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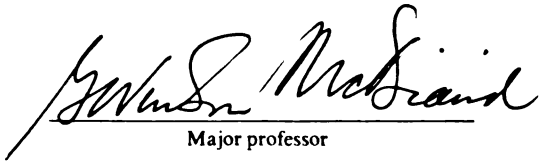

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TEACHING WITH AND WITHOUT MIRRORS:

EXAMINING SCIENCE TEACHING IN ELEMENTARY SCHOOL

FROM THE PERSPECTIVE OF A TEACHER AND LEARNER

by

Margery Diane Osborne

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ABSTRACT

TEACHING WITH AND WITHOUT MIRRORS:
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This thesis is about how relationships--between subject matter and teacher, subject matter and children, children and the teacher--are constructed in the context of teaching science in the lower elementary grades. Relationships are dynamic and shifting. Rather than try to characterize them, it is easier to try to characterize their dynamism--how they change. Therefore this thesis is a study of how relationships evolve, how they are initiated and how they change over time as the components interact and effect one another.

I have been teaching science in a school with a highly diverse population. In this thesis I have used transcripts of those classes to reflect upon the nature of teaching and upon the relationships involved in teaching. I ask the question: "How is a practice, based upon certain ideals about science, children and learning constructed?"

As people develop relationships they learn, they develop a purpose, methods and methodical ways of interacting. These methodical ways of interacting define patterns that enable our relationships. In particular, they allow us to understand each other and the purposes behind what we are doing. Methodical actions and method are at the heart of relationships: they are at the heart of science and also of teaching. They enable the construction of a community in the class--a relationship among diverse people enabled by a common pursuit. Method allows people to understand each other and live together even when doing, thinking, desiring very different things. It allows people to appreciate their differences as well as their similarities.

But method is seductive--it stops our thinking as well as enables our thinking. To act methodically means we are acting in expected ways. We aren't thinking about our actions. We are rather thinking about the outcome of our actions. When doing this we forget the assumptions, the value choices hidden within the things we are doing. Action becomes oriented towards a goal, towards the future, towards realizing a purpose. Method allows one to live within a relationship without thinking about it, but at the core of science and teaching is a questioning of relationships--a need to see and develop new qualities. To be able to do this necessitates a recognition of assumptions and a questioning and re-evaluation of them. It requires that those living within relationships periodically de-construct them and rebuild them differently.

Much has been written about what teachers need to know about children, diverse learners, subject matter, teaching skills. Little has been written about how a teacher changes as she tries to act upon that knowledge--how as she translates her knowledge into actions and interactions, it changes as the teacher is confronted with the demands of a complex situation. As the children interacting with the science are confronted by things that they don't know or things that they need to know differently, a teacher as she interacts with the children or with the subject matter discovers things that she doesn't know and she must act to change her practice and the knowledge that practice is based upon. This means fundamentally rethinking the value choices--emotional and moral as well as intellectual--upon which the knowledge is constructed. This thesis is an attempt to trace the course of this cycle of thinking, knowing, and learning for one teacher--myself.

I explore this through my interactions with children and a variety of phenomena--sound, music, gravity, soap bubbles and dinosaurs. Each chapter of this thesis recounts a story of these interactions and developing relationships. Each addresses the question of how teaching practice is constructed and also altered and evolved as these relationships develop.

ACKNOWLEDGMENTS

This thesis would not have been possible without the intellectual and emotional support of the members of my advisory committee: Deborah Ball, Bill McDiarmid, Kathy Roth, and Michael Sedlak. In particular I would like to think Kathy and Michael for helping me to find the ideas that I needed and the courage to speak them in this setting. I would especially like to thank Deborah for encouraging me with the initial idea for this thesis and for this teaching and for being so generous in sharing herself and her teaching. Without the last two, Deborah, I would never have been able to recognize what I needed to see in my teaching much less write about it. Finally I would like to thank Bill. Bill, I know a thesis is supposed to be an individualistic act of scholarship, constructed by me in isolation to illustrate to everyone what a smart person I am, but you know that the ideas in this thesis we worked out together--we talked about them and wrote and re-wrote them for years. This thesis is not something hatched from my brain alone, it is something that really we wrote together.

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CHAPTER 1

INTRODUCTION: THE SUBJECT-OBJECT RELATIONSHIP IN TEACHING AND SCIENCE

This thesis is about method; method in science, in teaching, in research, and in presenting that research. In order to make that assertion I need to write first about what I mean by method--what I think method is--and how my thesis will illustrate and illuminate my definitions.

Method is first of all doing something; purposeful action. But doing what to what? In this thesis, I will be talking about two things: doing science, doing teaching, with a number of different objects (who am I doing it to, for, with) and a number of different purposes which may or may not overlap for the two things. Are the things that I am doing (science, teaching) the object of the subject/object relationship? Is the purpose the object or maybe some "other" like the children I am doing science with and am trying to teach? My inability to define an "object" is not because there is none but rather because the object is a shifting one. At times it is the children or the particulars of the science or the purpose behind the things I am doing. At times it is the doing itself. I think this is in part because of the complexity of the context for the actions that I am calling method--I am "doing teaching" in a context of a particular subject matter, I am "doing science" in an environment shaped by particular children and a purpose framed by the word "teaching." Doing science and teaching are overlapping and each creates a lens through which the others are constructed and reflected upon. In a relationship between, say, the subject matter and myself, acted upon within the context of teaching, the relationship becomes one between the subject matter, myself and the children. If we say, in this instance, the object is science, the

subjects are multiple and interacting. They interact through a dialectic of subject and object, between children and myself, the science and myself, the science and the children.

