paragraphs, etc. changing the ways in which the students related their concepts to one another.

Students' Learning as Inferred from Writing and Talking

Tuning

Priscilla's home experiment is the only example I have of more than one draft for her writing. Unfortunately, she did not hand in two drafts for any of the other assignments. For her home experiment, she chose to test if hot pepper when mixed with water would make her skin hot, and if baking soda would then cool her skin. Her conclusion:

> The hot spicy mixture reacted with my skin and made it feel hot. It was a chemical reaction and the baking soda helped stop this burning

sensation because it is basic and helps balance out the other chemical reaction.

From her explanation, I was not convinced that she understood either chemical reactions or what she meant by baking soda being basic. I asked her about whether her skin felt hot because the cayenne pepper had been mixed with hot water, or because there was a chemical reaction. I also asked if baking soda and cayenne paste would react with one another if they weren't on her skin. She responded with:

> My experiment with cayenne pepper started with hot water because I know from other experiments that I have done that substances dissolve better in hot water than in cold water. I then let it cool down because I didn't want to be fooled by the "temperature" hot rather than the "chemical reaction" hot. The water was room temperature but went I put the solution on my arm it felt hot.
>
> I tried the cayenne pepper today without mixing it and when I put some of the cayenne powder on my wrist it didn't feel any different. I think that this is because you need to add water to get the chemical reaction out of the spice. I know that if you taste it on your tongue that it makes your tongue feel like it is burning. There is saliva on your tongue and it probably makes the spicy reaction.
>
> I took our thermometer and put it in the bag of cayenne pepper and nothing happened.

Priscilla tuned her explanation. She still believed cayenne pepper caused a chemical reaction on her skin; now she tuned the explanation by adding that water was required for this reaction to take place. I asked her more questions: I pointed out that garlic caused the same sort of feeling of heat on tongues and in eyes. I asked if the feeling of heat was because of the nerves being stimulated or if a chemical reaction released heat, which stimulated the nerves. (I still wanted her to measure the temperature of the water-cayenne mixture with a thermometer.) Last, I asked her "Why does baking soda cool the skin? Is there a chemical reaction between the cayenne and the baking soda?"

She responded with:

The hot feeling in your eyes from garlic is a type of reaction but garlic isn't a chemical so I don't think it is a chemical reaction. I think that people, like Mexican people, eat spicy foods all the time and they don't think these foods are hot. I think this is because they get used to it. I'm not used to spicy foods so they feel hot and taste hot to me. Maybe their taste buds are no longer as sensitive as mine.

...

When our hot tub is too acidic we have to add baking soda to make it less acidic. I think that the sodium bicarbonate and water mixture helps stop the acidic reaction on my skin, just like it makes the hot tub water not have so much acid. My mom says that it makes the water more alkaline and that alkaline is the opposite of acid.

In the first paragraph, Priscilla demonstrated that she did not understand what chemicals or chemical reactions were. This lack of understanding became clear to me as she tuned her explanation in response to my questions. I was able in her last draft to address some of the issues which she revealed in this last explanation.

Did she tune or shift her explanations in her talking? Prisicilla, Thomas, and Henry worked together for their thinking test, the test involving the difference between baking soda and baking powder. An important aspect of the discussion to notice is that Thomas dominated, making it difficult for Priscilla to develop her ideas out loud. Although she attempted to express her ideas, Thomas was willing and able to interrupt both Priscilla and me.

This section of the tape, from very near the beginning, was when Priscilla first put forth an explanation:

P You know ... I always wondered ... I always wondered what
  the difference was
T That's sodium. [indicating the baking powder jar]
  That's sodium. This has sodium in it right. And it reacted with
  the water? And this doesn't react with the water. The sodium
J So you think this doesn't ... baking soda doesn't have any
  sodium in it?
T It has sodium bicarbonate but not just plain sodium.

P Because sodium bubbles up but bicarbonate stops it from bubbling up

T But it's probably just not that pure. Just have a little bit of sodium 'cause otherwise it would bubble up a lot more.

Priscilla seemed to be arguing that bicarbonate in baking soda suppressed the sodium so it couldn't produce bubbles. This demonstrated a misunderstanding of the concept of a molecule. Thomas, on the other hand, pointed out that sodium bicarbonate did not have "just plain sodium," indicating some sort of understanding of molecules. His last statement, that the sodium in baking powder "was not that pure," however, seemed to negate his understanding. Priscilla seemed not yet to understand the difference between compounds and elements, and Thomas was at a preliminary and uncertain stage in his understanding. The difference in their interpretations might have been because of something completely different, though. Thomas thought there had been no chemical reaction between the baking soda and water, whereas the baking powder had reacted. Priscilla thought that both the baking soda and baking powder had reacted because she had noticed bubbles rising from both of them.

In the next section of the tape, Priscilla pointed out some empirical differences between the two jars, and attempted to further her explanation:

P Can I see this one. [Picks the baking soda jar up.] It's sticking to [?] It just stays there. It's firm. Looks like there's something in the water. It looks like the bicarbonate is putting pressure on it and making it stay on the bottom so the sodium can't bubble up.

T I think it is just that the sodium the sodium is pretty heavy so ... it is heavy in the water so it just sticks to the bottom and it can't react. It has no chemical reaction that will happen so it just stays there ... like that ... um if that most of the stuff if you put your finger in there or something you'd feel all the

stuff at the bottom and you but the sodium went up just the sodium nothing else.
P	I think this one's lighter [baking powder] and that one's heavier [baking soda] so that one stays to the bottom.

Priscilla was apparently tuning her earlier suggestion. Baking powder is lighter, baking soda is heavier, the sodium in baking soda went to the bottom, and the bicarbonate kept it down so it couldn't react. The lighter baking powder could react with the water. Immediately after the above exchange, Priscilla added more empirical evidence suggesting that a chemical reaction had not occurred between the baking soda and water:

P	'Cause you can just move that one around while shaking this one around [she holds and jostles the baking soda jar] and it just stays there.
T	'Cause it's heavier probably. Just like oil and water do the same thing
[They both stop talking and look at me.]
J	OK. What about this? [indicating the jar with baking powder]
P	[looks at it closely] I think it combined with the water. It mixed together 'cause you can't see water.
T	Maybe the un uh I bet I think it got chemical reaction and it tastes a little bit like water and a little like bit like baking powder. Or we just it just made made a totally new taste.
J	A totally new taste?
T	Yeah.
J	What would that totally new taste be a sign of?
P	Yeah.
T	A chemical reaction?
J	Do you want to say anything? [to Henry]
P	I agree.

Thomas had decided that baking powder might have chemically reacted with water, compared to the baking soda which had not. The baking soda and water were like oil and water, but the baking powder and water might have made a totally new taste - one of the signs of a chemical reaction which had been discussed in class. Priscilla seemed to agree with Thomas' explanation. I had the impression earlier that

Priscilla believed both baking soda and baking powder reacted with water. If my initial impression was true, Priscilla now had shifted her understanding.

However, Thomas and Priscilla had different conceptions of the word molecule. Thomas had learned the scientific concept that a molecule was a different substance than the atoms that made it up. Earlier, he had struggled with this, but in the following exchange, his understanding became apparent:

P What's pyrophosphate? Something like that.
T Is that the uh phosphorous?
J It has phosphorous in it and has oxygen in it and I'm not sure what the pyro is.
T There isn't, there is sodium in there, but it might be might just be a different kind.
P There's lots of sodium in there.

Priscilla said there was lots of sodium in baking powder, yet sodium was never mentioned once on its own. Thomas mentioned that it was a different kind of sodium; in other words, it would not act in the same way as the element sodium would.

Priscilla went on to elaborate on her earlier suggestion, still tuning her idea that the baking soda was heavier than the baking powder, so that the sodium would stay low and not be available for reacting.

P Well I think that um maybe there's some chemical reaction to tha - this is similar to Thomas - to um in the baking pow baking soda and that um since there's different chemical reactions um maybe there's a little more um of sodium or there's something in the baking soda that causes it more weight and that the baking soda would just stay down to the bottom um and that that baking powder is more light and maybe it has something in it lighter and so when the water and um baking powder mix together it reacts to it and it floats up because maybe the um the uh sodium uh the baking powder is lighter than the water so it bubbles up.

However, at the very end of the tape, when Thomas finally made clear his chemical reaction explanation, that the baking powder had both a base (sodium bicarbonate) and an acid, so that a chemical reaction could occur as soon as it was mixed with water, Priscilla seemed to agree:

T Well the baking sodium bicarbonate that's the baking powder no soda. Is it just sodium bicarbonate, nothing else?
J Um hm.
T Maybe it and 'cause there's no that's a base and there's no other acid in it and water isn't a acid or a base so it has nothing to react with so it can't react.
P Can't react with anything.
T And here it has sodium acid phosphorate and sodium bicarbonate acid and a base and react.
P Great.

Earlier, Priscilla had said her explanation was similar to Thomas' when it was very different. This last exchange can be evidence either of her shifting her earlier weight difference explanation, or she might again have misinterpreted what Thomas had said. Without her taking the time to explain what she thought Thomas had said, I cannot be sure.

In the samples I have given of Priscilla's writing, she was more certain, more authoritative, than in her speaking. In her speaking (in this particular group, and in the whole class discussions), she was much more tentative. Despite the tentative style of her speech, she did not seem really to shift her ideas; rather she seemed just to tune her ideas. (I cannot be certain of this, though. She might actually have shifted her explanation at the end, when she apparently agreed with Thomas.) In her writing, in the one example I have of a first and second draft, she tuned but did not shift her ideas.

Shifting

In this section, I examine whether students shifted their explanations in their talking or in their writing. I focus on those students who showed most clearly that they did shift their explanations. The reason for this focus on shifting, as described earlier, is because shifting is most likely to be an example of student learning. If a student changes his/her explanation from one written draft to another, or from one section of spoken transcript to another, I would think the student had rejected the earlier conception for the later one.

I start with an analysis of Adam's talk, since he seemed to demonstrate there very clearly that he was shifting his ideas. However, I will not discuss Adam's writing in this section, since he did not seem to shift his ideas in his writing.

In his thinking test, Adam demonstrated very effective use of oral language to develop explanations. Adam talked a lot during the test. His partners, Brad and Levine, were new to Canada, and were just learning to speak English. However, they contributed to the final explanation.

The particular thinking test involved dipping a two dollar bill into water, then into rubbing alcohol, and then lighting it. When I did this, the two dollar bill burned. (The students were amazed, not so much that the bill burned, but that I would do this. I did not intend that the bill would burn.) The only bill I had left was a ten, so I tried it again (the students told me quite clearly they thought I was crazy), this time leaving the bill for a long time in the water before putting it into the rubbing alcohol. The following section of transcript shows Adam's first attempt at explanation:

A Oh I think I know what you're doing.
L Oh I know ...

J OK. Tell me about it if you know what I'm doing.
A OK. First you're putting it in water because water puts out the flames so you're dipping the ten dollar bill in water and then you're trying to put a little rubbing alcohol on it because it'll it's flammable and then you're trying to light a match and see if it will flame on like uh light up ... and that one didn't work 'cause it did light up but it usually doesn't right? See. [I light the match and put it to the ten which lights up.] Uh uh. Yeah.
J Did it go up? Whooops. [The bill started to burn on the corner, then went out.]
B Cool.
A Now you toasted a ten dollar bill.

Adam's explanation was based largely on what he had observed. He knew that rubbing alcohol was flammable, because he had looked at the bottle. He had noticed what had happened with the two dollar bill, and interpreted (correctly) that I did not want to burn my money. So he predicted that the ten would not burn, which it didn't.

From here, the students noticed that the ten dollar bill was dry. At this point, Adam made another explanation:

A I think it's because um
L the water
A OK the water ... ... mix with the rubbing alcohol I think there's a kind of um reaction or something? I dunno. First you dip it in water. WATER PUTS OUT FIRE.

Adam had drawn on the scientific conception of chemical reactions. In his statement, though, we get little idea of whether he understood the concept or whether he was just using the words. After this section of transcript, Levine attempted an explanation. During this time, Adam must have been thinking. He hadn't given much time to Levine to develop her idea, when he interrupted:

A Oh I know [hand up]
[I look at him. But while A talks, L draws a picture and shows it to B. I hear her say the word "dissolve."]

A OK I think the fire and the rubbing alcohol kind of makes CO_2 and the fire needs O_2 to burn and if there's too much CO_2 or something then it kind of goes off bet yeah
J That's possible. [to L] But "dissolve?"
L [nods]
J You think something dissolved?
L You
A Dissolve [quietly]

In the next section, Adam shifted his explanation, this time using Levine's concept of dissolving:

A I have another idea. I have another idea Miss McVittie. OK I think OK since you put it in more water so water becomes a so water is a solvent and then uh rubbing alcohol you only have a little bit so it's a SOLUTE and solute usually dissolves into the SOLVENT. So rubbing alcohol dissolves in the WATER and if you light it up um puts out FIRE so if you light it up water puts it out so water like it kind of dries it up.

Here, Adam's explanation changed to take on the scientific concept of solution, a concept we had learned in class, and here first introduced by Levine. But this time, we can tell that he understood this scientific concept, since he described the relationship between the words solvent and solute. However, he did not elaborate why one bill burned but the other didn't. I assumed he was claiming that since there was more water, the water could put out the fire.

Brad and I had a discussion, in which Brad seemed to claim that the rubbing alcohol was burning because it was on the bill last. But during this conversation, Adam kept attempting to interrupt. Finally, he raised his voice:

A I don't agree. OK. I disagree. I have a different idea. OK. Since you put it into um water? but you put it into rubbing alcohol like longer? so THAT becomes the solvent and this is the solute so the solute dissolves into and so this time it's the water that dissolves into the rubbing alcohol?
L [Yeah and you put it longer in water.

A ⌊and so rubbing
alcohol is flammable so if you light it up? it goes on fire.
J So what burned here? [indicating the singed corner of the ten]
A It was probably just a little bit of rubbing alcohol on it but most
of them dissolved into the ...

This time, he explained his mechanism more fully. He used the word solvent to refer to the larger volume, so he seemed to be saying it was the ratio of water to alcohol which made the difference. If there was more water, the water could put out the fire; if there was more alcohol, the water couldn't put out the fire. Hence, the two dollar bill had burned, the ten hadn't. I was satisfied with his explanation, and did not question him on it. However, he obviously thought he had missed explaining an important point, despite the lack of questioning from me. The following section begins with me addressing Brad on his interest in the order in which the bill is dipped:

J [to Brad] What would happen if I dipped this in rubbing
alcohol first ... and then dipped it in water?
A Um I don't think it would quite make a difference. It's the
AMOUNT that makes the difference.
B You could do it.
A It's the amount.
B You can do it. This longer and this shorter.
A ⌈IT'S THE AMOUNT.
J ⌊This one longer and this one shorter?
B [grinning. He has indicated longer in rubbing alcohol] Yeah.
This burn.
L This burn.
J And then it will burn.
B Yeah.
A The amount [he puts his hand up] Miss McVittie. I think it's
the amount that the ten dollar bill absorbs I think OK it absorbs
more rubbing alcohol so I think more water dissolves into
rubbing alcohol well OK that means if you have two pieces,
OK that means if you have a little over here and a lot over here.
J Um hm.
A OK this dissolves into that that means it takes some over so
that like dissolves in it in it [?] and then there's still something
like a part of rubbing alcohol left so it'll burn 'cause the water's
gone. So OK *talk about the amount* yeah ... the more the

> longer you put it in the rubbing alcohol so that's more the more the paper will absorb unless it's saturated? and then you put the water. Sometimes if you put it longer in rubbing alcohol it's already saturated right it can't absorb anymore so water if you just put it in it doesn't absorb anymore.

Adam really was unable to contain himself, making several attempts to interrupt. He had to explain what he felt had been unclear in the last explanation. It was the amount, the comparative volumes of water to alcohol. I have put in italics his phrase "So OK talk about the amount" to illustrate the only use of meta-talk which I found in all the transcripts. Adam commented on his talk, to remind himself of what he was supposed to address.

Goody (1977, 1987), Havelock (1963), Emig (1977), Fondacaro and Higgins (1985) all argued that it was in writing that people would most easily be able to reflect back on their thoughts. In Adam's speech, he demonstrated how he could reflect on what he had said and what he intended to say. Further, he tuned his explanation without any interrogation from me. I had been satisfied with his earlier description, which seemed to imply quite well that differences in amount were the issue. But he was dissatisfied with his explanation and interrupted to tell me about amounts. This does not mean that writing isn't a better tool for noticing contradictions. It merely points out that talking is also effective for some people.

Adam made one more attempt to make his idea clear, and in this last attempt, he clarified his notion of the bill being saturated. He had now combined the ratio of water to alcohol explanation with the order in which the chemicals were added. (In both actual cases, the bill was put in the water first. The discussion of order was a hypothetical situation.) This last explanation came after he had explained in

Cantonese to Brad and Levine, and they together had explained to me their theory of amounts and order:

> A [interrupts] I mean. OK. It's it's saturated. It can't absorb anymore. If you dip it in there? it absorbs so much water that it becomes saturated with rubbing alcohol and if you dip it in into that the water probably just takes a little bit out but there's still lots of rubbing alcohol so wherever the money has rubbing alcohol it will burn and wherever it doesn't have it won't burn so the same with that OK so here burn here it didn't so.

To summarize: Adam developed one explanation - that there had been a chemical reaction. Soon, however, he picked up on the word "dissolve" from Levine. He shifted his theory to a solvent-solute explanation, and tuned this explanation more and more, making it more and more clear. Then he used his explanation to predict what would happen if we changed the order in which we dipped the bill. Adam connected his explanation to scientific concepts which had been discussed in class, both chemical reactions and solutions. He was able to draw on his spontaneous concepts and relate these to the scientific concepts.

Adam demonstrated in his talk that he could shift his ideas. There was no evidence in his writing of shifting ideas. This could be because he thought more carefully about what he was going to write; perhaps he could use the writing in the same way as his talk, and not rely on commentary from me on his first drafts. However, there are examples of him tuning his explanations in his writing. I believe that Adam demonstrated more radical changes in his learning in talking than in writing because talking was a more effective learning tool for Adam than was writing. I believe this not just because of the demonstrated shifts in his talk, but also because of the demonstrations of his oral ability for reflection.

I don't want to downplay the importance of Adam's partners in this discussion. Both Brad and Levine seemed to understand quite well what was happening. They did not talk as much as Adam and they did not explain their ideas as well, but they were just learning English. During the discussion the three had in Cantonese, Adam began explaining his theory to Brad and Levine, then Brad interrupted and took over the explanation.

The reason the focus in my discussion was on Adam was because I was able to examine his writing to compare it to his talking (Brad evaded writing when he could, and Levine's explanations were sketchy because of her lack of vocabulary), and because Adam was more able to explain his ideas to me.

In the previous section, where I gave examples of students shifting their conceptions, I used a sample of Mary's writing. She used her writing to shift her explanation from her first draft "surface tension" to her second draft "chemical reactions" in her home experiment. Mary demonstrated she could shift her ideas in her writing. Did Mary also shift her ideas in her talking? Mary's group, like Adam's, attempted to explain why the two dollar bill had burned and the ten dollar bill had not. I did not burn another two dollar bill for this group, but rather showed them the burned two dollar bill, and emphasized the things that I did differently between the two situations. First, I dipped the ten in water while telling the group that I would leave it in longer than I had left the two. Then I quickly dipped the ten in rubbing alcohol, telling them that this would be a much shorter time than the two had been left in. Then I lit the match and put it to the ten. Flames went up, but the fire went out before the bill caught.