It seems though that I have defined five aspects that method has: purpose, subject, object, audience, action. I would propose that it is the interrelationships between the first four that determine action. And at the basis of method is the subject/object relationship. That relationship is fundamentally shaped by audience and purpose. Before I discuss this further however, let me situate this thesis within the larger educational research community.

This thesis speaks to a number of communities. By speaking to and with these communities, I am joining conversations in these communities. There is a logic in the thinking which links my participation in these conversations and this logic in turn is underlain by my thinking about this subject/object relationship. I will write a bit about how I think my thesis is part of three conversations in the education community and then I will talk some more about my ideas about the subject/object relationship and why this needs to be considered in order for me to think meaningfully about these conversations. The conversations are:

- The learning science conversation, particularly the misconceptions interpretation of learning. A sub-conversation here is the knowledge children bring with them and what teachers ought to do with that knowledge.
- The teacher knowledge/learning conversation and the idea of pedagogical content knowledge. This has implications for teacher education--what prospective teachers should be taught in their pre-service programs.
- The socio-cultural learning conversation, particularly the idea that, for cognitive and emotional reasons, learners' cultures must be incorporated, somehow, in both the curriculum and the teachers' pedagogy.

• *The learning science conversation, particularly the misconceptions interpretation of learning.* The literature of this community addresses the way that phenomena are understood by both scientific means and by the practical, commensensical, empirical ways that people make sense of the world. The latter are termed "naive" understandings or misconceptions in this literature. These naive understandings are often inconsistent with each other and the scientific canon and are judged scientifically incorrect. In order to be able to teach the "correct," scientific understandings of phenomena, the "naive" understandings have to be directly addressed and the student has to

become cognizant of how these "understandings" don't work--are insufficient in certain contexts to explain the phenomena. This theory of learning and the derived theory of teaching owe a lot to cognitive studies (Piaget, 1972; Vygotsky, 1978) and especially to Thomas Kuhn (1970) and other pragmatists.

Teaching prospective teachers (or people in general who know very little about the workings of the science community) this interpretation of children's mistakes in science tends to reinforce these people's beliefs about the nature of scientific knowledge. That is, many may already believe that scientific knowledge is "hard," is indisputably established, can be augmented and expanded but not refuted and revised, reflects transcendent "truths" about the universe rather than soft transcendences about our own (people's) beliefs. They also probably believe that inconsistent and mutually incompatible scientific theories aren't allowed to co-exist when in fact they do and scientists happily use whichever one works best in particular contexts. These same scientists spend much of their time arguing with each other, with no real desire that a final consensus be reached, about that choice (after all, if a consensus were acheived, the argument would be over, the purpose of research would be over). Pointing out children's "misconceptions" or "naive beliefs" without questioning the "correct conceptions" themselves--where they come from, what can be done with them (and what not), what they reflect about their makers--focuses prospective teachers' attention exclusively on the learners' and how well their expressed beliefs conform to "right answers."

This thesis offers a different perspective on learners' understandings. In the first place, my pedagogy is designed to encourage learners not only to express their initial understandings but to develop these with others. As stated, this is not inconsistent with current conceptual change literature on effective science teaching (Roth, 1987; Resnick, 1983; Driver, 1985). It differs from the misconception model because the emphasis is upon developing these understandings in such a way that their strengths are respected and utilized. Because different children have different understandings and all are valued (in different ways and in different contexts and uses), these "naive theories" are portrayed as part of a continuum of scientific understanding upon

which the recognized "scientific explanations" also lie. In the misconception model of teaching and learning, the learners' manifest their initial understandings in order to merely reveal the inadequacies of these. I try in my teaching to develop with the children the potential of their ideas. I believe that these ideas--subject to examination, discussion, revision, revisiting--can yield useful, powerful ideas that advance the children's individual and collective understandings.

My vision of science, as it is reflected in my teaching, is as much about the process of doing science as it is about the content of that science. In teaching science in this way, in which the various ways of making sense of phenomena--scientific, spiritual, magical, sensual, intuitive, empirical--are honored and placed on a continuum, I am cognizant that I am working on a re-definition of the traditional, Western meaning of the concept of science. This is connected to a continuing conversation about feminist visions of science (Harding, 1991; Keller (1985). Usually this conversation involves those who are actively doing science--scientists-- and observers of those people. I am extending that conversation to teaching and education. Maybe by developing and immersing children in this "other" idea of what science is, the reality of science can be changed.

At the same time my teaching is not totally relativistic. Not all the ideas the children have are thoughtful or useful or worthy of extended examination. Gravity boots (Chapter 4), a theory some of my students developed when asked to explain people being able to walk on the moon--a place they decided had no gravity--while symptomatic of certain ideas and understandings, doesn't further a more general understanding of what gravity actually is or why it is important. The theory of gravitational attraction is a powerful one, it explains the motion and apparent position of all objects. It is my own understanding of scientific knowledge and processes that assists me in determining what are or are not potentially fruitful ideas.

Finally, eliciting learners ideas is not without risk. What do I do with theological or magical explanations for natural phenomena or with explanations that parents give to children that they believe are true or even just to stop an episode of questioning? (For example: Why do you get rainbows from prisms? They're made that way, the prisms store them inside and they're

let out by the sunlight, god made them that way, they're magical. Where do babies come from?) Again, it is my judgement--a combination of my knowledge of the child, children in general, the classroom situation, the subject, politics--that determines the decisions that I can make in a particular situation.

• *The teacher knowledge/learning conversation, particularly the idea of pedagogical content knowledge--what do teachers need to know to be able to teach?* Following from the preceding discussion of conceptual change literature, my thesis also addresses the conversations about pedagogical content knowledge--what a teacher needs to know to be able to teach. Literature on this subject make the claim that teachers draw on various kinds of knowledge and understandings in deciding how to teach. My thesis rather than being directly concerned with contributing to an enhanced description of what this knowledge is in science teaching, addresses what, in my particular case, it means to "draw on" knowledge. How do I *use* my knowledge to teach? Derivative from this might be a description of what this knowledge actually is.

In this thesis I wish to describe the processes that go into and lie behind the decisions that I make in classes. In discussing the decisions I make, I can give a glimpse of how I appear to balance my understandings and commitments to the children and to the science. At a deeper level I can expose how these apparent balancings are actually the tip of the iceberg of deeper and more fundamental conflicts. Striking a balance between what I might like the children to do and think in science, goals I might have about how people should interact and respect each other, how I might like to have scientific discourse or educational discourse different than the way it actually is, involves compromise, discordant choices, sacrifice of one set of goals for others. Because of this, these kinds of choices shift over time. For example, I usually choose to respect and work with children's ideas about how things work but sometimes I choose to teach correct science. (Did dinosaurs co-exist with cave-men?--No.) A similar discussion of the balancing act a teacher is forced to make between various commitments can be found in Ball (1993).

Fundamental to my teaching is my interest in working within these conflicts which I believe are endemic to teaching rather than resolving them--I find this sort of conflict stimulating, it forces me to rethink my values and goals continuously. This quality of myself guides my choices in designing the things that we do in classes and the ways that we talk about those things. Likewise a need in myself to explore new things guides my choices of the science that we do in class, the actual content of the classes. It is only interesting to me to teach if I am finding out new things at the same time, new things about teaching (children, schools, how to teach) and about the content of that teaching (the particulars of the science, for example why are bubbles round?). The level of my questions about the phenomena that we explore in class are at a different level of sophistication than the children's but it is very important to me that they are there. They guide how I manipulate the children's questions.

Underlying this exposure of my own personal pursuits in my teaching is the idea that I am continuously altering the knowledge that I bring to my teaching. I do this through the teaching. This ideal is different from traditional writings about pedagogical content knowledge (Shulman, 1986). Implied in much of this literature is that knowledge is static--it is a body of knowledge somehow quantifiable or at least describable. I would argue that the latter can only be possible retrospectively. Others suggest that during teaching the representations of knowledge alter, left undiscussed is whether that means the understandings of that knowledge itself alters (Wilson et al, 1987). Still others suggest that a teacher's use of "rich" subject matter understandings can be used as a vehicle for learning about other domains of teacher knowledge, for example learning about the children (McDiarmid, 1989). This leads me to the third conversation.

• *The socio-cultural learning conversation, particularly the idea that, for intellectual and emotional reasons, learners' cultures must be incorporated, somehow, in both the curriculum and the teachers' pedagogy.* Again my participation in this conversation follows from the preceding description of how I engage the "teacher's knowledge" conversation. It is a quality of my teaching that I

incorporate a great deal of knowledge of the children into how I teach and also into what gets taught. Unlike suggestions in the literature about how to do this (Heath 1983; Evans et al, 1989), for me this knowledge is attained through teaching. Also by the nature of the goals of my teaching--of my vision of the science, in which different ideas are respected and shared, and the sources of ideas are recognized--the ideas themselves and the children's presentations of those ideas are used to construct a classroom culture which has its own identity. This identity is not describable as a simple compilation of cultures the children and I bring to class from outside. Again, the multiple identities of the children and the cultures which we bring to the class and which we construct in class are often in conflict. Knowing a lot about these various cultures doesn't make it clear how I should interact with students or what the result will be for either the curriculum or the teaching. This differs from suggestions in the literature that differences in cultures should be directly confronted and engaged (Delpit, 1986; 1988).

When I think about these three conversations, specifying the object of the subject/object relationship is central. All these conversations assume a two-fold relationship between the teacher and child in which the child is the object and the subject matter is the objective. The evolution of the teacher or the subject matter is ignored. I would argue that the relationship is, first of all, three-fold--between teacher, subject matter and child--and the identity of both subject and object shifts. Hawkins (1974 a,b) also defines this relationship as a triad but one in which the child and teacher are objects of the subject matter--one member of the triad (subject matter) is held constant and the other two define themselves against it. This is a useful simplification, to hold the identity of one member constant and define the relationship of the other two as constructed through interacting around it. It also suggests an inversion of the usual (scientific) subject versus object location--I am defining the one assumed constant as the subject, the other two which change in nature against it are the objects. But unlike Hawkins, I would argue that the object identity shifts, relationships shift, method--the actions that define the relationship, both pro-active and reactive--is redefined and reshaped. If I argue that the object can be the

relationship between, say, child and subject matter and I, as teacher, am the subject, then those two interact to define themselves against me. The subject matter and the child redefine themselves, evolve in nature as I present an (apparently) unchanging aspect. But in this process, as the subject matter (for example) changes meaning, my relationship to it must change, the identity of subject and object alter with respect to each other.