Mary worked with Wally and Emile. Wally was one of the most co-operative speakers in the class, often overlapping other students' talk with supporting words. He would repeat what others had said, and agree with them. In this group, Mary did most of the meaningful talk, but the support of the other students must be noted. With Wally's co-operation, Mary could feel more confident about what she was saying. Emile, when encouraged to talk, would explain his ideas, and Mary drew on one of his ideas.

This section of the transcript came just as I lit the ten dollar bill on fire, and represents Mary's first attempt at explanation:

J OK Now ... there is a smoke detector in here and a sprinkler so if ANYTHING goes wrong [exclamations as students look at the ceiling] OK
M Oh oh.
W Nooooooo.
E No [shouts, sounding very agitated]
M [normal tone of voice] Steam
W Steam
M It's burning off the water.
J It's burning off the what?
M Water.
W Yeah, water, yeah.

Why would Mary suggest the water was burning? All the students knew water did not burn, that water was often used to put out fires. I can only think that she actually meant that it was boiling, turning into steam, which was her first observation. I asked her about her conclusion:

J Where are the flames coming from?
M It was burning the alcohol and water.

A few minutes later, I asked them again about what was burning:

J What was burning?
E Just something.
M Well just

W └the water
M └and the alcohol and the water.
J The alcohol and the water?
W Yeah, both were burning.
J Does water burn?
M It evaporates.
W Probably
M └It was evaporating because of the steam the [?]
W └Yeah it had steam, it was evaporating.
J Emile.
E Huh?
J Do you want to say something?
E I already did!

This time, Mary made clear the difference between burning and evaporating. Students can be expected to confuse burning with evaporation when both give off what looks like smoke. Mary had correctly identified what she saw as steam, and now clarified that the water was evaporating, not burning. Notice that Wally supported Mary's ideas, and that Emile seemed to be satisfied with his simple explanation that there was more water. But I was not going to let Emile rest with his simple explanation. I asked him to tell us what he had said:

J OK try it again ... say it again so everyone can listen to you and tell you what they think.
E OK. Well when you put it in the water, it's kind of like a coating, like ... so it doesn't burn ... much but when you put it in rubbing alcohol, it kind of takes it off you burn it? enough to [?]
M Enough to ...
E I dunno.
W I think I know why because
M └And after it burns off the 'cause it burns off because the thing is cold, but when you warm it up, it gets warmer.
J Which is colder?
E It's not cold, it's wet but like when you put the flame it got dry.
┌It doesn't got water
J └OK but the bill was cold ... or wet.
E WET. It was wet.

J And the flame?
E Yeah with the flame it got dry.

Emile explained much that had not at all been apparent before. From what little he had said earlier, there was no indication that he thought the bill had a "coating" of water and rubbing alcohol. Yet he seemed to believe that he had shared his ideas. While stating his ideas, however, when he said "I dunno" he seemed to realize that he did not understand. (I commented on Emile's writing in the section on contradictions, and will discuss it in more depth in the section on literate tools.)

The transcript continued with me encouraging this group to give me an explanation for the difference between the way the two bills reacted to burning:

J Try to explain what happened using your chemistry as much as possible to explain why THAT one didn't burn up and THAT one did burn up. They are made of the same paper, it's not because of the paper.
E Because you didn't put much water in it.
M Yep ... one had a lot more water
W You said you said you put uh the ten dollar bill longer in the uh water

They have now, all three, picked up on the amount of water that one bill had on it versus the amount on the other. Mary's first complete explanation seems then to be that the ratio of amounts of water to alcohol made the difference for whether the bill would burn.

While we went on to discuss other possible differences, Mary began smelling the bills.

[M puts the two dollar bill in front of W]
W [to M] Don't stick it up my nose ... ooooh this smells ... this smells different.
M This part here is dryer and it smells like
W └Like normal
M └Like fire. But this stuff. You don't want to know. It stinks. One side is dryer

than another than the other. So I guess the side that you burn is the dry one.
W Yeah yeah.

Mary was a student who really used her spontaneous concepts, her personal experiences, to understand scientific concepts. Immediately after smelling the bills, Mary developed her final explanation, a very different one from her first one, and one which drew both on Emile's coating idea and the empirical evidence she had collected. In the following conversation Wally made supportive comments; Emile participated very little.

M I have something to add to what Emile said, it probably does have a coating but I don't think, I don't think the rubbing alcohol took the coating off, I think it added to the [coating
W [Yeah.
M like the water just made it, the water probably just made it like damp so it doesn't burn
W [Yeah.
M [and the rubbing alcohol made a coating.
W [Yeah.
M A clear coating of ... alcohol.
J And then what happened with the match?
M Then with the match burnt it
W [When the match burnt it it probably uses the water and just gets steam
M [Yeah I
W [there from the coating stopped it from burning.
M I think it doesn't smell as bad
W the wet side.
M [as the wet side. I think probably this the coating came off and it most of the dampness from the water and this
J [And it doesn't smell like this? [I hold out the jar of rubbing alcohol.]
W, E No, not at all.
M [wafts her hand across the top of the jar in the way she was taught. She leans back so W can waft his hand over the jar.] There go my nasal passages.
[J hands the jar to E.]

W [giggles, picks up bill and smells it] Close, close.
M A little bit like water. Mostly like water though.
W Yeah. [giggling]

This explanation was Mary's final explanation. Her explanation as I understood it was the rubbing alcohol and water did not mix, but rather formed two separate coatings on the bill. The water was on the bill first, so protected the bill from being burned when the coating of rubbing alcohol burned off. But in the case of the two dollar bill, the water coating was not thick enough. Thus, the heat from the burning rubbing alcohol evaporated all the water, leaving the bill unprotected. This was very different than her first simple explanation which was that the water and alcohol were burning, or her second explanation which was that the ratio of the amounts made the difference.

Mary shifted her explanations in both her writing and her speaking. Also, in both her writing and speaking, she better articulated (tuned) her ideas as she progressed, either from first draft to second draft or throughout the thinking test. An important point to notice, a point which will be discussed in detail in Chapter 6, is that Mary drew on her spontaneous concepts for her explanations.

Emile did not seem to shift his ideas in this one example I have of his small group talk. In the tapes of him in small groups in the classroom, he said very little that was on task.

Emile enjoyed the writing assignments. He commented one day that science writing homework was fun homework. His writing had a sense of drama, which made it enjoyable to read. He would often write as if he and his lab partners were scientists working in a laboratory. He would start his writing with the information students had been asked to record for the archaeology unit we worked on before this research began.

In the following example of Emile's writing, I have only focused on his original explanation for one observation, and compared it to his second draft explanation for the same observation. In his first draft, Emile noticed that the Alka Seltzer™ tablet produced less gas when the graduated cylinder was inverted over it, than when the tablet bubbled in the upright graduated cylinder. He did not consider that the gas was escaping when the cylinder was upright; rather the students thought they could measure the amount of gas produced by measuring the residue left by the bubbles on the side of the cylinder. His first draft explanation for this observation:

> The next day we tried to see how much more it would go if the measerer was upside down, it was less we thought that it was because there was no way air could get in, but it could go out

In his second draft, Emile dropped this explanation, and speculated that it might be either of two other reasons for less gas production. I have no idea what caused him to drop his first explanation.

> The next day we tried the same experiment but this time with the cylinder upside down.
> We discovered that this time the molecule level was less, almost none. We thought that:
> 1) there was not enough space for the molecule to move
> 2) the reaction may be stronger with the oxygen from the open air

Emile demonstrated a shift in his writing. This example will be more fully discussed in the section on literate tools.

Ruth wrote almost as much as did Mary, but, unlike Mary, she spoke very little. In her thinking test, her group very quickly decided on an answer to the problem posed, articulated it, and dismissed themselves by telling me they were done.

To find more evidence of her talk, I looked at tapes of her in small groups in the classroom. In her small groups, she took charge of recording the results of the activities. She talked very little. She allowed her lab partners to make decisions and carry out the experiment. Ruth was one of the most co-operative of students. She rarely criticized what others did. If her partners wandered off task, she would laugh at their jokes and quietly bring them back on task.

Her writing is an interesting study in shifting however. Ruth, as described in Chapter 4, was perhaps the most accomplished writer in the class. She used the most literate tools of all the students. In her writing, she included speculations (as did Emile) about different possible explanations for the phenomenon under study. In the following example from her home experiment, there are three speculations all in one paragraph. I have put each speculation in bold.

> THE NEXT DAY: When I woke up the next day I realised that on the commercial they hadn't put the egg in anything they'd just left it sitting on a counter with toothpaste on one side over-night. But at least I "invented" a new type of experiment. When I went to look at the egg later on that day the top of the egg was sticking out of the vinegar and it was a peachy type color. When I had put the egg into the vinegar the night before the egg had been brown. **I think that the brown stain on the cling wrap was caused by the coloring coming off the egg.** There was also lots of white filmy bubles, **that was probably caused by the vinegar and toothpaste mixing because it was the color of the toothpaste and the vinegar probably made it bubble.** The plastic on the top of the alluminum cup had puffed up into a dome shape. **The reason why it did that might have been some type of chemical reaction in the cup causing the cling wrap to puff up like a dome.**

There are a number of interesting points to note about Ruth's writing. First, Ruth attributed a change in her conceptions to something other than writing. She wrote "When I woke up the next day I realised..." This statement implies her learning was due to a time lapse, perhaps more time thinking about her project, but perhaps just time away from the project. Second, Ruth made three different speculations, and each was an explanation. All three explanations were causal: the first attempting to explain where the stain on the cling wrap could have come from; the second connecting the bubbles, the vinegar and the toothpaste; the third attempting to explain why the cling wrap puffed up. Since each of her explanations was about a different topic, I look for further comment on one particular topic to determine if she shifted her explanation.

The topic that Ruth continued to address in this first draft was the apparent reaction between the vinegar, toothpaste, and egg. Immediately following the excerpt above, she wrote:

> LATER ON THAT DAY: I decided to take the egg out of the vinegar and see what had happened to the egg. When I took the egg out of the vinegar it was completly mushy except for a couple of tiny bits at the top that were still hard. **The egg was so squishy that it felt like it didn't have any shell left on it. I'm pretty sure that it did, but it got softened by the vinegar or some other chemical in the egg or the toothpaste.**
>
> When I was holding it (over the sink of courese) I started to rub it with my finger to see what would happen. It popped! **The egg yolk was fine, it hadn't been harmed by the vinegar.** The outside of the egg that was supposed to be the shell felt sort of like a ballon.

In one of the bolded sections, Ruth speculated further about the reaction between vinegar, toothpaste, and egg shell. In the second of the bolded sections, she seems to have internalized that vinegar did react with the egg shell, when she noted that the egg yolk hadn't been harmed by the vinegar. Her explanations went from speculation to more firm; Ruth tuned this particular explanation, but did not shift, throughout the one draft. However, this is an important observation. The other students I have discussed tuned or shifted between first and second drafts. The possibility of her learning by herself through writing rather than through written dialogue with me is much greater for Ruth than for the other students.

For her second draft, Ruth carried out the experiment that she believed the commercial had demonstrated, by coating one side of an egg with toothpaste, and leaving the other uncoated. She then left the egg on the counter overnight. She noted some results that surprised her:

> The next morning I checked on it again. Nothing had happened and the egg shell was still hard. It just felt a little flakey where I had put the toothpaste on it.
>
> **It might have been flakey on the side of the egg that I put toothpaste on because maybe the toothpaste had dried up and started to flake off, or maybe it was bits of the shell flaking off the egg.** Then I left it over-night again.
>
> When I checked on it again the next morning it was still hard. It felt sort of weird and smooth. On the side that I had put toothpaste on felt sort of warm, on the side with no toothpaste on it felt cold. **I would have thought that it would be the other way around. Because the toothpaste might have trapped the coldness under it and the other side would be warm. But the toothpaste must have kept the warm air in and the other side must have kept cool somehow.**

Notice that in the first bolded section, Ruth suggested two possible explanations for the flakiness of the egg shell. She did not attempt to resolve the issue. In the second bolded section, she was surprised by the result, noting that the evidence was contrary to what she would have predicted. Then she gave a different explanation which accounted for the evidence. Ruth showed a shift here, in giving what her original explanation would have been and basing her final explanation on the evidence. However, rather than the shift being due to her writing, there is every reason to believe the shift was due to her empirical observations. Perhaps she would not have paid such close attention to her observations without the demand to record them. However, the most I can conclude is that Ruth, in her writing, demonstrated a shift, but might not have shifted her ideas because of writing.

Adam demonstrated that he could shift his ideas while speaking. Further, he showed an example of meta-talk, the only student to do this. He was able to consider what he had said and re-construct his explanations. In the section on contradictions, I will show how he did not do this in his writing. Mary demonstrated shifts in her explanations in both her talk and her writing. Emile demonstrated a shift in his writing, but not in his talking. Ruth demonstrated a shift in her ideas in her writing, and did not demonstrate any shifts in her talk. Just because a student demonstrated a shift in explanation in one mode of communication and not in another does not mean that student never shifted in the other mode. This analysis has merely shown that grade 5/6 students demonstrate shifts in talking and in writing.

The question of whether the shifts were caused by the writing cannot be answered with any certainty. Students might have shifted their explanations because of the dialogic nature of first draft - second draft writing, or because of empirical evidence. However, writing did create a situation where students had to focus on the science activity and attempt to explain. The focus might have facilitated learning. Also, if the first draft - second draft nature of the writing assignments facilitated dialogue which led to learning, then writing, in this sense, can facilitate learning.

Contradictions in Writing

I have shown that some students demonstrated shifts in their conceptions in their writing, others demonstrated shifts in their speaking but not in their writing. The question remains of whether students were able to see contradictions in their writing.

Mary was a student who shifted her conceptions in both her writing and her talking. In the following draft, I have put her explanations in bold, and have put an example of a speculation in italics. This sample is the complete first draft of her Alka Seltzer™ experiment:

> Alka Seltzer Experiment
>
> Our first time we just put the tablet into the gar to see what it does then we filled the cylindar with water to 60 mls, the bubbles rose to 71 mls.
>
> Then we got our other two tablets and we filled the cylindar with new water and filled it to 52 mls, the bubbles rose to 65 mls, Xander put his hand on the cylindar and the gas was pushing all the air out, preassure. We all tried it and felt the air pressure, it was pushing hard!
>
> We noticed that when the tablet stoped pushing there were gas bubbles left in the water, that made the water depth rise a few mls. **The reson is because there were so meany bubbles that they took up lots of space wich made the water depth rise** when we droped the last Alka Seltzer tablet in we put our hands on the cylindar right away and kept our hands on it, the gas pressure was so hard that it just about made our hands come right off! The water depth rose a lot too. **I guessed it was because the gas could not push out the air and the air was pushed into the water in the form of water.** We poured the water to 73 mls, the bubbles rose to 94 mls! But the water rose to 80 mls! *I bet that if we did not let go of the top of the cylindar the bubbles would have rose even more.*
>
> **In concution the bubbles rose little if exposed to the air, if not exposed to the air the bubbles rise eaven more.**
>
> We tried it one more time this time we put Xander's Highlighter in the water and then put the Alka Seltzer in it went over 100!!.

Mary explained the increase in volume of water by bubbles being left in the water. She went on to explain a systematic difference she noticed, which was that the volume of water was greater when they had covered the top of the graduated cylinder. She hypothesized why this would be. What is particularly interesting is that Mary's explanations derived directly from her own experiences. She was "growing" her spontaneous concepts up towards scientific concepts. Mary did not attempt to use words which had no meaning to her. This was a change from her home experiment, in which she started out attempting to explain using the term "surface tension."

Mary demonstrated that she would shift her explanations in her writing in response to questions from me. Her shift was towards using explanations which made sense to her. She also tuned her writing from her first draft to her second draft; however, the tuning could have been a result of recognizing her audience's need for more detail, rather than articulating her theory more clearly for herself.

It is noteworthy that Mary's explanations were consistent within the writing. Each of the three explanations addressed why the volume of water would be higher when the graduated cylinder was covered than when it was open. She did not leave anomalies. This is supposedly one of the advantages of writing as a means of learning - that students would be able to recognize inconsistencies when their ideas were written down. Supposedly we are more able to recognize anomalies visually than aurally. (In the above section on shifting, Mary was shown to shift her ideas in her thinking test. As she shifted, she seemed well aware of what she and her peers had said earlier. In other words, she seemed able to detect relationships between ideas aurally.)

In Adam's first draft of his Alka Seltzer™ experiment, he generalized his results by averaging how much gas was produced per tablet. Since averaging is a type of generalization, an abstraction of each individual tablet to how all tablets might act, I considered this to be a type of explanation. Adam also commented that "Next time our group should cover it tightly and be more careful." I asked him for more explanation. His explanation in his second draft appears below:

> Next time our should cover it and be more careful. [1]After every time when the alka seltzer is dissolved [2]the water added a teeny more. [3]I think its because the tablet has a little water in it too [4]and when it is dissolved, [5]the water in the alka seltzer comes out [6]because the tablet kind of acts like a barrier [7]and when it is destroyed [8]the water comes out [9]and adds to the water in the graduated cylinder. I don't really think that covering makes a very big difference.

In this draft, Adam attempted to explain the increase in the volume of water instead of the volume of gas produced. He laid out his explanation with much detail, using nine idea units in all. The questions I had asked seemed to prompt him to do some more thinking, to attempt to explain more of the results he noticed.

Then, in his final point, he clarified why he considered averaging to be acceptable. Although in both drafts he noted that his group should be more careful, he added in his second draft that covering the cylinder would not make much difference. There is an inconsistency here. He suggested that his group should be more careful with how they cover the cylinders, yet he later wrote that he didn't think covering made a big difference. Writing just for himself did not seem to help Adam. Rather, it was writing in the form of first draft, questions from the audience, and second draft (a form of dialogue), which made the difference to his learning. But, perhaps with more experience with writing, he would learn to consider the questions his audience would ask before they were asked.

Adam did not display evidence of shifting theories in his writing. Not only that, in his writing, his theories were not as well connected to scientific conceptions, and there were inconsistencies in his explanations right within the same drafts. In his talking, Adam shifted and tuned his explanations, and connected his spontaneous conceptions to scientific ones.

Interestingly, Adam showed evidence of shifting theories in his talking, which he did not show in his writing. He tuned his ideas in his writing, and demonstrated he could do this in his talking as well. Why the difference?

It could be that Adam did shift his theories in his writing, but I had no evidence of these shifts in the sixteen written assignments I had collected. Or, Adam perhaps had thought out, or discussed different explanations already before he wrote, so they didn't appear on paper. This would explain why there were no examples of shifts right in one draft, but does not explain why he did not change his explanations in response to my comments. Nor does it explain why he did not detect contradictions in his written work, yet seemed to be able to resolve these in his talk. Perhaps Adam learned better by talking rather than by writing. Perhaps writing was a final product for him, so that once something was in black and white, he had difficulty changing. This might make sense, if I didn't have the example of his home experiment, where he speculated about several possible explanations in one draft.

Although I found more examples of students contradicting themselves in their writing than I did of students shifting their ideas, I did not find many instances of contradictions at all. This is quite possibly because of what Goody (1977) and Fondacaro and Higgins (1985) suggested - that writers can see their contradictions and correct them. Students might have noticed problems in their writing and changed what they were writing to eliminate the contradictions. However, that more students accepted anomalous details in their writing than shifted their explanations suggests that anomalies are not as important to us as retaining our prior conceptions. Further, the examples of students shifting in response to their peers' oral comments suggests that talk is perhaps just as effective for detecting contradictions as writing. One would write to learn at those times when one didn't have a conversational partner who could contribute.

Literate Tools and Learning in Science

This section is the last analysis in my search for evidence that students used their writing to learn. In this section, I attempt to determine if the literate tools students used were associated with changes in students' perceptions.

I do not examine the literate tool of transitionals in this section, because transitionals were optional for the students. The students were not required to use particular forms of transitionals as they wrote their science. Consequently, I could not tell if students were better articulating their ideas with the use of tranisitionals, or if they were actually changing their concepts. It was easier to examine literate tools that imposed a structure on students. Then, if I saw a change in the way students expressed their ideas between first draft without the tool and second draft with the tool, I could consider the tool might have made a difference. Literate tools which imposed structures were sentences and paragraphs. I focused considerable effort on teaching the students how to write in paragraphs, and less effort on sentences. Thus, the following analysis is limited to paragraphs.

In this first example, Mary seems to have tuned her explanation because she was using a literate tool, paragraphs. The demand to use paragraphs seems to have helped her to realize that some information had been missing from her first draft. In the first sentence of her first draft of her Alka Seltzer™ experiment, Mary wrote:

> Our first time we just put the tablet into the gar to see what it does then we filled the cylindar with water to 60 mls, the bubbles rose to 71 mls.

I commented after her first draft that she should separate the two trials into separate paragraphs. Her second draft demonstrated how she took my advice:

> Our first time we just put the tablet in to see what happens, it bubbles.
>
> Then we filled the cylinder with water to 60 mls, we put 1 tablet in and the bubbles rose to 71 mls.

In both drafts, she described what she did to the same degree. However, once she separated the two actions into two separate paragraphs, she seemed to realize that she had not described the result of her first test. She added "it bubbles." The literate tool of paragraphs seems to have affected how much Mary made explicit. At this stage, Mary did not yet understand how to construct sentences, but she was learning quickly how to use paragraphs. The paragraph change I suggested above was the only one I made to her for her first draft, since she used paragraphs so well. Throughout the unit, she became better at writing sentences.

I have commented on Emile's Alka Seltzer writing in the section on shifting and in the section on contradictions. It is an important example in this section on literate tools also. In Emile's first draft, he did not use paragraphs, and his final explanation was a simple summary of experiments in general. In his first draft below, I have bolded the transitionals Emile used, and numbered the idea units.

> Alka Selser Experement
>
> [1]Are group took the millilietre measerer [2]**and** poured water to make 20 millimetres, [3]**then** we drouped the alka-selser in the measerer [4]**until** it fully bubbled to the top of it's compassity. [5]**Then** we measured the same amount of water as before [6]**this time** we droped the alka-selser by qaurters, [7]we discovered [8]**that** each qaurter of alka-selser has 5 millimetres of energy. [9]**The next day** we tryed to see how much more [10]it would go [11]**if** the measerer was upside down, [12]it was

less, [13]we thought [14]**that** it was [15]**because** there was no way [16]air could get in, [17]**but** it could go out [18]**last** we poured 10 millimetres of water [19]**and** droped two alka-selsers [20]it floated to the top of the whole measurement [21]we learned [22]**that** different reactions happens [23]**when** experementing on different things.

That is our groups experement
Thank you
Emile

In Emile's writing, a major problem with beginning writers is apparent. Emile knew how to communicate his ideas, but did not know how to construct the literate tool of sentences. His first sentence had five idea units, his last had fifteen. His first sentence described one experiment his group did, and the observation they made. His last sentence described all the experiments he did the next day, and included his general summary of what he learned. Emile, although he communicated very well in idea units, had no idea how to construct sentences or paragraphs. He, as with many students in the class, did not seem even to consider that either sentences or paragraphs should have consistency in structure. But his idea units were very well constructed, and they fit together in easy to read fashion.

Emile used many temporal transitionals, the logical transitionals "that," "if," and "because," and the comparative "but." He also used the implicit transitional of chronological order. His last explanation is a simple summary "different reactions happens when experementing on different things."

I responded to his first draft by adding punctuation (thus pointing out where sentences should end) and noting locations where he could start new paragraphs. In written comments at the end of his draft, I complimented him on his reasoning about the tablet not producing as much gas when the graduated cylinder was upside down.

Then I asked him how much gas had been produced in each case. He responded with a more thorough description of his experiment.

Alka Selser Experiment

[1]Our group took the milliletre measurer [2]**and** poured 20 mL of water.

[3]We poured one tablet of alka-selser to the 20 mL of water, [4]it started bubbling to the full capacity of 75 mL.

[5]**Then** we measure again 20 mL of water, [6]**this time** we dropped the alka-selser by quarters.

[7]We discovered [8]**that** each quarter of alka-selser would raise the level by 5 mL [9]**whitch tells me that** the molecuelar energy of the alka-selser is about 20 mL.

[10]**The next day** we tried the same experiment [11]**but this time** with the cylinder upside down.

[12]We discovered **that this time** [13]the molecule level was less, almost none. [14]**We thought that**:
[15]**1**) there was not enough space [16]**for** the molecule to move
[17]**2**) the reaction may be stronger with the oxygen from the open air

[18]**Finally** we tried to do the same experiment with 10 mL of water and [19]two tablets of alka-selser. [20]The alka-selser floted with boiling like reaction. [21]**It makes me think that** [22]the reaction of the mixture has to do with the ingredients of the alka-selser and the components of the water H_2O.

Emile

In Emile's second draft, he developed a much fuller explanation. He has suggested two possible reasons for the anomalous decrease in amount of gas produced when the graduated cylinder was upside down. His final explanation is specific for this experiment, and all his explanations develop (tune) his term "molecuelar energy." He does not use the term the way it is used in science, but I was able to understand what he meant.

Note that Emile used paragraphs in this version of his writing. He made his own decisions about where to start new paragraphs, rather than taking my written advice. His first five paragraphs are one sentence long, and each of these sentences (except one) contains two idea units. The two idea units are poorly connected with only commas as transitionals. Emile's paragraphs do not have the consistency that the literate tool should have. Emile's paragraphs are an example of a early type of complex, as described by Vygotsky (1934/1986) rather than a pseudo-concept or a scientific concept.

Vygotsky (1934/1986) believed that children developed scientific concepts because of a number of factors, including memory, determination, the desire to solve a problem. Vygotsky wrote, "Memorizing words and connecting them with objects does not in itself lead to concept formation; for the process to begin, a problem must arise that cannot be solved otherwise than through the formation of new concepts" (p. 100). For Vygotsky, all three factors were important, and the interplay between them was what brought about the child's learning. But, beyond what happened with the child, Vygotsky considered word meanings as derived from the culture to be integral to the process of concept formation. The child had to connect his/her spontaneous concepts with the culture's scientific concepts. For this, the child required opportunities, and dialogic engagement with adults. Learning was not just memorizing and using words, but also trying the words out in different situations, and thus acquiring the meaning of the word.

Vygotsky described three different phases towards concept formation. The first phase is when a child "heaps" things together for purely personal reasons. Vygotsky believed the heaps had no basis for belonging together; perhaps it would be more appropriate to say that children group objects for reasons we are unaware of. This phase is not of much interest in this study. The second phase Vygotsky described was complexes. Complexes are objects united both for reasons accessible only to the child and for actual bonds (I would guess this to mean bonds which adults would consider reasonable) between the objects. Vygotsky noted that the bonds between the objects are "*concrete and factual* rather than abstract and logical [Vygotsky's emphasis]" (p. 113), and that the factual bonds are those which the child has discovered through direct experience. The last stage of this second phase (the complex phase) Vygotsky called the stage of pseudo-concepts. Pseudo-concepts are difficult to separate from scientific concepts (which are the third phase). The difference is not in their function, but in the way the child justifies the objects belonging together. As an example, children might group all triangles together. If a child groups triangles together because of observable similarities, then the child has a pseudo-concept. If the child recognizes that all triangles have the similar abstract qualities of three sides and three angles, then the child has a true scientific concept.

As Vygotsky traced the development through this stage towards scientific concepts, he noted the importance of word meaning for concept development. He argued that mere association between a word and an object would not lead to the child developing the concept. As I pointed out in Chapter 4, this is fundamentally different than von Glasersfeld's (1993) beliefs about language. For von Glasersfeld, a child learned words through association, and learned concepts through direct experience with the world. Vygotsky argued that "*complexes corresponding to word meanings are not spontaneously developed by the child: The lines along which a complex develops are predetermined by the meaning a given word already has in the language of adults*" [Vygotsky's emphasis] (p. 120).

Paragraphs are a scientific concept, a culturally created concept. They have a meaning in the language of adults. For children to learn this meaning, they must have the opportunity to use paragraphs in different ways, to try out their spontaneous notions of what paragraphs are, and to interact with adults who use paragraphs in a more consistent, culturally constructed way.

In Emile's first paragraph-sentence, he connected two actions that his group did: "[1]Our group took the millilitre measurer [2]**and** poured 20 mL of water." In his second paragraph-sentence, he connected an action and a consequence: "[3]We poured one tablet of alka-selser to the 20 mL of water, [4]it started bubbling to the full capacity of 75 mL." In one case ("[7]We discovered [8]**that** each quarter of alka-selser would raise the level by 5 mL [9]**whitch tells me that** the molecuelar energy of the alka-selser is about 20 mL."), Emile had three idea units in the paragraph, and these idea units are connected with logical transitionals. Emile's paragraphs were complexes, not pseudo-concepts, not scientific concepts. He knew there was such a thing as paragraphs, he was trying them out, but he used them in inconsistent form. He had not reached the stage of pseudo-concepts, using paragraphs appropriately but unaware of the abstract reasons for placing ideas together.

At this stage of Emile's writing, I would have been content for him to use paragraphs in a consistent manner. Paragraphs could not really serve as a literate tool if Emile didn't use them in a consistent way. Consistency would impose a structure on his writing, so that he would have to reconsider what information went together.

Donald used paragraphs in a more consistent way when he wrote his experiments. A good example is from his second draft of his stained fabric experiment. He started with a list of all the materials that were used, then each paragraph included one of the tests his group carried out. For example:

> Then we put a marker on a coffee filter and put it in hydrogen peroxide. Nothing happened. Mabye magnesium sulfate should do the trick.
>
> Then we got another piece of coffee filter and put a crayon mark on it and put it in ammonia and nothing happened. Try hydrogen peroxide.

Each of his two paragraphs described the kind of mark, the surface the mark was on, what solvents they tried to dissolve the mark, and the results of the test. Importantly, he ended each paragraph with a suggestion for what might work. Almost all his paragraphs had this kind of consistent structure. The consistency with which he wrote his paragraphs put a demand on him to suggest a different solvent in every case, not just in the first case. In this sense, the literate tool could organize Donald's thinking in a particular way. Unfortunately, suggesting different solvents was as far as Donald got. He did not try the suggestions he made. There was potential in the interplay between the literate tool and the construction of science knowledge, potential that was not being utilized.

Two other changes Emile made from his first draft of his Alka Seltzer™ experiment were to use a list (a tool which is both literate and oral) to write out his two speculations about the unanticipated results from the second day's experiments, and shorter sentences. The list was very useful for helping me to understand his thinking. But, since there had been no call to use a list, I would guess that he used a list to illustrate what he was thinking, rather than having his thinking influenced by using a list. It would have been interesting if I had asked the students to list their possible hypotheses in one of their experiments, to determine if the suggestion of using a list made a difference to the number of hypotheses they suggested.

The sentence length is an interesting issue when compared to Viola's writing of her last experiment. Viola never did get to the point of using sentences. But in her first draft of her acid/base experiment, she lumped idea units that belonged together in a string. It was relatively easy to show her where to start new paragraphs. I have put an asterisk (*) after each set of idea units that belongs together:

> [1]I used a yellow coffee filter [2]and ammonia [3]it made the coffee filter trun red* [4]and put rubbing alcohol [5]actice acid [6]it made it trun yellow* [7]then I put baking soda [8]it got all smokey and bubble and a big lump of baking soda.*

Viola had placed her idea units together, but had not indicated how they should be grouped. She was ready to learn about how to use literate tools, tools such as punctuation, sentences, and paragraphs, to indicate to her audience that these ideas had been grouped together. However, as pointed out by Vygotsky, she was not going to spontaneously develop the concept of sentences and paragraphs. She needed instruction, and cultural feedback to help her learn. Emile was perhaps at a stage beyond Viola, knowing that the literate tools existed, but not yet sure how to use them.

Lastly, in the discussion of Emile's writing, I will consider the scientific concept of molecules. Emile's first draft explanation in idea unit 8 ("we discovered [8]**that** each qaurter of alka-selser has 5 millimetres of energy") was expanded to two idea units in the second draft, idea units 8 and 9 ("We discovered [8]**that** each quarter of alka-selser would raise the level by 5 mL [9]**whitch tells me that** the molecuelar energy of the alka-selser is about 20 mL.") Emile's first draft explanation, is a summary; in the second draft, it has been changed to a summary and a causal explanation. The summary is: "each quarter of alka-selser would raise the level by 5 mL," and the causal explanation is: "which tells me that the molecuelar energy of the alka-selser is about 20 mL." Both energy and molecules are postulated entities, which can be very powerful explanatory tools. I am personally skeptical of whether students actually understand when they use these postulated entities, because often they use them inappropriately. In other words, the word still represents the complex phase of conceptual development. Emile's addition of the word "molecuelar" to this explanation showed me he did not understand the scientific (culturally constructed) concept of molecules.

However, in Emile's next explanation, he made a shift from his first draft to his second draft. He changed from the postulation that:

> [13]we thought [14]that it was [15]because there was no way [16]air could get in, [17]but it could go out

to two speculations:

> [14]We thought that:
> [15]1) there was not enough space [16]for the molecule to move
> [17]2) the reaction may be stronger with the oxygen from the open air.

Both these speculations are consistent with his postulation of molecules. Thus, in his speculations, he further elaborated on his concept of molecules, and his explanations were consistent. Although his use of the term "molecule" bears little relationship to the concept used in science, he used the term consistently. Emile was using the word as a pseudo-concept - a type of pseudo-concept which Vygotsky had not considered. Emile has developed a concept, just not the one which the culture prefers. Vygotsky (1934/1986) argued that "the lines along which a complex develops are predetermined by the meaning a given word already has in the language of adults" (p. 120). Emile had learned the word from adults, but he had not yet learned the meaning. For him to develop the same concept as adults, he would have to engage in more dialogue with his teachers, and/or with culturally produced objects such as books.

I posed the question at the beginning of this section of whether the change in Emile's analysis was due to an improvement in literate tools. My answer is a tentative no. I do not think that Emile thought more carefully about his experiment because of the need to use paragraphs (which he did not use in a consistent form) or in his use of shorter sentences. I am guessing that the change in Emile's thoughts were related to the first draft - second draft format of his assignment. He was responding to the dialogue he and I were having in writing, which is only part of the dialogue that could exist. It is possible the demands of the literate tools themselves could prompt Emile to consider ideas he had not considered. It seemed that both Mary and Donald did this, although they might have been engaging in their writing with what Bereiter and Scardamalia (1987a) called intentional learning procedures. Perhaps both Mary and Donald invested more in their learning than Emile.

While examining Emile's writing, though, I compared his tools to Viola's and Donald's. Both these students demonstrated that they were ready to enter a new stage of their learning. Viola was ready to learn about the literate tool of paragraphs. Evidence for this was that she was placing related idea units together. She was not yet learning what Emile had already learned, that the idea units could be grouped into paragraphs, but she seemed ready. Donald did seem to be using paragraphs in a consistent way, and the way he used them seemed to be pushing him on to think more carefully about his experiments. A dialectic had been set up for Donald, a dialectic between his literate tools and his thinking in science. Thus, he probably was using his writing to learn science. The next stage for Donald's learning would be for him to test his thinking in experiments, further linking his spontaneous concepts to his culturally constructed ones.

Evidence from All students

Tuning and Shifting Explanations

There was evidence that students tuned their procedural descriptions, but evidence of tuning in procedural descriptions does not necessarily mean the students had learned anything about science. Students could not really tune their procedural descriptions by becoming more aware of what they had done. When students tuned their procedural descriptions, I used this as evidence of them learning better to anticipate the needs of their audience, rather than of them learning science concepts.

There was evidence that students tuned their explanations. Again, the students might just have been better articulating what they already knew. However, the possibility that students were learning science concepts as they tuned explanations is greater than the possibility of them learning science concepts as they tuned their procedural descriptions. Consequently, in this section, I will look for examples of students tuning explanations, although we must be careful about considering this as evidence of learning.

Students were much more likely to be learning science concepts when they shifted their explanations than when they tuned. For students to shift their explanations, they had to reject an earlier concept for a new one. I sought evidence of students shifting their explanations, and I used this as evidence of them learning science concepts. However, I am hesitant to attribute the shifts to their writing. There are other possibilities, such as that students had more time to think about their ideas, or that more empirical evidence brought about the shifts, or that the written dialogue between first draft and second draft made the difference.

To be able to summarize the findings from the class, I examined the students' writing to determine if they attempted explanations, and what kinds of explanations they attempted. At the same time, I examined their writing for evidence of tuning or shifting their explanations from first draft to second draft.

The least difficult type of explanation would be a summary of the results of the experiment. Nineteen of twenty-six students attempted to summarize the results of at least one experiment. A particular case of summary would be comparative, where one set of results is compared to another. Only seven students attempted comparative explanations. This is perhaps because I did not specifically ask the students to categorize their observations, so there was no reason to make comparative summaries.

A much more complex type of explanation is a causative one. For causative explanations, students have to define a relationship between two or more variables. They had not only to notice both variables, but attempt to determine how one affected the other. Fifteen of the students attempted some sort of causative explanation.

A fourth type of explanation is one which draws on postulated entities. Postulated entities could be considered scientific concepts. These entities are cultural constructions, and have taken centuries to describe and articulate. They are abstract and generalizable, and are used to explain a variety of natural phenomena. Of the twenty-six students involved in the study, nine used postulated entities or other terms which come directly from the science community. I considered these postulated entities or specialized terms to be scientific concepts. However, when I questioned these students regarding the postulated entities, three of these students abandoned the postulated entities. This will be discussed at greater length in Chapter 7.

Figure 5: Kinds of Explanations Students Used

	Summaries	Causal	Comparative	Scientific Concepts
Number of Students	16	14	7	9

Eleven students used speculative words, such as "I think" or "I guess" in their explanations. However, if I were more rigidly to define speculation to be a discussion of different possibilities and/or to show the evidence associated with the explanation, only five students would fit in this category. This kind of speculative explanation would mean the student was, in a way, engaging in dialogue with her/himself. Of these five students, only Ruth, after considering a number of possibilities, eliminated any. Thus, she showed the ability to shift right within one draft of her writing. Ruth was definitely capable of using her writing to learn in this way. The other four students considered other possibilities, but did not attempt to decide which speculation was best. All except these five students seemed to rely more on the dialogue between themselves and me to develop their answers.

In all, only three, perhaps four, students demonstrated shifts in their explanations from first draft to second draft - Ruth, Mary, Emile, and perhaps Joan. Joan attempted an explanation in the first draft of her home experiment, then attempted to explain a different aspect of the phenomenon in her second draft. I was not sure if I should count this was an example of a shift. At the other extreme, Ruth showed shifts right within one draft for her home experiment. In this experiment, she considered a number of different possible explanations, then explained her reasoning for eliminating one of them.

The number of students who demonstrated shifts in their talking was the same as those who showed shifts in their writing. Adam, Mary, Thomas, and perhaps Priscilla all demonstrated shifts during talking; Ruth, Emile, Mary, and perhaps Joan did in their writing.

Figure 6: Number of Students Who Shifted and Tuned Explanations in Writing

Total number of students	Number who attempted explanations	Number who tuned explanations	Number who shifted explanations
26	19	11	3 or 4

Contradictions

Very few students contradicted themselves in their writing. There are several possibilities to consider to explain why this would be so. One is that the experiment write-ups were short, so there wasn't much time for contradiction. Another is that students often did not attempt explanations; consequently, there was no contradiction possible between data and explanation. An important possibility is that the written format did help the students to notice contradictions. However, since the number of students who shifted in their talk was the same as the number who shifted in their writing, I am not sure if this is a good explanation. Adam certainly demonstrated a greater ability to demonstrate his learning of science through talk than through writing.