Possibly a more real way to look at this is to reject the reduction of the triad into subject and object and rather say that all three are subjects interconnected, interrelating, interdependent for definition. The truth is, though, that the subject matter is a "body" of knowledge that stands in relation to what we make of it, both the children and myself are sentient, willful beings that act upon assumptions about each other--assumptions grounded in knowledge which is treated as static. Although I would be unwilling to say that I "know" the children or even the science, I act like I do. We act on an assumption of subject and object. I wish to write about why we act the way that we do so I need to work within this paradigm to push against its usefulness. Then I can argue for a relationship of inter-definition through interdependence.

I have been reading Hannah Arendt (1978), *The Life of the Mind* and (1964/77) *Eichmann in Jeruselem*, Jean-Paul Sartre (1963), *Search for a Method* , Jacque Derrida (1987), *The Truth about Painting* , Luce Irigaray (1985), *The Speculum of the Other Woman* , Julia Kristeva (1986), *Woman's Time* , Martin Heidegger (1962), *Being and Time* .[1]These readings and other readings that I have

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[1]My pathways into this literature have been multiple and have spanned a number of years of work in many different domains and from many different directions. I would like to write here about how this literature connects to the more traditional educational literature so that readers, if they wish, can possibly construct pathways in to it. Most important to my thinking have been the various writings of Vivian Paley (in particular, 1979, 1981,1986 and 1990). In writing about her own practice and the reflections that she has had about herself, her children and her teaching, she has demonstrated the suggestive sort of writing that I have tried to emulate. She has also embodied the qualities of proactive/reactive reflective thinking that I think Heidegger writes of in combination with the emotional and subjective feeling described by Arendt. Others who write about this sort of reflection on teaching or more general forms of practice both during teaching and divorced from the act (but shaping later actions) are John Dewey (1902/56, and 1933), Joseph Schwab (1976, and 1978), Winograd and Flores (1986), and Schon (1983). Researchers who describe the effect of reflection as well as the shape of that reflection (that it often isn't explicit or divorced from actions or a person's history, emotions, desires) are Connelly and Clandenin (1990) and Johnson (1989). This idea that "reflection" isn't purely

done in hermaneutics and symbiotics have shaped my thinking about how subject and object are defined through relationships. I will summarize the ideas from these authors I have used to construct my own ideas.

All would argue, in a number of different ways, that the subject/object relationship is not created and maintained by the subject standing apart from the object--looking at the object from a distance. Rather the basis of the relationship is in recognizing what the object shares with the subject. The relationship becomes one that isn't purely one of recognizing similarities, it's also

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intellectual in its shape, result, cause has been very important to me. Again this is a link to the writings of Heidegger in particular.

The writings of Margret Buchmann (1986a, 1986b, and 1989) concerning the role of contemplation (which is more than just purely intellectual reflection), the person and the teacher's purposes while teaching, suggest an educational philosophy which underlies the connections between the authors I have just described. Fundamental to these writings is the idea that a teacher is pulled in multiple directions intellectually, historically, emotionally and the actions of a teacher reflect that struggle. A teacher does not act to fulfill one set of expectations only but is rather caught in a juggling act trying to please both multiple facets of herself and multiple audiences (a description of this in context is Lampert, 1985). This quality of teachers immersed in a struggle is described most significantly by women attempting to define in their writings "feminist pedagogy" (Maher, 1987a, 1987b, Maher and Tetraeult 1993, Walkerdine, 1990, Weiler, 1988, and 1993). These women describe teachers struggling with their own personal political agendas as they teach. What is the role of our own moral/political beliefs in our teaching? This is also a quality of teaching which I wished to capture in this thesis and fuse with a description of another struggle concerning subject matter teaching with a diverse student population.

Paley writes of her own "coming to know" her political agenda and her struggles with this in *White Teacher* and also more recently in *You Can't Say You Can't Play* (1993). She does this by both paying attention to herself--awakening self-knowledge--and by paying attention to the children, what they do and say. She must pay attention to both their actions and their language and how she is able to make meaning of those--the fundamental concern of symbiotics. Rommetveit (1980) as well as Fish (1980) and Scholes (1985) write about how this mutual understanding (and misunderstanding) are constructed by the actors in a setting. Integral to this is a play between the states of "thinking within" and "thinking from outside", connected and objective thinking (Belenky, M. F., B. M. Clinchy, N. R. Goldberger, J. M. Tarule, 1986). This is embodied in the acts of naming and description. In particular Fish and Scholes speak to this as do the authors Lakoff and Johnson (1980), Lakoff (1987), and Johnson (1987).