An interesting activity for future research would be to set a challenge for students where they had to explain a contradictory phenomenon - to explain one of those situations science teachers consider discrepant events. Students would be forced to come to terms with contradictions between the empirical phenomenon and their explanations in their writing.

Learning and Literate Tools

I divided the students into four groups, depending on their competency with the literate tools of paragraphs and sentences. (In Chapter 4, I discussed students' competency with transitionals.) The groups were, first, those students who used paragraphs and sentences in a consistent manner. I believed that the constraints of using the tools in a consistent manner might impose a need for more thought about their experiments. The second group was the group that attempted to use paragraphs and sentences, but had not yet reached the stage of using them in a consistent manner. Thus, the students could add more material as they wished, without the constraints imposed by the literate tool. A third group was composed of those students who did not use sentences or paragraphs on their own. The fourth group was composed of those students who were very poor at writing, usually writing briefly or demonstrating very poor spelling.

Figure 7: Number of Students at Different Levels of Competency with Paragraphs and Sentences

Consistent Use of Tools	Attempting Tools	No Paragraphs and/or Sentences	Great Difficulties
6	10	7	3

I drew specifically on Vygotsky's work in an attempt to determine if students' literate tools affected their learning. Mary, Donald, Priscilla, Ruth, Zoe, and Levine all used paragraphs and sentences in some sort of consistent form. Of these six, four (Mary, Donald, Ruth, and Zoe) seemed to be using the tools so that they had to add information, or be more thoughtful about their science. Another ten students used sentences and/or paragraphs, but not in a consistent form. Consequently, the tool was not what might be considered a scientific concept. Rather, paragraphs and sentences were still complexes (Vygotsky, 1934/1986). Included in this group are Emile, Adam, Thomas, and Joan, and three others. The lack of consistency in the tools meant the tool did not put demands on the students' thinking. There was no dialogue set up between their reasoning and the constraints of writing.

Summary

In this chapter, I examined the students' writing for signs the students were learning from their writing. I started by looking for signs of learning and then compared writing to talking to determine if one mode was preferred over the other. My next examination was to check the students' writing for contradictions, since several researchers have suggested that it is easier to see contradictions than to hear them. Lastly, I looked at the literate tools the students used, and tried to determine if the literate tools could possibly have led to more learning.

There are examples of students shifting and tuning their ideas in talking and writing. An important aspect of their shifting or tuning was the dialogue they engaged in - either talking with their peers and me, or by writing their second drafts in response to my comments on their first drafts, or by speculating in their writing - engaging in a kind of dialogue with themselves. Five students demonstrated a type of written dialogue with themselves in their writing - a feature I called "speculation." Only one of these students attempted to choose one speculation over others. One student demonstrated that he could shift his ideas in talking with very little input from me.

Some students showed that they did not recognize inconsistencies between their observations and explanations right within one short piece of writing. Most students, however, did not have any inconsistencies. Interestingly, one student, Adam, showed in his talking that he could shift and tune his ideas, clarifying ideas and perhaps getting rid of inconsistencies which he had not made explicit. Although in his writing, Adam demonstrated tuning, this seemed only to be in response to my comments.

As I examined the students' use of literate tools, I thought that I could discern where I could have facilitated different students' learning. For example, since Mary and Donald were already using literate tools so that a dialogue existed between the tool use and their thinking, they could have been encouraged to test their thinking with empirical materials. Emile, Joan, and Adam seemed ready to learn more about the literate tools they were using. All three of these students were learning science. I might have been able to facilitate more independent learning by teaching them the literate tools. Viola, who was enthusiastic about her writing and her science, seemed to be at a stage of requiring teaching about sentences and paragraphs. Science was a good location for her to practice her writing. She was improving vastly in her writing, and she was gaining familiarity with natural phenomena, but she never did attempt to explain any of her science.

Interestingly, in interviews with the children about the purpose of writing, all nine of those interviewed said that writing was to help them remember. Not one suggested that writing could help them re-organize their ideas. Perhaps if teachers explained different purposes for writing to students, students would better be able to use writing as a tool for learning.

While analyzing the students' writing, I noticed something else worth discussing. To be considered in Chapter 6 is that some students drew almost entirely on their empirical experiences (spontaneous concepts). A few students seemed to prefer to work on the abstract level of explanation, using theoretical constructs (scientific conceptions). What is important about the issue of spontaneous concepts and scientific concepts is that different students seemed to have different preferred ways of learning about science. To be considered in Chapter 6 is whether the children could be put into groups as to their preferred ways of learning. What I will examine in Chapter 6 is not so much the children's writing to learn in science, but what I learned about how students learn science. And what I learned came from the students' writing.

CHAPTER 6

GENDERED WRITING AND LEARNING?

Introduction

In Chapters 4 and 5, I examined the literate tools that different grade 5/6 students had available, and whether the children in the class demonstrated learning through talking and writing. I found considerable variation within the class. Many students had well developed language tools; however, most of the language tools that children had were those which could be acquired and used orally. Only a few children often used tools (such as paragraphs and sentences) which were strictly literate. When I examined the students' writing for evidence of them tuning or shifting their explanations, I found only three, perhaps four, who shifted their explanations. All those students who shifted their explanations in writing were at least trying to use paragraphs, a strictly literate tool, and a tool that is probably more difficult to learn than sentences. However, there were many students who were using paragraphs who did not shift their explanations, even some who did not tune their explanations.

While teaching the class, it seemed to me that more girls handed in their homework than did boys. While examining students' writing, I thought that I detected other gender differences, such as that girls wrote more than the boys. As well, I noticed that some students speculated about different possible explanations for the phenomena under investigation. Another interesting observation was that some students seemed to drew on postulated entities, and others seemed to draw more on their own experiences as they attempted to explain the results of their experiments. Gender issues have and still are a concern in science education. Since I thought I detected some in this class, I thought I should re-examine the data in light of gender to determine if boys and girls write science in different ways.

The history of Western science has been a history of exclusion (Davis, 1996; Harding, 1998; Schiebinger, 1989; Wertheim, 1995). Much of the exclusion focused on women. This makes sense. Since there were women in Europe, women could and did demand a place in the institution of science. Only recently have Africans, North and South American First Nations people, and Asians made these demands. Part of the justification for the exclusion of women from science was that they were considered emotional, irrational, and therefore not logical (Gould, 1980; Schiebinger, 1989). These terms were applied to the insane, children, and "savages" (people of other races) as well.

But is logic something that only a select group of people are capable of? Lloyd (1996) pointed out that axiomatic deductive logic was probably not so much a result of Greek alphabetic writing, or even of writing, but seemed to represent the ancient Greeks' particular approach to creating knowledge. Axiomatic deductive logic seems to be a culturally learned way of dealing with knowledge. Lloyd also noted that, in ancient China, scientists came up with similar understandings of the universe as ancient Greeks by using different approaches. Axiomatic deductive logic might be easier for some people than for others, but it is not a superior way to think. Perhaps those who find this kind of logic easier are more likely to find a place in Western science.

Another way in which women and people of other cultures were excluded form science was that these "others" apparently did not attempt to explain. Women's science was considered to be technology - women patiently collected data, or women learned what worked and applied this knowledge. Women, and people of other cultures, however, according to the misogynist view, did not seek the reasons for why things worked the way they did (Harding, 1998). Thus, the findings of women and people of other cultures were not recorded in mainstream history books.

Because of lack of awareness of exclusion as a cultural issue, women's poor performance in science was blamed on their "essential" (in this case meaning a genetic predisposition) deficiencies. The central claim of an essentialist argument is that women are, in their natures, different from men. We still hear that women are not as good at spatial relationships as men. (And, from Gilligan (1982/1993), we hear that women are more caring than men; from Grumet (1988) that women are more nurturing than men.) With the belief that girls were not suited to science, girls were treated differently than boys in science classrooms. Kahle (1988) summarized research showing that boys were given more attention than girls, and boys were asked higher order questions than girls; when boys asked questions, they were often told to figure it out, whereas the girls were told the answers. Boys tended to dominate the equipment, and took the active roles in empirical situations. All this led to boys feeling more confident about science. Often, those girls who had good marks were less confident than boys with lower marks.

As a reaction to these research results, much has been done to encourage girls to become interested in science. The encouragement seems to have made a difference, because girls are getting just as high marks in science courses as boys, and, in some locales, just as many (sometimes even more) girls are taking secondary science courses as boys. Yet women are still not taking up careers in science, and when they do, they are not promoted as quickly as men (Wertheim, 1995).

Far less research has been done on other groups of people than has been done on women. But the research that has been done tends to show similar results. For example, in a recent study of teachers of aboriginal children in Saskatchewan (Aikenhead & Huntley, 1998), the teachers claimed that aboriginal children should be just as capable of doing science as white children. The teachers did not feel they had to modify the curriculum or their teaching styles. Yet when asked why their aboriginal students do not do well in science, the teachers resorted to the same sorts of claims as were made about women. Aboriginal children are essentially different; they don't think logically; they don't work hard enough. As well, some teachers believed aboriginal culture was not conducive to scientific thinking.

In my study, as mentioned in Chapter 1, there were 27 students in the class, 16 boys and 11 girls. Fifteen of the boys participated in the study; all the girls participated. The class was a mix of ethnic backgrounds and income. There were children whose families were on social assistance, and children from upper middle class families. There was also disparity in student labels, with three children having been part of a gifted education program and three students labeled as learning disabled. Two students in the class were involved in a behaviour management program. (Interestingly, two of the three learning disabled children and both of the behaviour management children were from lower socio-economic single-parent families. This makes me think that children from lower socio-economic homes are more likely to be discriminated against.)

There were, besides English, eight different languages spoken. The children from the class had been born, or their parents had been born, in ten different countries. I would have liked to have looked at cultural differences as well as gender differences, but there were far too many originating cultures in this class for a cultural analysis.

In this chapter, I will examine the students' writing for gender differences. The first examination will be on a gross level, counting the number of assignments handed in and the number of words students wrote. Second, I examine the writing to determine what students were writing about. Third, I will look for the number and kinds of explanations students attempted. Particularly, I will look to see if more boys than girls attempted causal explanations, since one of the justifications for excluding women from science was that women did not look for the why of natural phenomena. Lastly in this chapter, I will examine which gender seemed to draw more on spontaneous conceptions, and which on scientific conceptions.

Gender Differences in Writing

Quantitative Differences

I used numerical data to seek differences in writing. When I found a difference, I excluded those students who were at the extreme end of the number range. I excluded these students because just one student might exaggerate the gender differences. Once I had excluded the students at the extreme ends, I re-examined the numbers. After calculating a number of differences between boys and girls, I found only one number that stood up to the exclusion test - the girls wrote much longer assignments than the boys did. However, I started this analysis by checking the number of assignments handed in.

Assignments Handed In

From my experience working with these students, I immediately thought one of the differences between the boys and girls was that the girls completed more homework. Consequently, my first analysis was to compare the number of assignments handed in by boys and by girls. There were sixteen assignments the students had to hand in, including first and second drafts.

The total number of assignments the students were to do was sixteen. In the data table below, I have listed the number of boys and the number of girls who handed in sixteen assignments, then the number who handed in fifteen, etc.

Figure 8: Assignments Completed According to Gender

Number of assignments completed	Number of boys	Number of girls
16	5	6
15	2	
14	1	2
13	3	1
12	2	
11		1
10		1
9		
8	1	
7	1	
Average Assignments	12.7	14.4

The averages calculated are the average number of assignments handed in per boy in the class, and per girl in the class. If I eliminated the two boys who handed in the least number of assignments from this data set, the average number of assignments for the boys increases to 14.4, the same as for the girls. The reason I had the impression that girls handed in their work much more than boys was that I spent a lot of time nagging two boys in particular to get their work handed in. Thus, the majority of the boys were just as quick about handing in their homework as the majority of girls.

Assignment Length

I compared the word lengths of the assignments handed in according to gender. I had to make three decisions about counting numbers for this analysis. I only counted the students who handed in all their assignments. The reason for this was that those students who handed in a small number of assignments also handed in very short assignments. To include all students in this analysis would have skewed the data against the boys, since more of the girls handed in their assignments. Another problem I faced was that some of the students made drawings; since there were so few drawings, I disregarded the drawings, and only counted the words written on them. Thirdly, I didn't count all the assignments in this data. I counted those for which I had copies of first and second drafts. This meant the home experiment was excluded because there were three drafts of this, and the second experiment was excluded because I only collected the second draft of this one. The reason for only counting those assignments for which I had two drafts was that included with this analysis is a comparison of lengths of first and second drafts.

Figure 9: Word Length of Two Draft Assignments for Those Students Who Handed in All Their Work

Name	Average: Draft 1	Average: Draft 2	Average: Total
Nathan	254	301	278
Emile	224	191	208
Adam	138	227	182
Donald	140	180	160
Thomas	150	153	152
Average for Boys	182	213	198
Mary	347	451	399
Ruth	335	425	380
Joan	251	362	306
Katie	188	227	208
Gillian	137	182	160
Viola	149	157	153
Average for Girls	234	301	268

Note that the boy who wrote the most (Nathan) wrote just a little more than the average for the girls. The girl who wrote the least (Viola) wrote the same amount as the boy who wrote the least (Thomas). If I were to eliminate the data from Mary, the girl who wrote the most, the average for the girls would still be 241, still higher than all the boys except Nathan. Thomas wrote the least of all these boys, but he only wrote a small amount less than Donald. Consequently, I did not consider Thomas to be an outlier. It is in the length of the assignments that I see a great difference between the girls and the boys.

Overall, the girls wrote considerably more than the boys. Another interesting aspect of this data is to compare the per cent increase in word length of the assignments, according to gender.

Figure 10: Change in Assignment Word Length

Number	Average for all Assignments	Average Length Draft 1	Average Length Draft 2	% Increase to Draft 2
5 Boys	198	182	213	17 %
6 Girls	268	234	301	29 %

There would seem to be a big difference in how the boys and girls modified their second drafts. The girls increased the length of their second drafts by almost thirty percent, the boys by less than twenty percent.

Two questions arise out of the analysis. The girls wrote more than the boys. What were the girls writing about in all those words? Secondly, what changes were the girls making that made their second drafts so much longer?

Qualitative Analysis

There are two qualitative questions that I derived from the numerical data above: what were the girls writing about that made their assignments longer than the boys? and, what changes were the girls making that made their second drafts so much longer? Other than the old fashioned claim that women are less likely to attempt causal explanations, there was no research that I could draw upon to suggest what I might look for. Consequently, the analysis in this section is derived from perceptions I made while reading and analyzing the students' writing. One difference that I thought I detected was that the girls wrote more detailed descriptions of the phenomena they were investigating. As a follow-up to the claim that women were less likely to attempt causal explanations, I also decided to investigate the number and kinds of explanations that students made, and compare these according to gender. Lastly, in another section, I will investigate something else I noticed - that some students seemed to draw more on their spontaneous conceptions and others on scientific conceptions.

Empirical Descriptions

One of the things I thought I had noticed as I read all the assignments was that the girls seemed to write much more detailed empirical descriptions than did the boys. For example, in Ruth's description of the solutions experiment, she described the mixing of rubbing alcohol and vegetable oil, and rubbing alcohol and acetic acid. In the following excerpt, I have numbered the idea units.

> C_3H_5OH and Vegetable Oil
> [1]We poured 5 mls. of C_3H_5OH [2]and 5 mls. of Vegetable Oil together in a cup. [3]It started to separate [4]as soon as we poured them together. [5]After awhile it layered completly, [6]there was Vegetable Oil on the bottom [7]and C_3H_5OH on top.
> Rubbing Alcohol and Acetic Acid
> [8]We poured 5 mls. of Rubbing Alcohol [9]and 5 mls. of Acetic Acid into a little cup. [10]It mixed together [11]almost as soon as we poured them together. [12]There were a few tiny bubbles coming up, [13]but they dissapeared after a few seconds. [14]After the bubbles had dissapeared [15]the mixture a sort of oily layer on top, [16]but it stayed clear.

These two descriptions are one hundred and twelve words, and there are sixteen idea units in all. It is not surprising that Ruth used a lot of words. She was one of the students in the class who wrote the most. Nor is it surprising that she had a lot of idea units. More words almost always results in more idea units. What is interesting is what she chose to write about. First, she described what she did, very briefly, in two idea units. The next five idea units are a patient description of details about the separation or mixing of the two liquids. The same thing happens in her next paragraph. The first two idea units tell what she did, and the next seven idea units are empirical description.

When I contrast this to Thomas' description of the same two events, a very different account comes out.

> [1]When we tried to make solutions [2]our first one was, rubing alcohol and vegtable oil. [3]They did not mix. [4]When we mixed acetic acid and rubing alcohol, [5]it made a solution, [6]if there was more rubing alcohol than acetic acid.

Thomas wrote about the same two mixes in forty words, six idea units. He used less idea units to describe two mixes than Ruth did to describe one. But, more interesting, Thomas included almost no descriptive details. He did not tell me amounts of liquids, what he mixed them in, how or when they separated or mixed. It is important to note that Thomas did meet the point of the activity. He concluded that, in one case, a solution had been formed. Ruth did not use the word solution, although she did describe the mixes so that I could make my own conclusion about whether a solution had formed or not.

On the day of this experiment, Thomas had stayed through recess because he wanted to know why vegetable oil did not mix with either vinegar or rubbing alcohol. He told me he thought it was because of density differences. I asked him which liquid floated on which, and he, with no further prompting, decided that rubbing alcohol was the least dense and vinegar was the most dense. He tried very carefully pouring rubbing alcohol onto vinegar, and found that he could get rubbing alcohol to float. He pointed out that the rubbing alcohol had an oily appearance (Ruth described this in writing). Then he tried putting vinegar, then vegetable oil, then rubbing alcohol in the little plastic cup. Just before the end of recess, he told me he no longer thought it was density differences that caused two liquids to separate. Now he was thinking it was surface tension. Thomas did notice details. He just didn't record them in his writing.

Comparing Thomas to Ruth is not a fair comparison, since Thomas wrote the least of all the boys who handed in all their assignments, whereas Ruth wrote almost the most. Since Nathan wrote the most of the boys, I will examine his description of the two mixtures:

> [1]For all of the experiment our group did [2]it was 5 ml of one chemical and [3]5 ml of another chemical.
> ...
> #2 [4]We mixed Rubbing alcahol and [5]vegetable oil. [6]The two seperated on top of each other, [7]rubbing alcahol on the vegetable oil.
> #3 [8]acetic acid rubbing alcahol it made an oily substance.

At the beginning of his write-up, Nathan very efficiently wrote a description of how much of each liquid he mixed. Then he went on to describe each mixture. Since he described what he did for both, I counted this as three extra idea units, and counted the twenty-one words of method twice. Consequently, the total of idea units is eleven, and the total number of words is seventy-four. Unlike Thomas but like Ruth, Nathan recorded which liquid floated on which for the first mixture, and, like both Thomas and Ruth, recorded that the rubbing alcohol and vinegar seemed oily.

Nathan wrote eight idea units describing what he did, and only three describing what he observed.

An interesting aside is that Nathan did not record that rubbing alcohol and vinegar mixed, which both Thomas and Ruth did. He seemed to have missed the point of the activity, and did not use either descriptions or summaries to make the point clear.

I wanted to examine Viola's writing next, since she was the girl who wrote the least. Ideally, I would examine her writing in the same way as I examined the other three students, but I could not. For this experiment, Viola, unlike Ruth, spent her writing time on describing what her group had done, rather than on the observations:

> Group wrok and experiment
> IN MY group was Nathan and Emile and myself. We all got the cup and tape to stick on the cup and put name on the tape like vegtable oil and rubbing acehol. We all mixed the liquids togerth. We all had job to do. I had to get the liquids and solids. that is my job. Nathan job was to pot the liquids name on the tape. Emile job was to get the cup and tape. And I had to rip the tape after Emile and Nathan got the right size then we did the experiments vegetable oil and sugar. And salt and acetic acid. They all were neat and great. The one I like was vegetable oil and acetic acid when we mixed them togerth we got a bubble that was cool! And we write it down. I like do experiments! Bye that's my story.

Viola expressed an interest in one of the mixtures, the vegetable oil and vinegar. This was the only one she described. The activity and the writing were definitely important to her, but, in this sample of her writing, recording observations and attempting explanations were not.

Generally, Viola's writing was enthusiastic, and she described details of what happened in her experiments. For example, in her stained fabric experiment, she noted that:

> We all coloured the fabric and made pictures. *Like are names and shapes.* We got all the fabric *dirty and oily.* Then we put ammonia on the *blue* fabric. nothing happen. So we tried the second one. We put rubing acohol and something happend *the rubbing acohol move across the picture.* We did the third one and put acetic acid on the blue fabric and it maed a *beautiful* picture.

In the example above, I have put in italics the words and expressions which are details of empirical description. They are perhaps unnecessary to the flow of her story. However, these details add to my ability to determine what was happening, and perhaps are important for Viola in the development of her ideas. When I contrasted this sample of Viola's writing to Nathan's, the degree of empirical detail became apparent. Nathan's write-up for this experiment was a fiction:

> My lab partners and I were trying to test stain removers so that we could tell people what would we bought Hydrogen peroxide, ammonia, and rubbing alcahol we put it on cloth and coffee filters we tested day and night for 2 days on things that made *large* stains we took a paper that was blank and drew a table up some of the things we tried didn't work at all and some worked just a bit I then made a chart to be published in the provincial and papers around the world. This is what it looked like

Liquid	Felt on paper	Highlighter paper	White out on cloth
Hydrogen Peroxide	Just spread all over the paper	Took mostly everything out	Didn't take any out
Ammonia	Took out most of it but left *red* stain	Did not take any of the stain out	Did not take any out *left it whiter*
Rubbing Alcahol	Took out a little bit *still pretty dark*	Took some of it out	Didn't no take any

Nathan started by describing the experiment and adding a purpose for it. As with Viola's writing, I have put in italics the empirical details that were not procedural. Nathan included far less in the way of empirical details than Viola, despite that he wrote much more. In a total of one hundred and seventy words, eight were empirical details. His descriptions of the stains his group made were brief, just noting the medium and the material, such as felt (marker) on paper, and white-out on cloth. Viola had included details of the colours of stains, the kinds of pictures they made and information regarding the kinds of changes. In a total of seventy words, somewhere between ten and seventeen words (depending on whether we count the "ands," etc.) were directed towards describing empirical details.

I am not making an argument for the superiority of one kind of writing over another. The only claim I could make from this is that Viola seemed to have more of an aesthetic experience from her science activities than did Nathan, despite that Nathan chose most often to write his experiments as fictions.

The stained fabric experiment was the only experiment that Thomas chose to write as fiction. Similar to Nathan, he too focused more on what his group did than on what was happening. And, as was the case in his other writing, Thomas went to the point of the activity - to remove the stain.

> One day Priscilla, Nathan, and Thomas were drawing on a table and suddenly a felt droped on the carpet. Thomas knew his mom would get mad at him so they tried to take the stain out. First we tried hydrogen poroxide. It only took out a little bit. Then the next solvent we tried was Ammonia. It took out most of it but not all of it. Then we tried rubbing alcohol. It only took out some of the stain. Nothing took out the *red* stain from the felt.

In this example, as was common for Thomas, he went straight to the point of the activity: which solvent would remove stains. In a total of eighty nine words, he used only one word which was beyond the call of the actual goal of the experiment - he noted that the stain was red.

I had suspected the girls wrote more in the way of empirical description, and my preliminary analysis of Ruth's, Thomas', Nathan's, and Viola's writing seemed to confirm the suspicion. Thomas and Nathan wrote very little in the way of empirical details, and Ruth and Viola wrote much in the way of empirical details. But before concluding that all boys in the class were like Nathan and Thomas and all girls in the class were like Ruth and Viola, I examined all the students' writing. It was difficult to determine what was good empirical description, so I looked only for extreme examples. When a student included much in the way of details, that was good empirical description. If there were very few details, such as with the examples I have described of Thomas' and Nathan's writing, that student's writing was at the other extreme. Then, I looked to see if the gender of the student was associated with the amount of empirical description. I compared only the two ends of the continuum, so as to leave out those I could not put into either category.

Of all the students, twelve had at least one assignment with good empirical description. Of these twelve, eight were girls, four were boys. (Emile's writing was described in Chapter 5. He was one of the boys who included much in the way of empirical detail.) To put the numbers in a different way, eight out of eleven girls in the study demonstrated good empirical description; four out of fifteen boys demonstrated good empirical description. Of all the students, seven students had almost no empirical detail. Of these seven, five were boys and two were girls. So, five of fifteen boys had almost no empirical description, whereas two of eleven girls had almost none.

Figure 11: Amounts of Empirical Description

Total Number	Much Empirical Description	Very Little Empirical Description
15 Boys	4	5
11 Girls	8	2

My conclusions from this analysis are that, although girls tended to write much more in the way of empirical description than boys, there were boys who would include empirical details, and girls who would write very little.

Nathan was a student who wrote a lot, but with very little empirical description. Also, his second drafts increased about 23% over his first drafts. His second draft of each assignment was a fiction, and he included much in the way of plot for his fictions. The explanation for what he was writing that was not empirical description was that he was writing plot.

Above, I examined Ruth, Thomas, Viola, and Nathan's empirical descriptions. I pointed out that Thomas went to the point of the activity, writing that rubbing alcohol and vinegar made a solution. This led me to examine whether boys or girls were more likely to attempt to explain their assignments. The most common suggestion I made on students' first drafts was to ask for an explanation. Perhaps the girls were responding to this request, and thus making their second drafts longer.

<u>Explanations</u>

Still seeking what the girls were writing about, I examined students' writing focusing on the kinds and numbers of explanations the different genders attempted. In Chapter 2 and 6, I described different kinds of explanations the science community creates. For this section of the study, I counted generalizations from observations as a type of explanation - summaries. A special type of summary in which two generalizations of phenomena are compared is the comparative explanation. When students drew on their empirical observations to attempt to determine a causal relationship, I considered this to be a different type of explanation - causal. Although

Harding (1998) did not claim that causal explanations were the sort that women were supposed to be weak on, this is the kind of explanation in which the answer to the question "why" is most likely to be found. Hence, I was interested to see if the girls were as likely as the boys to attempt causal explanations. There is another type of explanation which Ziman (1984) described. This is the explanation which relies on postulated entities. I will discuss explanations which rely on postulated entities in the next section when I compare spontaneous concepts to scientific concepts, since postulated entities are a simple example of scientific concepts.

I start this analysis by examining the writing of those students who handed in all their assignments. There were six girls who handed in all assignments, and five boys who did. For all the girls except Katie, the biggest increase in length was for experiment three, when they changed a simple recording of observations to a fictional narrative in which to record their observations. In the fiction, not one of the girls attempted to explain their observations. The boys did not attempt explanations in their fictions either, except for Nathan's summary of experiment four, the stains experiment. For most of the girls, there were moderate increases in length for the other assignments, and Ruth, Gillian, Mary, and Joan all attempted to explain their observations in many of their second drafts. Katie only once attempted an explanation. Viola never attempted to explain, and her second drafts were almost the same length as her first drafts.

Interestingly, the greatest increase in length of any assignment was in Ruth's home experiment. (This assignment was not included in the data set where I analyzed assignment word length.) For her home experiment, Ruth added several extra experiments, searching for explanations for her initial observations.

For the five boys, Thomas, Adam, and Emile all regularly attempted explanations. Nathan and Donald only once each attempted explanations. Nathan wrote fictions for the most part, so his results seem similar to the girls'. Fictions were not conducive to explanation.

The increase in length, then, for four of the girls in this group, for almost all the assignments, was due to attempting to explain their results. Two of the boys did not increase the length of their second drafts, and one boy's increases were due to improving the quality of his fiction. Two of the boys increased the clarity of their explanations in their second drafts.

I examined all the students' work, all their assignments, looking to see if students attempted to explain their experimental results. As described above, I categorized the students' explanations as summary, comparative, or causative. First, overall, how many students attempted explanations?

Figure 12: Numbers of Students Who Attempted Some Type of Explanation

Total Number	Number who attempted some type of explanation
15 Boys	10
11 Girls	9

Next, I examined all assignments and counted the number in which students attempted to explain some aspect of their observations.

Figure 13: Per Cent Assignments in Which Students Attempted Explanations

Total Number	Total Assignments	Explanations	%
15 Boys	145	46	32 %
11 Girls	120	50	42 %

More of the girls' assignments showed attempts at explanation than the boys', even though there were more boys' assignments. The girls attempted to explain more often than did the boys. This is one of the things the girls were doing in the greater volume of writing they did.

I next examined the kinds of explanations students tried. I looked at each student's assignments and checked to see if that student tried to explain any of his/her observations, and what kind of explanation s/he tried. Not all the students attempted to explain even once. However, of those who did, some used several different kinds of explanations, depending on the assignment.

Figure 14: Kinds of Explanations

Total Number	Summary	Comparative	Causative
10 Boys	9	4	7
9 Girls	7	3	7
19 Total	16	7	14

Seven of the girls made summaries in at least one of their experiments; three made comparisons in at least one of their experiments and seven attempted causative explanations. For the boys, nine of them summarized, four of them made comparisons, and seven attempted causative explanations. There really isn't much here in the way of gender differences. An important finding is that the girls were just as likely as the boys to attempt causal explanations, despite the old fashioned comment that women did not try to explain their observations.

My last analysis of explanations in this section was to look for evidence that students had shifted or tuned their explanations. Three (perhaps four) students shifted their explanations in their writing. Ruth suggested a number of possible explanations at the beginning of her second draft of her home experiment and continued to reflect on these throughout the draft. By the end, she had eliminated several explanations, and considered a few more. She demonstrated she could shift her explanation right within one draft of her assignment. Three of the four students who shifted their explanations were girls. Eleven students tuned their explanations. Seven of these were girls, four were boys.

All those students who demonstrated a shift in their explanations also demonstrated tuning. Consequently, the oumbers for tuning are the totals for students who demonstrated their learning in their writing. So, to put this analysis in other terms, seven of eleven girls demonstrated their learning in their writing, whereas only four of fifteen boys demonstrated their learning in their writing.

Figure 15: Demonstration of Learning in Writing

Total Number	Tuned	Shifted	Either
15 Boys	4	1	4
11 Girls	7	3	7

To summarize, the girls wrote more in the way of empirical description than their male peers. The girls wrote more explanations in total than did the boys, but were no more likely than the boys to attempt causal explanations. However, the girls were more likely to demonstrate their learning in their writing, tuning or shifting their explanations. Two of the girls did not attempt any explanations at all. One of the boys demonstrated a shift in explanation in his writing, and four boys tuned their explanations. One of the girls was very poor at empirical description, and four of the boys wrote much in the way of empirical description.

This begs the question of whether the children who were writing much in the way of empirical description were also those who were demonstrating their learning in their writing. At first glance, I thought evidence of a relationship between empirical description and tuning or shifting explanations might be evidence for students using their writing to learn. On second consideration, I dismissed this possibility. Those who wrote more generally included more in the way of empirical description. Those who wrote more generally included more explanation. With explanation, students were more likely to demonstrate how they had changed their explanations. Consequently, one would expect there to be a relationship between empirical description and tuning or shifting. But, when I examined the results from individual students, there was no trend apparent. Of the eleven students who engaged in good empirical description, six shifted and/or tuned their explanations. Of the six students who had very little in the way of empirical description, three tuned their explanations. Three of the four who shifted their explanations used detailed empirical descriptions. But one of the four who shifted used a moderate amount of empirical description. It would seem there was no trend apparent. I would think this might be evidence that some students might demonstrate their learning with their writing, but do not use their writing to learn.

Speculations

There was one other aspect of the students' writing which I noticed. Some of the students speculated in their explanations. By speculation, I mean that they suggested two or more possible explanations. To examine the speculations, I will look more closely at the home experiments.

The students were asked to hand in three drafts of the home experiment. Many of the students chose to follow an activity from a book of science activities. These books often have a simple activity for children to carry out, then a perfunctory explanation which the evidence from the activity could not possibly justify. However, since the students did three drafts of their home experiment, I could ask them questions about their activity which would lead them on to explore other aspects of the phenomenon under investigation. Not all the students chose to use activities from books. Often, the experiments were from television commercials. Many of the students put an egg in vinegar, some of them referring to the toothpaste-test commercial, others just observing. Adam's experiment came from a story I had told the class.

I examined the students' home experiments to determine if there was a difference I could pick out between the girls' writing and the boys'. Although girls attempted explanations more than boys, both groups did attempt to explain. However the type of explanation was very different. The girls were much more likely to be speculative. They would suggest a number of possibilities and discuss them in light of their observations. Part of the reason the girls could do this was because they gave much more detailed descriptions of the phenomena they were investigating.

In Chapter 5, I gave examples of speculations from Ruth's home experiment, examples such as:

> On the side that I had put toothpaste on felt sort of warm, on the side with no toothpaste on it felt cold. **I would have thought that it would be the other way around. Because the toothpaste might have trapped the coldness under it and the other side would be warm. But the toothpaste must have kept the warm air in and the other side must have kept cool somehow**.

Ruth's home experiment is a narrative, a chronological account of her actions, observations and interpretations. She differentiated carefully between her observations and inferences. Ruth never drew on postulated entities. She used everyday words, rather than science words, to explain her results.

Thomas wrote very differently. This was his third draft, and he responded to one of the questions I had asked about his earlier explanation. His explanation in his third draft was the same as his explanation in his first draft, except that he was much more clear the third time (as if explaining to a particularly slow teacher.)

> Home experiment
>
> First I got a glass 2 leter bottle and filled it up with hot water. Then I got a 2 leter plastic bottle and filled it up with hot water. Both bottles were the same temperture. I capped both bottles, and put them in the fridge for 30 min. Nothing that I could see was happining except the plastic bottle slowly caving in because the O (Oxygen) atoms in the H_2O (Hydrogen $_2$ Oxygen) molecule is contracting but the glass bottle was'nt. When I took the two bottles out the water in the glass bottle was warmer than the other. Why?
>
> My hipothesis is the reason why the water in the glass bottle is warmer than the other. Is because the O (Oxygen) atoms in the water from the glass bottle contracts less than the other because there is less contraction space than the other. This slows down the cooling process. Therefore, one bottle is warmer than the other.

I really liked the clarity in Thomas' explanation. It made it much easier for me to see where his explanation deviated from the traditional science explanation. Because I valued his explanation, it took me some time to notice the qualitative difference between his explanation and Ruth's speculations. Thomas wrote with authority. He suggested, with no evidence for the existence of molecules, that the decrease in volume was due to oxygen atoms in the water molecules getting smaller. He explained this could not happen in the glass bottle. The cause of the temperature difference was due to the difference in contractions. This explanation is close to that currently accepted in science. As mentioned in Chapter 5, with the explicitness of his explanation, I could see where his explanation deviated from that of science, and so could question him, or explain what scientists believe.

All the students handed in at least two drafts of the home experiment, thus, there were fifteen sets of boys' writing and eleven sets of girls' writing to examine. The results are listed in the table below.

Figure 16: Explanation, Speculation, Detailed Description in Home Experiment

Total Number	Good description	Explanation	Speculation
15 Boys	4	8	0
11 Girls	7	8	2

Eight out of fifteen boys attempted some type of explanation in the home experiment. Not one boy engaged in speculation about his explanation. Four of the boys gave detailed descriptions of their phenomena. Seven of the eleven girls gave detailed descriptions and two engaged in speculation. Eight attempted some sort of explanation.

For this analysis, I have defined speculation as the suggestion of other possible explanations. If I were to expand the definition to include the use of tentative language, words such as "I think" or "it seems," the results are different.

Figure 17: Explanation and Tentative Language in Home Experiment

Total Number	Explanation	Tentative Language
15 Boys	8	2
11 Girls	8	7

In other words, only one girl gave an explanation with an authoritative explanation. All the other girls used tentative language as they considered their conclusions.

However, returning to the original definition of speculation as the generation of alternative explanations for the same phenomenon, I examined all the students' assignments. Six students speculated in at least one assignment. Two of these students were boys and four were girls.

This, then, is another reason the girls were writing more than the boys. Speculating about why something happens usually takes more words than giving one succinct explanation. Using tentative language also takes more words, and the girls were much more likely to use tentative language than were the boys.

Summary

The girls wrote more than the boys. They wrote more in the way of empirical descriptions, they were more likely to attempt to explain their results than were the boys, and they were more likely to speculate. Further, they were more likely to use tentative language in their explanations. However, in every case, there were students who were exceptions. There were girls who did not demonstrate one or more of the characteristics attributed to girls, and there were boys who demonstrated one or more of the characteristics attributed to girls. As with most cultural (in this case, the sub-culture of gender) differences, generalizations are not to be used as rules.

Gender Differences in Scientific and Spontaneous Concepts

What first drew my attention to whether students used spontaneous concepts (experiential concepts from their own experiences) or scientific concepts (which for the purposes of this discussion, I am considering to be specialized terms), was the analysis of shifting in explanations. Of the three girls who shifted their explanations, two shifted from scientific concepts, to drawing on their own reasoning, and relating their explanations to their personal observations. I have considered specialized terms to be scientific concepts because they are an example of culturally created concepts which the students could not possibly derive from their own experiences. Postulated entities and specialized terms are cultural creations, and have usually taken the science community years, even centuries, to articulate and define.

In the following example, notice how Mary recorded her observations and explained the first draft of her home experiment:

> I then put my finger into the bowl and in an instant the pepper sped away to the rim of the dinner plate.
>
> ...
>
> Why I think it happens:
>
> I think the soap breakes the surface tention of the water. The water at the edges of the dish pull away, the pepper flows with the water.

I asked her what surface tension was, and suggested she try some more experiments to try to find out more about surface tension. In her second draft she tried another experiment, and made a very different explanation:

> Why:
>
> I think that some thing like a chemical reaction happened because when I was waiting for the peper to calm down, I saw the pepper giving away a sort of oil texture and I think that texture reacted with the soap! I tried without the soap on my finger and nothing happened!

"Chemical reactions", like "surface tension" is a specialized term representing a scientific concept. The meaning includes macroscopic observations, causal explanations, and postulated entities. On the surface, it would appear that Mary had adjusted her explanation from one scientific concept to another. However, there is an important difference between the two scientific concepts. We had defined chemical reactions in class to be a phenomenon when a new substance (as indicated by the appearance of new properties) had been formed. We had done experiments in class so the students had experiences with chemical reactions. Mary adjusted her scientific concept of surface tension to her everyday knowledge of chemical reactions. She described how she recognized a chemical reaction by referring to her observation of the new appearance of an oily texture. There was a substance with different properties formed when the pepper and soap mixed.

Joan also shifted from a scientific conception in her first draft to her own explanation in her second draft. In her first draft, she added salt to water, then put the solution in the freezer. She explained the slushy result by claiming that salt lowered the freezing point of water, the explanation currently accepted in science. For her second draft, she tried sugar in water, and chose to explain the appearance of the liquid rather than deal with the freezing. She wrote:

> I observed that the one that had sugar in it was not clear, and I could not see the bottom of the cup. It did not have bubbles in it and it was kind of white and it was slushy. The non-sugar water was clear and I could see the bottom of the cup, it had bubbles and it was solid not slushy. I think that the sugar one was not clear because the sugar evaporated and made the color change into white.