A final important author for me has been Nell Noddings and her book *Caring*. In this book Noddings describes the sort of caring that a teacher such as Vivian Paley seems to illustrate. Through this caring which is focused upon an "other" the "one-caring" undergoes a loss of self. I found this conceptualization of caring both compelling and puzzling. Something seemed to be missing to me--in caring unselfishly for another there must also be a selfish component it seemed to me. To be continually compelling for the "one-caring" mustn't there be something intrinsically rewarding for that person also--something beyond seeing all rewards in the other? I brought this concern to my reading of Hannah Arendt's books. Arendt also describes a similar loss of self in the book *Eichmann in Jeruselem*, a similar selflessness but here paradoxically the motivation is selfishness, a selflessness that is self-serving. I think that the loss of self involved in teaching--the immersion in the other and in actions and subject matter is both selfless and self-serving and needs to be thought of in both ways.

one of comparing differences. "The semiotic continuum must be split if signification is to be produced."[2] The "object" of inquiry must be differentiated, extracted from a background. This relationship is the "signifying process" in which meaning is constructed through a continuous comparative movement between identities shared and identities defined oppositionally. This is intimately tied to the process of naming. The act of naming is fundamental in doing science. Naming a variable in science separates it from the continuum, gives it identity when before it was part of another. For example energy: the concept of energy is a human-made idea which can only be quantized and qualified after it has been named. Before that it was part of the totality of the phenomenon. Once named it acquires substance and reality. The children in my class also play with the act of naming, of reducing a phenomenon into parts. For example, in talking about music (Chapter 3), they separate the "whole" into pattern, rhythm, beat. How the children then work to make sense of music and sound is fundamentally shaped by these variables (rather than tone say). But how, in what way, do they partition the whole into the three--what is included and excluded in each of the terms? Doing this determines meaning and use and occurs through use (application) and reflection on meaning (listening to the sounds identified as one or the other).

The sharing of identities--overlap of parts of the definitions of things--and recognizing these shared identities, is important because otherwise there could be no understanding (Rommetveit, 1980). The words pattern, rhythm and beat overlap and are different in definition and the children use their understandings of each one to construct their understandings of the others. According to Derrida (1976, 1987), defining what is shared and what is not, so that they can be recognized is through framing--creating a frame around the "other." This frame is the context of the object and is also a context in which the subject can place themselves. For example, a teacher could be teaching science or literacy skills all day long possibly not recognized as such until the time period is demarcated (named) "language arts time" or "science period." This context composes the basis or background of the relationship between subject and object,

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[2]Kristeva (1986) Women's Time. In *The Kristeva Reader*, ed. T.Moi. New York: Columbia University Press, page 13.

something not normally articulated or examined "for-itself." The context or frame is continuously being re-made by the recognition and examination of similarities and differences as the object's definition is refined--there is a developing meaning of "science" from what is done in "science period" that is different from what is done at other times. How that is understood, though, is through an interplay between differences and similarities of those actions during science period and other actions. For example, when I use language and categories taught during language arts time in science activities (Chapter 5). Thinking about similarities and differences between ourselves and others can also cause us to become aware of qualities of this context.

In science often the naming of an idea or object obscures both its background (frame) and also its history. Through the scientific process this same idea is often refined and even redefined further obscuring history and the "oneness-that-once-was." There are two aspects to science. The first is progressive. Science is done for what it can do to transform an object or the environment or even ourselves. This buries both the past and the nature of the science. The other aspect allows a new, critical reflection upon both the scientific concepts themselves and upon the continuum. Science is a balance of the two as is teaching. Teaching involves reaching towards a goal which in turn can cause reflection upon both the goal itself and the process. When and why, though, are each of these two aspects of science and teaching in play?

> The real question is whether one sees the function of reflection as bringing something to awareness in order to confront what is in fact accepted with other possibilities--so that one can either throw it out or reject the other possibilities and accept what the tradition de facto is presenting--or whether bringing something to awareness *always dissolves what one has previously accepted.*[3]

Does thinking about the object make us increasingly blind to qualities of the frame or can we turn our understandings of the object back to a critical examination of the frame? In the children's explorations of the nature of musical sounds, the usefulness of the concepts they are developing is balanced between what they can do with them and what new thoughts are enabled as they examine both music and language. In defining pattern, rhythm and beat they work to construct music of their own. They apply these concepts to bird song and ask whether or not that is really

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[3]Gadamer (1976) *Philosophical Hermaneutics.*,page 34.

music or is, rather, language--they think new thoughts about the phenomenon and in turn question the usefulness of the labels. I think in the course of teaching this also can occur. In the process of transforming both the children, the subject matter and myself during teaching there are opportunities to reflect on this transformation as well as the assumptions that underlie them. I write about this in Chapters 4 and 5. This process of becoming both cognizant of assumptions and questioning those assumptions is the essence of arguments of critical theorists such as Habermas (1991) as well as Arendt in *Eichmann in Jerusalem*.

The subject/object relationship is defined by what the object and the subject share as much as by how they are different. Now the instruments that the subject uses to "look" at the object must also be able to access similarities as well as differences. In order to do this, these instruments mimic in some way the qualities of the object under study and also the qualities of the subject. For example, we can see the world around us because the wavelengths of visible light are similar in size to the sizes of the atoms and molecules that make up the world. Our ability to see is because of this similarity but also what we see (say color) is because of the qualities of this similarity and also because of differences--there is an object there, different from light, or there would be nothing for the light to interact with and refract. There would be little point in teaching children if they were clones of myself. They are intrinsically different. I also could not teach them if we did not share certain things, for example, a language. A similarity such as language which is fundamental to the relationship, shapes what can be learned about differences--between the children and myself and between children--as they debate the meanings of scientific words by discussing the different ideas of each child, they learn about each other as well as the science. Language is a tool, an instrument in the relationship which both reflects a relationship and shapes it. It embodies the culture which contains the relationship and is instrumental in altering it. Its ability to be a tool is grounded in similarities between subject and object. Its purpose can be to "see" differences or similarites. The lenses, tools, instruments used by the subject to look at the object selectively focus or image the similarities and differences. If

these lenses mimic the subject only rather than the object, the image seen is of the object rather than the subject. The lens is a mirror and the study is a false one (Irigaray, 1985).

Both the context and the instruments that shape and enable us to look at an object are designed by us (the subjects) purposefully--to be able to do particular things. We choose (consciously or unconsciously) how things appear to us as well as objects choose their appearance. This idea of presentation being a purposeful act is from Hannah Arendt (1978) *The Life of the MInd*. The idea of presentation being a purposeful act also means it is a conscious one, at least on some level--we choose what we want others to see about us. This makes the subject/object relationship a reversible one. If Cory is the object to me, the subject, then I am also an object to him. If every act is one of self-display then it is that fact that makes those acts meaningful--they are meaningful because of their purpose to the actor.

> [When I choose what to show, how to show it] I am not merely reacting to whatever qualities may be given me; I am making an act of deliberate choice among the various potentialities of conduct with which the world has presented me. Out of such acts arise finally what we call character or personality, the conglomeration of a number of identifiable qualities gathered together into a comprehensible and reliably identifiable whole.[4]

Now I think that this presentation or self-display can be a form of play--trying on different self-images, trying on different effects on the observer. This is enabled by this back and forth, shifting subject/object identity. The idea of purposeful self-display also links the creation of subject versus object identity directly to method, to the things done by either the subject or the object. Defining subject or object is through method. Neither the subject nor the object exist as concepts without the actions or thoughts in between the two that construct and shape the relationship. Again this is also what I feel Derrida is saying with his idea of framing--the thing, actions, context--that sets the object apart from a continuum.

This takes me to Sartre. If the subject/object relationship is based upon both self-presentation and perception which are purposeful--both the object and the subject want to do something--it is motivated by a *need*. Sartre differentiates between *desire* and *need*. In *Being and*

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[4]Arendt (1978) *Life of the Mind*, page 37.

Nothingness (1965) he claims that acts of free will are motivated by desire. In *Search for a Method* (1963) he modifies this to need. The difference between desire and need, it seems to me, is one of an intellectual desire versus more emotional, felt need. To desire is in your head, to need is in your stomach. Most importatly need addresses a vanishing point--needs can never be satiated. Desires can and then one can move beyond them. I think of Sartre's need as similar to belle hook's (1990) "yearning"--a longing which emanates from the heart as well as the mind, which shapes thought, actions, emotions and which is not satiated even when directly addressed.

> *Desire* suggests the possibility of unrestricted movement, of a freedom which may change the objects of its desire at will. *Need* brings in something from the outside, a necessity which man cannot ultimately escape, no matter how much he may vary his reaction to it.[5]

The tension between what is known and unknown which I write about as central to both the act of teaching and of doing science reflect needs. For a scientist the need to discover can't be fulfilled--each new discovery uncovers new questions. Likewise for a teacher--goals in teaching and learning are always moving away, constantly redefined as progress or even just change occurs. Presentation of self, of science, of relationships becomes a vehicle for expressing and acting upon this need but on the other hand so does perception--both sides of the subject/object relationship are shaped by need.

Presentation is also a symbolic act, I think. It is a way of expressing something hidden. I think of this as similar to Levi-Strauss's description of ritual as symbolic:

> The shaman provides the sick woman with a *language* by means of which unexpressed, and otherwise inexpressible, psychic states can be immediately expressed. And it is the transition to this verbal expression--at the same time making it possible to undergo, in an ordered and intelligible form, a real experience that would otherwise be chaotic and inexpressible--which induces the release of the psychological process . . . ..it is a matter of provoking an experience; as this experience becomes structured, regulatory mechanisms beyond the subject's control are spontaneously set in motion and lead to an orderly functioning.[6]

These regulatory mechanisms occur in a classroom because the act of self-presentation is a social act to which others react. This is really another explanation of how expressions of thoughts,

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[5]Barnes, H. in J.-P. Sartre (1963) *In Search of a Method*, page xv.