Priscilla was the only girl who attempted to use a scientific explanation and persisted with it in spite of my questions about it. She tuned her explanation in her second and third drafts. Her experiment was to test if hot pepper mixed with hot water would make her skin hot, and if baking soda would then cool her skin. Her conclusion:

> The hot spicy mixture reacted with my skin and made it feel hot. It was a chemical reaction and the baking soda helped stop this burning sensation because it is basic and helps balance out the other chemical reaction.

At the time of this first draft of the home experiment, we had discussed the signs of chemical reactions, but we had not yet examined acids and bases. From her explanation, I was not convinced that she had constructed any sort of personal meaning for either chemical reactions or baking soda being basic. I asked her about whether her skin felt hot because the cayenne pepper had been mixed with hot water, or because there was a chemical reaction. I also asked if baking soda and cayenne paste would react with one another if they weren't on her skin. She responded with:

> My experiment with cayenne pepper started with hot water because I know from other experiments that I have done that substances dissolve better in hot water than in cold water. I then let it

cool down because I didn't want to be fooled by the "temperature" hot rather than the "chemical reaction" hot. The water was room temperature but went I put the solution on my arm it felt hot.

> I tried the cayenne pepper today without mixing it and when I put some of the cayenne powder on my wrist it didn't feel any different. I think that this is because you need to add water to get the chemical reaction out of the spice. I know that if you taste it on your tongue that it makes your tongue feel like it is burning. There is saliva on your tongue and it probably makes the spicy reaction.
>
> I took our thermometer and put it in the bag of cayenne pepper and nothing happened.

Priscilla tuned her explanation. She still believed cayenne pepper caused a chemical reaction on her skin; now she tuned the explanation by adding that water was required for this reaction to take place. I asked her more questions: I pointed out that garlic caused the same sort of feeling of heat on tongues and in eyes. I asked if the feeling of heat was because of the nerves being stimulated or if a chemical reaction released heat, which stimulated the nerves. Last, I asked her "Why does baking soda cool the skin? Is there a chemical reaction between the cayenne and the baking soda?"

She responded with:

> The hot feeling in your eyes from garlic is a type of reaction but garlic isn't a chemical so I don't think it is a chemical reaction. I think that people, like Mexican people, eat spicy foods all the time and they don't think these foods are hot. I think this is becaues they get used to it. I'm not used to spicy foods so they feel hot and taste hot to me. Maybe their taste buds are no longer as sensitive as mine
>
> ...
>
> When our hot tub is too acidic we have to add baking soda to make it less acidic. I think that the sodium bicarbonate and water mixture helps stop the acidic reaction on my skin, just like it makes the hot tub water not have so much acid. My mom says that it makes the water more alkaline and that alkaline is the opposite of acid.

In the first paragraph, Priscilla demonstrated that she did have a consistent understanding of what chemicals were, a concept which is common in everyday language. Garlic is a food, so is not a chemical. Chemicals are somehow more pure than food. Thus, as she tuned her explanation, the concept she had became clear to me. Consequently, I was able in her last draft to address some of the issues which she revealed in this last explanation.

Of the boys who attempted explanations in their home experiments, Thomas, and Steven were the only two who started with specialized terms. In both cases, these terms referred to postulated entities. Both of them stuck with these explanations, further articulating them to answer my questions. Thomas' home experiment and the scientific conception he drew on were described above. Steven's experiment was an exploration of the same phenomenon, expansion and contraction of fluids, but from the more familiar approach of temperature changes. He put a balloon on a bottle, and put the bottle in the freezer. He recorded the results, then put the bottle in the sun. His experiment was described in Chapter 5 as an example of a student tuning his explanation. Note that he drew on the scientific conception "The reason for this is that cold air contracts" in his first draft. His second draft, after I challenged him on the contraction theory, was better articulated:

> Because: In cold air the molicules move slow, therfor there is little space in between each molicule so the colder it gets the less space.

In this last draft of this experiment, Steven used a postulated entity to explain his observation. There certainly wasn't enough data for him to justify the existence of molecules, but he used them for his explanation.

The postulated entity of molecules is a much simpler concept to explain than the projects Mary and Priscilla took on. Chemical reactions have layers of abstractions, of which molecules occupy just one layer.

In the section on explanations, I examined all the write-ups for student experiments to see how many of the students attempted causal explanations of the phenomena they were observing. The total number of students who attempted causal explanations was fourteen. Of these, seven were boys and seven were girls. Seven of the fifteen boys attempted causal explanations about phenomena, and seven of the eleven girls did. It would seem that, in this class, girls were just as likely to attempt causal explanations as were boys.

Next, I examined all the students' write-ups to determine which students used scientific conceptions - postulated entities. At the same time, I examined the writing to determine if students drew on their spontaneous concepts for their explanations. These are not mutually exclusive categories. For example, Thomas and Priscilla drew on both scientific concepts and spontaneous concepts in their attempts to explain the results of their experiments.

Figure 18: Scientific and Spontaneous Concepts in Explanations

Total Number	Causal Explanations	Scientific Concepts	Spontaneous Concepts
15 Boys	7	6	4
11 Girls	7	3	7

Six of the seven boys who attempted causal explanations drew on scientific concepts, and four drew on spontaneous concepts. Three of the seven girls drew on scientific concepts. Two of these three girls shifted to spontaneous concepts for their explanations in their second drafts. All seven girls drew on spontaneous concepts in their explanations. It would seem that the empirical experiences are very important to the girls for explaining their results.

Of the students who attempted causal explanations, only three of the seven girls attempted to use scientific concepts in their explanations. Two of these girls, when questioned, abandoned the scientific explanation and relied on their own reasoning. Six of the seven boys attempted to use scientific concepts. None of them abandoned their explanations when I questioned them. Again, however, there are important exceptions. One of the girls did persist in using the scientific explanation, despite my questioning of her. And, one of the boys did not attempt to use a scientific concept. Note, though, that girls and boys were just as likely to attempt causal explanations. The difference is that the girls were more likely to rely on their own experiences and reasoning, and the boys were more likely to persist in their attempts to explain the culturally constructed concepts.

Summary

I examined the students' writing looking for differences according to gender.

Most of the girls wrote more than all the boys. Also, the girls' second drafts increased more in length than the boys' did. The difference in length seemed to be due to the girls writing far more detailed empirical descriptions, the girls speculating more about their results, and the girls using more tentative language than the boys. Further, the girls were more likely to attempt to explain their results than were the boys.

An interesting finding about the explanations the students gave was that the boys were more likely to draw on scientific conceptions or postulated entities than were the girls. The girls were more likely to draw on their spontaneous concepts, to theorize about their data from their own experiences, rather than use new words. In Vygotsky's (1934/1986) words, boys seemed more likely to "grow" their scientific conceptions down to their spontaneous concepts, whereas the girls were more likely to do the reverse. Boys seemed more willing to accept the authoritative explanations of science, whereas the girls were more likely to rely solely on their own observations about the data.

The comments I make in this summary must be kept in context. In this group of twenty-six children, there were boys who speculated, who used tentative language, who used spontaneous concepts, and there were girls who wrote very little, who used very little empirical description, and who used scientific concepts. An important example: six boys used scientific concepts; this means that nine did not. Boy sub-culture is one thing; the sub-culture of science is another. Although more boys than girls might find the sub-culture of science attractive, the boys in this classroom who chose to use scientific conceptions were in the minority.

The greatest difference between these boys and these girls was not so much in their scientific conceptions as in their writing. It would seem that, despite that schools are attempting to treat boys and girls the same, boys and girls are still being encultured differently. The girls in this class were, for some reason, more likely to use their literate tools to explore ideas. Although the boys seemed just as thoughtful as the girls, they were far less likely to show this in their writing.

CHAPTER 7

WHERE HAVE I BEEN, WHERE WILL I GO?

Introduction to the Conclusion

If I compare my intellectual journey in this dissertation to the search for the North West Passage, I can perhaps illustrate some of the frustrations I encountered. Not that my dissertation has taken as long, or covered as much territory as those who were searching for the North West Passage. However, as metaphors go, there are some similarities and differences which the metaphor might help to illustrate.

My original intent for the dissertation changed as I learned more about the topic. The same happened for those who sought the North West Passage. My original intent was to show that the particular claim of the Great Divide hypothesis, the one about there being no science without the prior invention of the Greek alphabet, was inaccurate. The original intent of the search for the North West Passage was to find a quick easy water route across North America. The explorers project ultimately proved impossible. I learned that others had already done a very good job of critiquing this claim of the Great Divide hypothesis. The intent of the dissertation changed, just as the intent of the search for the North West Passage changed.

In both cases, however, much was learned. The search for the North West Passage opened much territory to Europeans, and the Europeans learned a lot, although they could have learned more if they had co-operated more with the indigenous people. Further, the opening of the territory had a tremendous impact on the lives and cultures of the indigenous people. In my journey, I made many false starts, followed many ideas that seemed full of promise and flowed quickly, and later learned that many of them were trivial. However, I learned much that I wouldn't otherwise have learned, and now have other ideas of how I could have conducted this study. Mostly, though, I hope that my research will have an impact on the lives of the students. Unlike the effects of the early European explorers on local cultures, I hope the impact my work makes will be beneficial.

The trip that eventually took a crew through the Queen Elizabeth Islands was merely for show (despite being incredibly arduous), to draw closure to a challenge that, with the development of rail lines, was no longer necessary. The intent to find a quick and easy water route was impossible, so a land route made quick and easy with rail was invented instead. As for me, searching the literature about cultures, science, literacy, and technology, opened up many areas of thought, and changed my way of looking at a more interesting issue than whether science was dependent for its invention on alphabetic literacy.

Two intellectual rivers which I thought were connected – the one being the cultural change hypothesis, the other being individuals learning through writing – were not. However, there are enough parallels that I think some researchers are led to believe they are the same argument, and consequently, some fundamental assumptions regarding the individual argument have not been explored. In this dissertation, I explored some of those assumptions. For example, writing *per se* might not help children to learn. Rather, particular kinds of writing might help children in particular kinds of learning. Langer and Applebee (1987) examined the different kinds of learning brought about by different forms of written assignment. I was interested also, to know if particular literate tools might facilitate children learning in science. For this, I had to define what learning in science was. Then, I examined children as they are just becoming literate, to determine what literate tools they have which might help them to demonstrate they have made connections between ideas. I also examined if some of the literate tools might help children not just to indicate they have made connections, but also help them to make connections.

The dissertation process has been sometimes very frustrating. The intellectual journey I travelled took many twists and turns. If the reader were interested in a historical study of my thoughts, the various drafts, counter-drafts, rejected drafts, would be interesting to read. However, I assume the reader is not interested in the history of my thought processes, but more interested in what value is ultimately derived and where the research is likely to lead.

The most frustrating part of the dissertation process, though, has been in the writing itself. First, my research has led me to believe that exploratory, tentative, speculative writing is more conducive to learning. As yet, in science education research, the expectation is still that writing will be transactional and authoritative.

Second, a much greater frustration was in getting my thoughts onto paper. As Vygotsky (1934/1986) noted, language is sequential. Language imposes an order on thinking that is not necessary for non-verbal thoughts. Non-verbal thinking can be imagistic and episodic; connections are intuitive and complex. Language imposes a different structure. Ideas must relate to one another in some sort of order, perhaps chronological or perhaps logical. Although we can use writing to show some of this complexity, I believe language limits us. We cannot show the full range in which we connect ideas through writing.

I have had greater trouble sequencing my thoughts since beginning to use word processors. When I wrote longhand, then typed out the good (and final) copy, I organized what I was about to write much more coherently in advance of the actual writing. With word processors, however, I could put words on the screen almost as soon as they connected to my thoughts. I could engage in a written stream of consciousness, similar to speech. Unlike speech, I could go back to edit what I had written. This might be used as evidence that word processors have made me sloppy in my thinking. A perhaps more likely explanation is that the topics I chose to analyze before word processors were easier-to-sequence topics. A dissertation of this type is much more difficult to sequence. I believe that word processors have given us leeway for different ways of thinking – forms where more complex relationships can be displayed; unfortunately, these new ways are not yet accepted in academies.

Third, a less frustrating and very beneficial aspect of writing this dissertation has been to make the intuitive connections between ideas more explicit. I do not think that we can ever make the connections between ideas fully explicit, since if we had to do that, there would be no connections left. (Every connection involves some sort of logical leap.) However, I believe that questioning the worth and validity of the connections I did dredge into consciousness was a good way to learn about myself and about the ideas I was working with. Putting words to intuitive connections was important for my learning.

The question I asked myself again and again as I wrote was whether *I* used my writing to learn. The answer to this is not a simple yes or no. Writing helped me to sustain my focus on my readings. Writing helped me to sustain focus on intuitive connections between ideas, so that I could search for how to make the connections explicit. It helped me to sustain my focus on my students' writing. In these three ways, writing helped me to learn. However, I would disagree with Goody (1987), Emig (1977), and Fondacaro and Higgins (1985) that writing was a useful tool because it helped me to visualize my ideas. When I was unsure of connections between ideas, I read the piece aloud to myself. Or, I talked the idea through with a peer. Or, I submitted my writing to my committee and asked for their feedback, their criticisms and comments. I detected contradictions aurally and in dialogue with others. Only after considerable dialogue with others was I able to detect contradictions visually by myself.

However, after analyzing the students' writing, and after thinking about some of the tools they might have used for writing to learn, I think that I might be reaching a new stage in my writing. I now might be able to use my writing as Scardamalia and Bereiter (1986) suggest – to transform my ideas instead of just reporting them. By using data tables, and re-organizing the data in the tables, by writing down the main point of a paragraph in the margin and then checking to see how one paragraph links with the next, by using transitionals of different types, I think that I can more clearly visualize what I am trying to express.

I have learned much from the dissertation process. I have visited many intellectual locations.

Where Have I Been?

My journey began when I first heard Havelock's (1963) thesis that the invention of the Greek alphabet was a necessary precursor to the invention of science. My reaction was immediate and visceral. Havelock's statement seemed racist. Only several years later did I realize that my response to his thesis was based on the high value I placed on science. If I had not valued scientific ways of knowing so highly, I might have responded to Havelock's thesis by considering oral cultures to be rather lucky. While looking for conceptual ways in which to critique Havelock's thesis, I learned that others had already done this.

By the time I realized this, I was well into another aspect of my journey - teaching in a grade 5/6 classroom, integrating writing into science. I wanted to determine if the children in the study used their writing to learn. But as I got deeper into the theories of writing to learn, and after hearing David Olson give a talk at the University of British Columbia, I realized there was a gap between theories regarding literacy and science, and individuals learning science through their writing. There was no logical connection between cultures being changed by technologies and individuals within those cultures having to possess the technology to develop those ways of thinking. This was pointed out very well by Scribner and Cole (1981), but for some reason, it wasn't until I heard Olson's talk and re-read Scribner and Cole's paper that I noticed more of what they had been saying. A dissertation that had seemed to be a coherent whole to me, examining literacy and science and writing to learn in science, suddenly became two separate topics. Scribner and Cole (1981) had pointed out that the two topics are often conflated. Further, they (and others) had already pointed out inadequacies in the cultural argument. Thus, I could focus more narrowly on the writing to learn argument.

But what is learning? From examining two predominant learning theories, psychological constructivism and socio-culturalism, I concluded that learning means changing (Driver, 1988). Intellectual change can be the acquisition of more knowledge, can involve adapting an idea to a new situation (tuning), or can involve rejecting one idea for another (Schumacher & Nash, 1991). Learning occurs because of connections we make between ideas. Vygotsky (1934/1986) was particularly interested in how children's spontaneous concepts connect to culturally created scientific concepts. Vygotsky, more than any other learning theorist, seems to have made a connection between individual learning and cultural knowledge. This relationship is an important aspect of the dissertation. It is because of his beliefs about scientific conceptions as culturally created versus the individual constructivists' belief in how science knowledge is constructed, that I could examine how it is that children interact with science words. One way in which a child participates socially is through his/her use of words as s/he acquires the meanings of the words. The child learns what the words mean through interactions with the teacher and other children in the class. In this dissertation, I examined the acquisition of scientific concepts as the child interacted with the teacher.

Another stop I took along the way was in the deep waters of post-structuralism. As I sought methods for analyzing the students' writing and talking, I read on discourse analysis, and this led to an examination of the relationship between discourse and culture. It became ever more evident that individuals capable of using authoritative genres – genres which have greater authority in the culture – are more likely to gain individual power. Thus, women and those of "other" cultures have often been excluded from science, not because they were irrational, or lacking in intelligence, but because of the ways in which they displayed their evidence and because of their less authoritative language. When gender issues appeared at the research site, I examined them in light of the authoritative language of science.

There was a great wealth of information and streams of questions from each of the places I visited. After visiting all these places, I attempted to narrow my focus to four questions which could be considered to be in three different areas. These were:

Area 1: What literate tools might help individuals to learn science?

What literate tools do individual students in grade 5/6 have?

Area 2: Is there any evidence that students use their literate tools to learn science?

Area 3: Do boys and girls adopt and adapt these literate tools in different ways?

<u>Area 1: The First and Second Questions</u>

The literate tools which I considered would be important for demonstrating connections between science ideas were what I called transitionals. Transitionals were those grammatical and lexical forms which connected one idea unit to another, or which showed a connection between a series of idea units. Examples of transitionals were conjunctions, punctuation, and implicit rules (such as writing a story in chronological or logical order). Another set of transitionals are those I considered to be meta-transitionals. They prepared the reader for a set of relationships between ideas. For example, headings announced to the reader that the next section of the writing would all deal with a particular aspect of a problem. Paragraphs and announcements were two other forms of meta-transitionals. Announcements were something the children seemed to have invented - announcing at the beginning of a sentence or paragraph what they intended to describe in the next section. Some transitionals were strictly literate, only available in written form, such as punctuation, paragraphs, and headings. Others were both oral and literate, such as conjunctions, implicit rules, and announcements.

Tools which could not only display relationships but could perhaps help detect patterns between ideas were lists and data tables. Lists are both oral and literate, whereas data tables are strictly literate tools. They only make sense on paper.

Next, I examined the students' writing to determine what literate tools they were already using in grade 5/6. I learned that all the students in the study used periods in their writing. Unfortunately, many of the students had not yet learned much about sentence structure. Their periods did not mark the end of traditional types of sentences. Many sentences were run on, and many others were fragments. Only about half the students used commas, and only seven used any other kind of punctuation. Those who used commas and other kinds of punctuation were much more sophisticated at using periods to construct sentences.

More students (twenty-one) used announcements than used any other kind of meta-transtional. About half the students attempted to use paragraphs. As with periods, many of these students did not use paragraphs with a consistent form. About one third of the students used headings, but some of the students who used headings used them for their home experiment. I believe that they were using headings because the science activity books they used as resources had headings in them. However, six of the nine students who used headings used them in other than the home experiment situation.

As well as itemizing the forms of transitionals that students used, I noted the different roles transitionals played. Transitionals can relate ideas temporally, additively, comparatively, logically, or in a subsidiary relationship. All students used temporal and additive transitionals, whereas only half used logical transitionals. The students who used logical transitionals attempted to explain their experiments causally. Less students used comparative and subsidiary transitionals. I never asked students specifically to compare ideas, however, I did ask them to explain. This could account for the difference between causal and comparative transitionals. I believe that subsidiary relationships are more difficult to detect, so this might be why so few students used this kind of transitional.

The students spontaneously developed data tables to display their observations. When they used data tables, they did not write, so I had no idea of what they had done in their experiments. The lack of sentences led to a lack of analysis. The data tables were used only to display information, not to interpret it. At the time, I had not thought carefully about the possibility of data tables being a useful tool for finding patterns in data. Rather than teach the students more effective ways of using data tables, I encouraged them to write stories about their experiments. Thus, very few students used data tables after this.

Area 2: The Third Question

Once I knew that children had literate tools for making connections between ideas, I could pursue in depth an analysis of whether the students actually used their writing to make connections between science ideas. In other words, I could address the question of whether grade 5/6 students used their writing to learn in science.

This analysis is complicated by some factors common to any analysis of learning. Students' talk and writing are merely windows to what they are thinking and what they know. These windows are not made of clear clean glass. Thus, we cannot be sure if what students communicate actually represents what they are thinking. A second problem is that, even if there is strong evidence that students have learned, we cannot be sure if they have learned as a result of their writing. They might have learned because of written dialogue between them and me, or because of further thinking on the topic, rather than by having a written dialogue with themselves. However, learning through written dialogue with their teacher might be considered a way of writing to learn. Further, as I found in my own writing, the writing itself might have forced the students to focus more closely on what they were thinking, and that in itself could have been a beneficial aspect of writing.

To determine if students were learning and if this learning was being displayed in their writing, I looked for evidence that students had shifted or tuned their explanations. Only three (perhaps four) of the twenty-six students shifted their explanations in their writing. Eleven students showed evidence of tuning their explanations in their writing. Since all the students who shifted their explanations also tuned their explanations, a total of eleven students out of twenty-six displayed their learning in their writing.

Six students were using paragraphs or sentences in a consistent form. In other words, six students seemed to have mastered this type of literate tool. Ten students were using these tools in an inconsistent fashion. In other words, ten students were in the zone of proximal development (Vygotsky, 1978) for these tools. Of the eleven students who displayed their learning in their writing, nine of them were in one of these two groups. Two were not using literate tools of paragraphs or consistently using sentences. Thus, the consistent or attempted use of a literate tool is neither a necessary nor sufficient condition for students to display their learning in their writing. However, some of the students really did seem to be using their writing-to-learn. For example, Mary improved her ability to use paragraphs throughout the research. In her second drafts, as she made her paragraphs more consistent, she included more information in her paragraphs. The demand for consistency in the use of paragraphs seemed to create a demand to for explicit relationships between ideas. This demand could be conducive to using writing as a tool for learning.

It would seem, then, that writing could be a tool for learning. However, most children in this grade 5/6 class did not seem in any way to be using writing as a learning tool. One last issue appeared in the data, however, which was that the girls seemed to be more literate than the boys.

Area 3: The Fourth Question

On examining the data closely, I concluded that the girls were much more literate than the boys. Of the six students who used literate tools consistently, there were five girls and only one boy. Further, girls wrote far more than the boys, and increased the length of their second drafts more than did the boys. Consequently, I wanted to know what the girls were writing about, and what they were adding to their second drafts.

Although the girls did write far more than the boys at both ends of the curve, with even the girls who wrote the least writing more than the boys who wrote the least, for all the other data, there were boys and girls who were exceptions to the descriptions I note below. In other words, I would comfortably claim as a gender difference, for this class of grade 5/6 students, that the girls wrote more than the boys. However, for all the other differences I noted between the girls and the boys, there were exceptions in every case.

The girls tended to include more in the way of empirical detail than did the boys. Of the fifteen boys in the study, four included much in the way of empirical description; five had very little empirical description. Of the eleven girls in the study, eight included much in the way of empirical description; two had very little.

Girls also tended to write more in the way of explanations for their experiments. Of the fifteen boys in the study, ten attempted an explanation in at least one lab write-up, whereas of the eleven girls, nine attempted an explanation in at least one lab write-up. Of all the one hundred forty-five assignments handed in by boys, thirty-two per cent had some form of explanation. Of all the one hundred twenty assignments handed in by girls, forty-two per cent had some form of explanation. So, as well as the girls including more empirical description, they also tended to write more in the way of explanation.

Something which drew my attention was the tendency to speculate. Girls were more likely to suggest more than one possible explanation for their observations than were boys. In the home experiment, none of the boys suggested more than one possible explanation, whereas two of the girls did. I also looked for tentative language. Tentative language involved the use of words such as "it seems" or "I think," phrases which imply the student is not certain of the explanations. For the home experiment, eight boys and eight girls attempted some form of explanation. Two of these eight boys used tentative language, and seven of the eight girls used tentative language.

In summary, the girls wrote more than did the boys. The girls tended to include more in the way of empirical description, explanations, speculations, and tentative language. These four factors make a constellation of characteristics which would, in this class, generally differentiate the girl-writing from the boy-writing, but would not identify the author of the piece as boy or girl. All of the girls displayed one or more of these characteristics in their writing. However, there were several boys who demonstrated all these characteristics in their writing. I could not look at a sample of writing and say with certainty that a girl or a boy had written the piece.

Lastly, I examined the students' writing to determine if there was a difference in the way the girls and boys learned scientific concepts. Vygotsky (1934/1986) believed that children should both grow their spontaneous concepts up to scientific concepts and grow their scientific concepts down to their spontaneous concepts. To do this, children should be using the words related to scientific concepts. Evidence that they were using scientific concepts would be when the students referred to postulated entities, such as molecules. Because I wanted to know the degree of understanding children had of the scientific concepts, I always asked them to explain what they meant when they used postulated entities or terms we had not discussed in class. I considered students to be using spontaneous concepts when they drew on their own reasoning, rather than relying on postulated entities.

Boys had a greater tendency to use scientific concepts than did girls. Of the seven boys who attempted causal explanations, six of them used scientific concepts, and four used spontaneous concepts. Of the seven girls who attempted causal explanations, three used scientific concepts, and all seven used spontaneous concepts. Of the three girls who attempted scientific concepts, two dropped them for the second draft of their write-ups; of the boys, all retained their scientific concepts for their second drafts, usually attempting to include more detail as they explained. In other words, for second draft writing, only one girl attempted to use scientific concepts, whereas six boys did. The boys seemed much more willing to use the authority of science.

In this last question I was not so much analyzing students' writing to learn. Rather, I was learning about the students through their writing. However, this last question, like the others, points to important implications for teaching.

Where Will I Go?

My Learning and Writing

As I wrote this dissertation, I learned about ways in which I could use my writing to learn. For example, I could use grammatical forms to hold me to certain patterns. These patterns could force a dialogue between me and my writing, so that I would be more likely to notice conflicts or patterns between my ideas. Also, I could use data tables to record observations, and then shift the information around in an attempt to see if different patterns appeared.

Teaching Science and Writing

What has helped me in my writing has implications for teaching. As mentioned, the students in interviews believed that their writing could help them memorize data, but that was all they expected of their writing. Perhaps if students were taught, both that writing could be a tool for learning, and some of the ways they could use their writing to learn, then they would make better use of their writing. That would be a first step towards children using their writing to learn. However, without the follow-up, the first step would be wasted.

The follow-up would have to involve a change in the kinds of writing that teachers ask for. Applebee (1984) noted that very little time in school is spent on sustained writing, and that very little school writing is exploratory. Most of school writing seems to be to display knowledge. For children to be willing to explore ideas in their writing, they must be given time to explore, and must be encouraged to take risks. Thus, when students are writing to learn they must not be evaluated.

The next research project I would like to attempt is to teach grade 5/6 students to attempt to shift data in their data tables to look for patterns. I would also like to try teaching students about the literate tools of sentences and paragraphs, and help them to use them in consistent form. In this way, just as paragraphs seemed to influence both Mary's and Donald's thinking, the students will have one more tool to help them to learn.

Another way of using writing as a learning tool is to have students write the main points of paragraphs in the margins. Then they could ask themselves how their ideas link together. Then, students could generate a list of transitionals and discuss what kinds of relationships each would illustrate. With grade 5/6 students, these should probably be conjunctions and announcements, since the majority of students used these tools. The last step would involve the teacher encouraging the students to use these transitionals to demonstrate connections between ideas.

During this study, I found a way to determine students' location in a zone of proximal development for their writing and science. Some of the students seemed to be using a literate tool or scientific concept fairly consistently, whereas others still required much assistance, and still others were not yet attempting to use them. This, then, is another area of study. Teachers could analyze students' writing in science to determine the students' literate and science zones of proximal development. In the writing, the teacher will have an opportunity to engage with each student in that student's zone of proximal development.

Gender and Learning

Lastly, the gender issues, as mentioned above, are important issues to be considered. Although girls are more literate than boys, writing more and with more fluency than boys, they are much less authoritative. Boys seem to be able to draw on the genre of science much more easily, using postulated entities and a more authoritative tone. Girls tend to write tentatively and seem to prefer to reason from their own experiences. They seem to be more explicit in what evidence they use to draw their conclusions, and use a variety of empirical details and spontaneous concepts. The boys are more likely to write their conclusions as "black boxes" (Latour, 1987), hiding the history of the explanation with scientific terminology.

I would argue that girls are less likely to succeed in the science genre since their way of writing is not valued. The girls are apparently just as capable as the boys in thinking logically and abstractly; however, for the most part, they display their thinking, their speculations, their own reasoning. When Millikan did this in a paper, the paper was rejected (Holton, 1978). Millikan had to write in an "objective" authoritative tone to have his paper accepted. The boys in this study tended to draw on authority, and to write authoritatively. I would guess that this alone could affect how well girls do in university science courses, and would certainly affect a woman scientist's ability to publish.

We are somehow failing our boys in schools as well, since the boys are not learning to write as well as the girls. At least, most of the boys in this grade 5/6 class were not writing as well as the girls. Issues worth exploring are to find if this is similar in other grade 5/6 classrooms, and to search for ways to encourage the boys to write more. How could we make writing assignments more interesting for boys? Some boys seem to prefer to write fictions. Perhaps giving students choices regarding how they write will encourage more of the boys to write.

<u>Culture and Learning</u>

There is another place worth visiting. Tannen's 1996 research showed that different cultures have different kinds of gendered discourse. In the study I conducted, there were many different cultures represented - so many different cultures that I could not possibly compare the learning of individuals of one culture with those of another culture. It would be interesting to conduct a study in a class of First Nations students to determine if the First Nations students display similar gender differences as this culturally diverse group did.

Non-Sequential Display of Thought

In the meantime, I will be playing with ways in which I can express a greater complexity of ideas. I do not think that the sequential form of writing is the best form for expressing complex arguments. It is possible that by using icons, and perhaps by using computers to a greater extent than as glorified typewriters, that more complex ideas can be expressed. For example, when I design a unit for teaching, I draw a concept web. The different concepts are linked and cross linked. Some concepts are addressed in one lesson, others in several lessons. As I teach, I can tell my students - "remember when we did such and such" to prod them into making those links. It should be possible to use a computer to display a dissertation which is not just sentences, paragraphs, and chapters to be read in sequence. It should be possible to have various ideas addressed in different ways, and to illustrate the complexity of the links between ideas.

Implications for Research

In this study, I used pragmatic discourse analysis in an attempt to tease out what children were doing with their language. This was an effective tool for determining what ideas the children were communicating, for determining what sorts of literate tools they had, and whether they were using their literate tools effectively. What is missing from this study and should be incorporated in any future studies would be to give students pre- and post-tests to determine what prior knowledge the children had, and what they had learned during the unit. A post-test given at a later date, such as several months later (a post-post-test?), would help to indicate if what the students learned had been retained.

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APPENDIX A

PERMISSION FORMS FOR PARTICIPATION

Letter to Parents and Students

To the parents and guardians of the students in M_____________ grade 5/6 class.

I am interested in studying how students use writing, speaking, and thinking in science class. To carry out this study, I will be videotaping students as they talk in the science classroom in small groups. I will also be photocopying their science writing assignments, and I will be interviewing selected students. The results of this research could have a beneficial effect on the teaching of science and writing in the future.

In this letter and with this attached form, I am asking for your permission for your child to be involved in this study. If you agree that your child can participate, I will then ask your child if s/he would like to participate. If either you or your child does not agree for your child to participate, your child will not be videotaped, and your child's written work will not be photocopied.

The research I will be conducting will take place in your child's classroom, during regular science class time. In no way will this research take time away from what your child would normally be learning in grade 5/6 science. All the children in the class will be doing the science activities; all will be completing the same assignments. It would be beneficial to the study if your child could participate in the videotaping of science activities and if I could photocopy his/her written work. Although all the children in the class would have much to offer, I haven't the resources for all children to be interviewed. At the time when interviews begin, I will send home a second consent form, requesting permission for the last stage of the research. In the meantime, I am hoping that all the children can be involved in the videotaping and photocopying of written work.

The only people who will watch the videotapes are myself, my supervisor, Allan MacKinnon, and perhaps M___________. Transcriptions will be made of the videotapes, and the tapes will be erased after the research is concluded. In the tape transcriptions, any information which could identify the children or the school will be changed. Transcriptions will be made of the written work, and any information which could identify the child or the school will be removed.

The research results will form part of my PhD dissertation. It is possible that I will write some papers for publication in educational research journals. The children and the school will be anonymous.

If you have any questions or concerns, you may contact me:
Janet McVittie at 291-5723

Or my supervisor:
Allan MacKinnon at 291-3432
Or the dean of the faculty of Education:
Dr. Robin Barrow at 291-3148

If you are willing for your child to be involved in the videotaping stage of the research, please sign the attached consent form on the "agree" line. If you are unwilling for your child to participate, sign the form on the "do not agree" line. If you agree for your child to participate, I will then ask your child if s/he would like to participate. If you and your child agree and later one of you changes your mind, you or your child may withdraw consent by telling me. If you do this, all photocopies of your child's work will be returned to your child.

Sincerely,

Janet McVittie

CONSENT FORM FOR VIDEOTAPING AND PHOTOCOPYING

I, ______________________________ the parent/guardian of
(print your name here)
______________________________ understand the nature of the study
(print your child's name here)
which Janet McVittie proposes to conduct in my child's classroom. I have read the attached letter and the request for informed consent.
I understand that Janet McVittie's study will have no bearing on my child's mark in science, and that Janet will guarantee my child's anonymity in any publications.
I understand that signing this form gives my consent for my child to be in the study, and that Janet will now ask my child for his/her permission.
I understand that my child or I may later decide to withdraw from the research and may do so by calling Janet McVittie and asking to withdraw from participation. If this happens, all photocopied assignments will be returned to my child.

I agree that my child, ______________________________,may be videotaped while
(print your child's name here)
working on science activities in class and agree that my child's written assignments may be photocopied.

______________________________ ______________________________
(sign your name here) (date)

****

I, ______________________________ the parent/guardian
(print your name here)
of______________________________ do not want my child to be videotaped
(print your child's name here)
while working on science activities in class and do not agree that my child's written assignments can be photocopied.

APPENDIX B

SAMPLES OF STUDENT WRITING

In the sampling of student writing below, I attempt to give a range of literate abilities, from Irene, who was the weakest of the girl writers to Zoe who was one of the three best girl writers, and from Henry, one of the weakest boy writers, to Donald, one of the strongest boy writers.

<u>Irene: Alka Seltzer™ assignment, first draft</u>

m Amount of water: 61 ml we put the tadlit in and we put a bolloon on the top after awhile the bolloon was getting smaller first it was 61 ml. than 26 ml. there is 80 ml of gas this time we stred the ballone a by it was biger than befor the went frm 70 ml. to 83 ml. to 71 ml. this time balloon did not srink axp. 100 ml. of gas

<u>Henry: Alka Seltzer™ assignment, first draft</u>

Alconselcer Henry
1 At first we stuck a half of alconseler in the tube
2 we filled the tube of water up to 50
3 The foam went up to 55
4 Then we pord it out and we filled it back up to 50
5 We stuck a whole alconselar in and foam went up to 70

<u>Gillian: Alka Seltzer™ assignment, first draft</u>

Gillian March 26
Experiment
-Amout of water 60mL
-We put a balloon over top of the thing and then the balloon started blowing up.
-It went to 62mL then to 71ml then it back to 61mL.
-Then the balloon starter shrinking
-There is 80mL of gas I think
-We meaused the air in the thing.
-This time we steched the balloon by blowing it up once. It got way bigger. It started at 20mL to 80mL to 71mL.
-This time the balloon didn't shrink its probly around 100mL of gas

Nathan: Alka Setzer™ assignment, first draft

"Alka Seltzer" Experiment

First we took the graduated cylinder and put a ping pong ball on top but we couldn't measure the gas so then we filled the graduated cylinder up to the top put the alka seltzer in and put the for on top then flipped it over so the gas pushed the water out into the jar it took 58sec to push out 100ml we then did the same thing except with half a tablet it took 90 sec to do 40 mL of gas so I came to the conclusion that the more alka seltzer the faster and more gas there is, and the exact opposite.

Zoe: Alka Setzer™ assignment, first draft

Alka-Seltzer Experiment — Zoe # 1 and 2 draft

OBJECT: I had to try to measure the amount of gas made by the Alka-seltzer tablet.

THINGS I USED:

-A Graduated cylinder
-A Jar / container
-Alka-seltzer tablit
-water

METHOD: I took a Graduated cylinder and filled it with water. I then flopped it over very fast making shure not to loose to much water. I ended up with only loosing about 5 ml of water. I took an Alka-seltzer tablet and slid it under the rim and into the cylender.

OBSERVATIONS: I started out with 10 mL of water. When I put in the Alka-seltzer tab, the water slowley got pushed down by the gas made from the tablet. At the bottom the water had knowere to go so it bubbeld out into the container the cylender was in. I started out with 90 mL of water and at the end I only had 5 mL of water.

CONCLUSION: 90 - started with
- 5 - ended with
I think there 85 - Gas
was 85 mL. of gas made by the Alka-seltzer tablet.

COMMENT: If Alka-seltzer is supposed to stop gas inside your stomic then why does it have so much in it when you add it to water. How does it stop gas when that's what it's made of?

Donald: Alka Setzer™ assignment, first draft

Alka-seltzer

March 26, 1996 Donald

Experiment #1

What we did - We broke a piece of alk-seltzer in half. Then we filled the graduated cylinder about 53ml and then we put the alka-seltzer in.

What happened - After we put the alka-seltzer in the water lots of bubbles came up. The tablet dissolved. But something went wrong. We forgot to cover the cylinder to trap the air.

Experiment #2

What we did - We used the other half of the tablet and dropped it in the graduated cylinder. Then lots of bubbles came out.

What happened - A while after that, the same thing happened like in experiment 1#. This time we covered it. We measured the foggy part. Then we found out that the foggy part was not all of the gas.

Experiment #3

What happened - We dropped the tablet in, and it bubbled up. We put 49 mL in. this time, we measured the bubbles. We did the same for 4,5,&6.

Experiment #7

What happened - Will filled the cylinder 10 mL and dropped a full tablet. It didn't work.

APPENDIX C

TRANSCRIPTS OF TWO "THINKING TESTS"
THOMAS, PRISCILLA, HENRY - BAKING SODA / POWDER
LEVINE, ADAM, BRAD - BURNING MONEY

The thinking tests involved three students and myself in a small room. I presented the group with a challenge, and asked them to talk through it. As they talked, I would encourage them to explore different possibilities and would encourage less talkative children to get involved. I told the students I was attempting to evaluate their thinking. Thus, I was hoping that they would talk as much as possible as they thought about the answer. I also told them that they could agree with what other students said. If they thought someone had a good idea, they could say they agreed, and repeat what that person had said. If they disagreed, they could say this, and explain what they thought might be the answer.

When I selected the groups, I tried to balance the groups so there was a gender mix, there were talkative and less talkative children, there were children who demonstrated greater capability with those who had not demonstrated ability, and, lastly, I had to balance the languages. Three of the children spoke very little English. Each of them was in a group with a child who could translate.

The transcripts are coded in the following way:

The letter in front of the speech is the student's initial. If a J appears, it is I who spoke.