[6]Levi-Strauss (1963/76) *Structural Anthropology*, pXXXX

needs and actions become method. The symbolic quality of actions, where actions mean something other than what they appear, is at the heart of Julia Kristeva's (1986) concept of cyclical time. Actions, when perceived in a generalized sense, repeat over and over, form a cycle, are in cyclical time. They also define a method (methodical). Because they repeat, they acquire a transcendence in meaning; each time they occur the setting is different, their meaning is different (yet the same), and they become generalizable in consequence and form beyond the immediate actions of a particular moment. For example when I ask for the class's attention by turning off the lights. I am not turning off the lights to make the room dark but for a different purpose. The act has acquired a meaning other than the obvious one. It is symbolic of something other than what it does. The action has a generalized meaning--that the children should give me their attention--and a specific meaning to the indtance it occurs in, for example at one time I may be stopping misbehavior at others I may be calling the class to large group discussion. Actions reflect something about the actor, about the actor's beliefs about the perceiver, about the actor's beliefs concerning what they are acting on. My using the lights as a signal implies that I believe the children need me to signal that certain actions are appropriate and when and that I know what the approp[riate behavior is. The act of perceiving is also an interpretive one, active not passive. The subject brings a lens to seeing also shaped by purposes and beliefs. The children are interpreting my actions in both a general and specific manner.

Heidegger argues that to separate subject and object, as is implied in metaphors about the subject "seeing" the object, is artificial. The subject and object occupy the same world-space, life-space: "By drawing a distinction that I (the subject) am perceiving something else (the object), I have stepped back from the primacy of experience and understanding that operates without reflection." Heidegger does not deny that we exist purposefully in this world, that we are trying to do certain things. He claims that this purposefulness involves decisions--what to do and what not to do, how to go about doing these things. These decisions are founded upon uncertainty, they reflect needs for things which we don't already have yet and hence don't know. We make

decisions on a basis of things felt, not articulated. The actions necessitated by decisions are symbolic interpretations of their unarticulated foundation.

> But Heidegger has a more radical reason for saying that we cannot get clear about the "beliefs" about being we seem to be taking for granted. There are no beliefs to get clear about; there are only skills and practices. These practices do not arise from beliefs, rules, or principles, and so there is nothing to make explicit or spell out. We can only give an interpretation of the interpretation already in the practices. This is why Heidegger says in introduction II that since phenomenology deals with our understanding of being, it must be hermeneutic. To sum up, an explication of our understanding of being can never be complete because we dwell within it--that is, it is so pervasive as to be both nearest to us and farthest away--and also because there are no beliefs to get clear about.[7]

The basis for making decisions are in: 1) emotions--how we feel about our choices: "Heidegger wants as usual to stress that moods provide the background for intentionality, i.e., for the specific ways things and possibilities show up mattering" (Dreyfus, page 174); 2) understanding--we know how to act:

> [E]ach of us knows how to be that particular for-the-sake-of-which each of us is--father, professor, etc. We are skilled at existing. "In understanding as in existentiale, that which we have competence over is not a "what", but being as "existing". Moreover we *are* such skills. "Dasein *[being]* is not something occurent which possesses its competence for something by way of an extra; it is primarily its ability to be. Dasein is in every case what it can be".[8]

and; 3) "falling"--we are already immersed in the situation that requires decisions to begin with. To me this defines where Derrida's framing context is constructed from. The frame is also a symbolic miasma of assumptions. We act using "skills and practices" from which we can articulate "beliefs, rules, [. . .] principles" by examining the background in light of our actions. I think that this idea of how we come to do the things that we do is central to thinking about the everyday decisions and choices that we make in teaching (Buchmann, 1986). The background to the things that I do when I am teaching is unarticulated knowledge of science, children, teaching, context as well as how I feel about those things founded in my history and also in the goals that I have set for my teaching. Acts of teaching are manifestations of a web constructed of these things which add up to an "understanding" of the moment and this moment itself is not extractable from

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[7]Dreyfus (1991) *Being in the World*, page 22.

[8]Dreyfus, page 185.

the situation itself. It's only when I can remove myself from the moment that I can think *about* my actions, knowledge and choices. The same is true in the process of doing the science. This is why the question of design in science is so interesting. To design an experiment or a course of action represents this thinking that can go on outside the moment but participating in science, utilizing the design, means immersion within the moment. The children in my second grade classroom are asked to participate in both of these ways of thinking as we explore soap bubbles--they design experiments and then they enact them; finally we discuss their activities--we move in and out of immersion in the moment.

The blending of subject and object, the dynamic between them constructed in a relationship composed of methods, purposes, and needs, is related for me to a concept that Julia Kristeva calls female subjectivity:[9]

> According to Kristeva, female subjectivity would seem to be linked both to *cyclical* time (repetition) and to *monumental* time (eternity), at least in so far as both are ways of conceptualizing time from the perspective of motherhood and reproduction. The time of history, however, can be characterized as *linear* time: time as project, teleology, departure, progression and arrival. This linear time is also that of language considered as the enunciation of a *sequence* of words.[10]

The relationship between subject and object conceptualized as metaphorical, symbol-ridden method is patterned. Qualities of it repeat and it becomes a design. This is how a method can be defined and also how meaning can be found in method--method can be abstracted from a background of random action and it attains its own symbolic, transcendental meaning. The subject and object evolve, though, through the relationship--they become something different from what they were before. Then how does method respond to this?

> [F]emale subjectivity as it gives itself up to intuition *[note similarity to Heidegger]* becomes a problem with respect to a certain conception of time: time as project, teleology, linear and prospective unfolding: time as departure, progression and arrival--in other words, the time of history.[11]

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[9] My citing this doesn't necessarily mean that I agree with her argument that this is exclusively female. Kristeva calls this idea "female subjectivity"--it's the substance of the idea I find useful.