Three dots indicate a noticeable pause of less than one second duration. Longer pauses are indicated by two sets of three dots, and even longer ones have the time indicated in square brackets.

I made no attempt to indicate students' accents by misspelling the words.

When one student overlapped speech with another student, a square bracket was drawn to connect the overlapping speech. Sometimes two speeches did not overlap, but the new speaker started speaking so quickly that I had the impression the first speaker had not finished. In these cases, there is no period at the end of the first speaker's talk. If the first speaker continued to speak after the second stopped, I indicated this by the placement on the line - the second speaker's speech began positionally on the page after the first speaker's talk, then the first speaker's began after the second finished.

If I could not understand what a student had said, I put a question mark in square brackets. Descriptions of students' actions, or summaries of talk which I have not transcribed word for word, are placed in square brackets.

When a student raised his or her inflection, as if asking a question, I put a question mark at the point where the inflection stopped rising. If a student spoke louder, I capitalized the louder words.

<u>Thomas, Priscilla, Henry - Baking Soda and Baking Powder</u>

The following is the transcript of Thomas, Priscilla, and Henry in their thinking test. The problem posed was "What is the difference between baking soda and baking powder?" I started by telling the students that I had once made baking powder biscuits and used baking soda by mistake. The biscuits tasted awful, which made me wonder what the difference between the two chemicals was. I put the materials on the table: a box of baking soda, a can of baking powder, a jug of vinegar, a saucepan with water in it. I also put two small jars on the table, a teaspoon and a bowl for putting the wastes in.

The tape reads 18 minutes at the start.

[I started the experiment by putting water in two little jars, explaining everything as I worked.]

T What's the temperature? Cold? Is it cold water?
J You can feel it.
T It's cold.

[I put 1/2 tsp of baking soda in one little jar, 1/2 tsp of baking powder in the other little jar, explaining which chemical each time.]

22:02 min.

J You can talk about what it is you're seeing.

[They all duck their heads down to look.]

P You know ... I always wondered ... I always wondered what the difference was
T └That's sodium. That's sodium. This has sodium in it right. And it reacted with the water? And this doesn't react with the water. The sodium
J So you think this doesn't .. baking soda doesn't have any sodium in it?
T It has sodium bicarbonate but not just plain sodium.
P Because sodium bubbles up but bicarbonate stops it from bubbling up
T └But its probably just not that pure. Just have a little bit of sodium cause otherwise it would bubble up a lot more.

[I invite H to participate. T picks up the jar with baking soda to show him.]

T There's bubbles on the top [showing it to H]
P Looks like [?]
J Do you want to talk about what it looks like H?
H [leans forward, hard to hear, sounds like "maybe kind of looks like"]
P Can I see this one. [Picks one jar up.] It's sticking to [?] It just stays there. It's firm. Looks like there's something in the water. It looks like the bicarbonate is putting pressure on it and making it stay on the bottom so the sodium can't bubble up.
T I think it is just that the sodium the sodium is pretty heavy so ... it is heavy in the water so it just sticks to the bottom and it can't react. It has no chemical reaction that will happen so it just stays there ... like that ... um if that most of the stuff if you put your finger in there or something you'd feel all the stuff at the bottom and you but the sodium went up just the sodium nothing else.

P I think this one's lighter and that one's heavier so that one stays to the bottom.
T Yeah.
P 'Cause you can just move that one around while shaking this one around [she holds and jostles the baking soda jar] and it just stays there.
T 'Cause it's heavier probably. Just like oil and water do the same thing.
[They both stop talking and look at me.]
J OK. What about this? [indicating the jar with baking powder]
P [looks at it closely] I think it combined with the water. It mixed together cause you can't see water.
T Maybe the un uh I bet I think it got chemical reaction and it tastes a little bit like water and a little like bit like baking powder. Or we just it just made made a totally new taste.
J A totally new taste?
T Yeah.
J What would that totally new taste be a sign of?
P Yeah. [I had the impression she was agreeing with T on the totally new taste prediction.]
T A chemical reaction?
J Do you want to say anything? [to H]
P I agree.
H I can't think of anything right now.
J Would you agree with T and P? Would you like to restate some of the things that they've said?
H Yeah. Sodium and the
P Baking powder
H Yeah in the baking powder.
J What about the sodium in the baking powder?
H There's sodium in ... makes ... chemical reaction.
T [25:20 - 25:55] Like when you told us, I remember you telling us when you're talking about the periodic table. You said sodium reacts with water and then uh there were a few other chemicals I'm not sure that also react with water and so I'm just saying that probably is sodium cause sodium was usually bubbles and stuff and looks like a chemical reaction.
P I never noticed that though. I thought both of them bubbled.
J Shall we read the ingredients on that and [I pushed the baking powder can to P] I wonder if I should read that one ... at least two.

[This starts a new line of inquiry, although T has not yet finished with the sinking baking soda vs. the reacting baking powder theory. H has not yet participated much. However, he has been invited to participate, and my invitation was followed up by support from both his peers. Notice in this next section how he participates more when invited, and especially begins to talk when I disappear for a moment. When I leave the table, H prompts T to reconsider an important point. The next section of talk begins immediately after the last one. There is nothing left out here.]

P Sodium acid pyro ...

T Sodium acid! That's the same thing as sodium right?
P Sodium bicarbonate. Corn and or wheat starch, mono calcium sulfate, calcium.
T Sulfate? Does that react with water?
J What are the ingredients in baking soda? So sodium bicarbonate are the ingredients in baking soda.
P [picking up the box] Where is the ingredients?
J It says bicarbonate of soda. Sodium bicarbonate. That's the ingredients.
T [reading the baking powder container] Sodium acid umm - this thing. Is that just mean like sodium but they add a little bit because sodium is an acid?
J [reading] Sodium acid pyrophosphate.
T Is that just normal sodium?
J No. That 's it it is a molecule sodium acid pyrophosphate.
P What's pyrophosphate? Something like that.
T Is that the uh phosphorous?
J It has phosphorous in it and has oxygen in it and I'm not sure what the pyro is.
T There isn't , there is sodium in there, but it might be might just be a different kind.
P There's lots of sodium in there.
T [kept mumbling while P was talking] [27:34 - 28:09] What is is that chemical it's an acid right? And water is uh neither acid or base? Then it must, something must react in the there must be two chemicals maybe inside the baking soda alone that could react if they get water with them but it just have to be in the ka[? I am not sure if the word was 'cans' or 'chems'] of the baking powder but I don't think it reacts with the water. I think it reacts with some other chemical inside of them.
J What do you think P?

[P picks up the can. There is a knock at the door, the next group would like to interrupt us. I tell them we need another ten minutes.]

P Could you come back. I just need a little time. I was going to say something. Oh yeah. I have a question. Is sodium heavier or is it light?
J Sodium?
T Heavier than water? I would think it is obviously lighter than water because there is there's only one atom.
P Is this one that bubbled up or that one bubbled up?
T And.
J This is the sodium uh this is the baking powder and this one is the uh baking soda.
T [29:01 - 29:57] Just like um I'd say if water it's has three molecules joined together and it will stay and there's like one specific weight and then everything bounces so there's some space but with sodium there's more space and just a little bit and a little bit of molecules? Cause with sodium of ah atoms they bounce around and there's some space but in the water H_2O there's thuh .. it's got more joined together and so it's you can so it's gonna have equal amount of space around it but there's gonna be more space in the middle so it's probably will have a little bit more.

[There is increasing noise in the hall.]

J OK P What do you think?

P [30:04 - 31:06] Well I think that um maybe there's some chemical rection to tha - this is similar to T - to um in the baking pow baking soda and that um since there's different chemical reactions um maybe there's a little more um of sodium or there's something in the baking soda that causes it more weight and that the baking soda would just stay down to the bottom um and that that baking powder is more light and maybe it has something in it lighter and so when the water and um baking powder mix together it reacts to it and it floats up because maybe the um the uh sodium uh the baking powder is lighter than the water so it bubbles up.

[67 second speech]

[The noise in the hall is too great. I go to talk to the students who are waiting. As soon as I leave, H begins to talk.]

H Actually you remember when you mix vinegar and baking soda how come they bubble up.

T [reaches for the can] Let me see if there is a base in here.

H Does it have anything in it.

T Sodium bicarbonate. [twists the can] Sodium bicarbonate.

J OK H have you got anything to add?

H It's kind of like when you mix vinegar and baking soda and it um some gas.

P Oh is there vinegar here?

T Sodium acid phosphorate. That is uh acid and there's sodium bicarbonate and that's a base and it might be reacting.

P They react.

J OK H would you like to explain your idea here. You started on this line.

H With the vinegar and the baking soda?

J Um hm.

H Um when you mix it it has a chemical reaction and it like bubbles and like let's off some gas and stuff [?] I don't know how to explain it.

J And then how would the baking powder and baking soda in water reactions be like the baking soda with vinegar reactions?

H Um. I'm not sure.

T Well the baking sodium bicarbonate that's the baking powder no soda. Is it just sodium bicarbonate, nothing else?

J Um hm.

T Maybe it and 'cause there's no that's a base and there's no other acid in it and water isn't a acid or a base so it has nothing to react with so it can't react.

P Can't react with anything.

T And here it has sodium acid phosphorate and sodium bicarbonate acid and a base and react.

P Great.

J OK We're out of time so if you could quickly jot something down.

[33:30 is the final time reading on the tape.]

Levine, Adam, Brad - Burning Money

Levine, Adam and Brad participated in the burning money thinking test. I used a two dollar bill for the first display. I dipped the two dollar bill into a jar of water, then dipped it into a jar with rubbing alcohol. Then I struck a match and held it to the bill. The bill lit up, and burned. (I hadn't intended that the bill would burn. I had tried the demonstration at home, and the flames had gone out before the bill burned.) When the bill burned, I checked my pockets for another bill to try the same demonstration with, and could only find a ten dollar bill. So I dipped it for a long time in the water, then briefly in the rubbing alcohol, then struck the match. This time, the flames burned and went out before the bill caught fire. The bottle of rubbing alcohol was sitting on the table, separate from the matches. I asked the students to explain why one bill had burned and the other had not.

J OK IN here is water.
[They all look]
J I'm going to put some water in here. [I pour from saucepan to jar.]
A Hot or cold? ... ... Cold?
J Good point. You tell me whether it's hot or cold.
A Can we feel it?
J Um hm.
B Cold.
A Cold.
B Cold. Very cold.
J It's cold? Very cold.
? No.
J You think it's warm [addressed to L]
L No. Cold.
J In here I'm gong to put ... rubbing alcohol [I pour it] that should be lots. And I'm going to put this over here out of the way. But it's rubbing alcohol. And in my pocket I have I have a bunch of matches and money.
A You're gonna rub it against the money to break it.
J Now what's in here?
A Water. COLD water.
[I put the two dollar bill in the water.]
B Unh? [shocked]
A You're wasting your money?
J That's a two dollar bill. They're not worth anything any more are they?
A Yes they are.
J OK NO:OW [I put the money in the rubbing alcohol jar.]
L & B [further gasps]
J OK what am I doing? Talk about it.
A OK. First you're dipping it into the water and then you're putting it into the rubbing alcohol.
J Um hm.

A And you hold it with the fork. And now you're gonna put a match on top of it I think and then its gonna light up.
J I didn't bring any paper towels so it's easier to do at home where I have everything.
B [attention totally focused] Oh boy oh boy WHOA [as I light it]
J OK talk about it whoopsie [I sound rather calm considering the two dollar bill just burned right up.] Whoopsie. That didn't work.
B [giggles]
J No more two dollar bill.
B No.
J OK. I'll try again. I don't have another two dollar bill. [I pull out a ten.]
[Now the tension in the room is high. The students are totally focused on what is going to happen.]
A You don't have to try it with a ten dollar bill you know.
J I can't do it with a two dollar bill. I don't have another two dollar bill.
A Do it with your old one dollar bills.
J Maybe I'll just leave it in the water a little bit longer.
B Yeah.
A How are you gonna show it to the other kids. You have no more money. Are you going to use a hundred dollar bill?
B [laughs]
A Try using a hundred dollar bill.
B Ooh. No one thousand. One thousand is good.
J You look sad L? You don't like to see me wasting my money like this.
L [shakes her head]
B Yeah it too long there. [indicating the water] Put it in there. [indicating the rubbing alcohol]
J I'll leave it in there LESS time this time. [indicating the rubbing alcohol]
A Dollars! Dollars!
J Now I'll try to wash this alcohol off my hands.
A OK ... because it's ... ... does the bottle have a caution sign on it ... for rubbing alcohol?
[I fetch the bottle and show it to them.]
A [Caution
B [?]
A It's flammable.
J Flammable.
B [waves his hand at it] Does it smell.
A Oh I think I know what you're doing.
L Oh I know ...
J OK. Tell me about it if you know what I'm doing.
A OK. First you're putting it in water because water puts out the flames so you're dipping the ten dollar bill in water and then you're trying to put a little rubbing alcohol on it because it'll it's flammable and then you're trying to light a match and see if it will flame on like uh light up ... and that one didn't work

'cause it did light up but it usually doesn't right? See. [I light the match and put it to the ten which lights up.] Uh uh. Yeah.

J Did it go up? Whooops. [The bill started to burn on the corner, then went out.]

B Cool.

A Now you toasted a ten dollar bill.

J Well. OK. Did you want to feel it?

A It's dry. [surprise]

J It's dry?

L & B Yes.

B It's dry - you feel it. [hands it to me.]

A I think it's because um

L the water

A OK the water ... ... mix with the rubbing alcohol I think there's a kind of um reaction or something? I dunno. First you dip it in water. WATER PUTS OUT FIRE.

J Let's hear L.

L Because the rubbing alcohol is flammable and you put the ten dollar in the water long time and then the water is ... ... safety ...

B Is somebody's if you put the fire then the water will ...

J Will what. What will the water do. What will it do to the fire?

B Dry it.

J Dry it?

B No.

A Oh I know [hand up]

[I look at him. But while A talks, L draws a picture and shows it to B. I hear her say the word "dissolve".]

A OK I think the fire and the rubbing alcohol kind of makes CO_2 and the fire needs O_2 to burn and if there's too much CO_2 or something then it kind of goes off bet yeah

J That's possible. But dissolve?

L [nods]

J You think something dissolved?

L You

A [Dissolve [quietly]

L [have a fire here and you put some water in here

A [Oh the

L [and the fire's will dissolve. Right?

J Um hmm.

A OK. I THINK [?]

L [This is the same thing. This is fire away. And you put the water in it. So you [?]

A [32 second speech] I have another idea. I have another idea Miss McVittie. OK I think OK since you put it in more water so water becomes a so water is a solvent and then uh rubbing alcohol you only have a little bit so it's a

SOLUTE and solute usually dissolves into the SOLVENT. So rubbing alcohol dissolves in the WATER and if you light it up um puts out FIRE so if you light it up water puts it out so water like it kind of dries it up.

J Um hm.

B [?] has the [?] oxygen.

A Solvent ...

B And you

A └Because

B └and you burn it.

J And can you tell me about this one. What happened to this one?

B You burn it.

J It burns. [laugh] Why did

A I know.

J └this one

A └I know.

J └didn't. Let me hear B.

B Just put a two dollar bill and in it .. and really fast and you put it in rubbing alcohol and it has also burned [?]

J OK. What burned. In this case.

A I don't agree. OK. I disagree. I have a different idea. OK. Since you put it into um water? but you put it into rubbing alcohol like longer? so THAT becomes the solvent and this is the solute so the solute dissolves into and so this time it's the water that dissolves into the rubbing alcohol?

L └Yeah and you put it longer in water.

A └and so rubbing alcohol is flammable so if you light it up? It goes on fire.

J So what burned here?

A It was probably just a little bit of rubbing alcohol on it but most of them dissolved into the ...

J This burned [indicates corner of the bill] and what else burned. Did anything else burn? We saw a lot more flame than just this.

A Let me see. [takes the bill] Oh right here.

J Yeah there was that little bit of a burn there. Oh it's on the back of it.

A Oh because you dipped the most .. uh [frustrated sigh]

[B examines the bill. As L reaches for it, he holds it away and says "Let me see. I see." L sits back for a few seconds, then reaches over and takes it from him.]

B Here.

L Because you start a fire here and it

A Heat usually dries up um water like wet OK heat usually dries up wetness so OK it's WET but there's some rubbing alcohol in it? I think when it burned it OK it doesn't quite burn it too much so I think it kinda dries it up because it's still wet with water and there's probably just a little rubbing alcohol over there that didn't dissolve.

J Does anybody have anything to add? What would happen if I dipped this in rubbing alcohol first ... and then dipped it in water?

A Um I don't think it would quite make a difference. It's the AMOUNT that makes the difference.
B You could do it.
A It's the amount.
B You can do it. This longer and this shorter.
A [IT'S THE AMOUNT.
J This one longer and this one shorter.
B [grinning. He has indicated longer in rubbing alcohol] Yeah. This burn.
L This burn.
J And then it will burn.
B Yeah.
A The amount [he puts his hand up] Miss McVittie. I think it's the amount that the ten dollar bill absorbs I think OK it absorbs more rubbing alcohol so I think more water dissolves into rubbing alcohol well OK that means if you have two pieces, OK that means if you have a little over here and a lot over here.
J Um hm.
A OK this dissolves into that that means it takes some over so that like dissolves in it in it [shudder?] and then there's still something like a part of rubbing alcohol left so it'll burn cause the water's gone. So OK talk about the amount yeah ... the more the longer you put it in the rubbing alcohol so that's more the more the paper will absorb unless it's saturated? And then you put the water. Sometimes if you put it longer in rubbing alcohol it's already saturated right it can't absorb anymore so water if you just put it in it doesn't absorb anymore.

[B & L have been shifting around on their chairs, as if bored.]

J OK. Did you understand all that B what A is saying?
B Yeah.
J Did you understand it all?
B Yeah.
J Did you understand it L? What A is saying.
L [embarrassed look] Too fast.
J [to A] Can you speak Chinese?
A Um. Yes I could speak Chinese but OK. [leans towards his peers]
J Would you like to make an effort to explain what you said to L? And you can understand what she says. So if she argued with you, then you can explain to me what she was saying.

[A begins speaking in Cantonese. B asks a question (I think it is a question). L asks a question (I think). Then B interrupts A and takes over explaining to L. Then they stop and all look content. I ask B to explain to me what he said, and tell him he is lucky to speak two languages, that I only speak one. He tells me no, that I speak French. I assure him that my French is not as good as his English.]

L What I said?
J Yes. No you can work together to try to explain it.
L I just say. So you have to uh put the ten dollar in this first. Right? So you you can put the first.

J	You think if I put it in the rubbing alcohol first and then put it in the water.
B	└It will burn.
J	What would happen.
L	Burn.
J	It would burn? And the whole thing would burn? The bill would burn.
L & B	Yeah.
A	It would be more saturated.
J	You both believe that.
L & B	Yeah.
A	Yes.
J	You think it would be more saturated.
A	I mean. OK. It's it's saturated. It can't absorb anymore. If you dip it in there? it absorbs so much water that it becomes saturated with rubbing alcohol and if you dip it in into that the water probably just takes a little bit out but there's still lots of rubbing alcohol so wherever the money has rubbing alcohol it will burn and wherever it doesn't have it won't burn so the same with that OK so here burn here it didn't so.
L	Ah.
B	[picks up the two dollar bill] It's wet. It has water.
A	'Cause some of .. water puts out the fires so it doesn't burn.
L	This has more of rubbing alcohol and this has more of
J	I'm not sure what the right answer is so the reason I'm stopping you here is because you're saying the same things as you said before and um what I would like you to do now is write down your ideas so that I can refer to them when I'm doing the marking.
L	If we are not saying something can we write.
J	Yeah. Even if you haven't said anything something you can write it down.

[Talk finishes at 1:30.]