[10] Moi, T. (1986) Marginality and subversion: Julia Kristeva. In *Sexual/Textual Politics: Feminist Literary Theory*, page 187.

[11] Kristeva (1986) Woman's Time, page 192.

Method is right at the place of intersection between these two world concepts. It is the place where the battle between cyclical time and historical time occurs. As an example, teaching: There is an internal conflict for me when I am teaching--I need to understand, stay in one place and contemplate what I know about children, science, myself and how I am able to know it, but I need to change--to teach, to do things, to learn. Method serves both concepts of time, it is progressive--in the service of change and it is symbolic--repeating. Thinking of method as purposeful is not the same as the false causality of history in which events are looked back on from the perspective of an outcome nor is it transcendental in the sense of pointing to an inner truth which transcends individual instantiations. Method is in historical time because it is not willy-nilly, the relationship between the subject and the object is purposeful, each is trying to do something to the object or with the object as audience. This purpose isn't necessarily realized but change is. Method is in symbolic time because of its own repetitive qualities and also because it allows the subject to look at the object in ways that are "framed," that have meaning. This is why talking about method as a form of design is important. In thinking about method and design as metaphorically linked, I wish to think of the word design as a verb and also as a noun. As a noun the word design captures the abstract qualities of a pattern signifying something transcendent. As a verb it should be understood as a plan, an activity oriented towards a goal. Teaching, learning, science as methods have both of these qualities.

In the second chapter of this thesis I wish to explore an example of design in teaching and in science through a description of a unit I taught in a first and second grade combination class. This unit is ostensibly about soap bubbles. The underlying thing it is about is experimental design. My goals in the unit involve the children participating in a process of experimental design and enactment using soap bubbles as a medium. Therefore there are two forms of design occurring in these classes: the design that the children and I participate in as we explore the soap bubbles; and between myself, the children and the materials we are using to design the teaching. This chapter is especially oriented toward an engagement of both the learning science and the teacher knowledge/teacher learning conversations which I discuss at the start of this chapter. I

talk about how the children use their previous understandings of many things to construct both new knowledge and also scientific process as we explore the bubbles. I also talk about how I use my knowledge to frame this pursuit and how this knowledge is altered as the children and I interact around the science and each other.

In the third chapter I explore another design problem, that of designing, or maybe re-designing the science so that I can maintain some particular goals in my teaching. Making a claim that both teaching and science are methods is, by my definition, making a claim that they are both purposeful activities with particular goals. That makes no claim that the goals for both are the same or that they are articulated ahead of time. My point in this argument that I have just presented about what method *is* is that goals, as part of the "need" that motivates action, are in part unarticulated. Some instructional goals are articulated at the outset of teaching, yet the experience of designing, interacting, etc. make evident other goals not previously articulated. Through my work in the classroom I come to recognize the goals (values) that I am using to shape my teaching. I learn to recognize what my teaching symbolizes. When, through interactions with others, I come to realize these meanings and that they are not consistent with each other, I choose to work to redesign the science so that I can maintain the goals of my teaching. I don't do this in the abstract or all at once. I do this incrementally, as I teach and as I need to.

The unit portrayed in Chapter 3 is about teaching music and sound. I picked this unit because the "science" examined is sound but the medium I chose to teach it through is music. I did this because this allows me to show an intertwinement of science and aesthetics, often not recognized by non-scientists. It is an illustration about how the definitions of words, both naming and defining meaning, which with method are the fundamental components of a science, is a process in itself. A more radical example of re-designing science is in Chapter 4, about teaching a third grade class about gravity.

Both Chapter 3 and Chapter 4 continue to engage the larger conversations about children's science learning and teacher knowledge and learning. They also address ideas about

the role of the children's home cultures in these classes. In Chapter 3 I make the argument that through discussion of the science a unique classroom culture is generated. This culture adds onto and respects the children's home cultures. This development of a classroom culture around scientific explorations and discussions is central to my thinking about how the children come to learn and also about how I come to use my knowledge and also learn. This is also true in Chapter 4 but here qualities of the "things"--knowledge as well as ways of thinking and expressing themselves--the children bring to class and use to construct this classroom culture are often problematic and cause me to think about how I am portraying the science and also how the science is evolving in my own head.

The fifth chapter of my thesis is about how teaching is based upon knowing but is also a process of coming to know. The other chapters are about this too, though. The process of design and therefore method isn't only a process of demonstrating what a person already knows, it's also a process of coming to know, of learning. This chapter quite explicitly addresses the questions of teacher learning and the role thinking about the child's home culture has in teaching. The science itself is no longer the focus.

CHAPTER 2

THE ROLE OF DESIGN IN SCIENCE AND TEACHING

In order to be a design, an object or an action needs to stand out from a background. We need to be able to "see" it. This happens through framing. The background is composed of emotions, understandings and already constructed ways of doing things. When we enter into a situation (any situation, including one that appears to initiate with our entrance) we are already immersed in pre-existing circumstances--we *know* how to act, how to interpret, what to do. This is Heidegger's idea of "falling" and explains how we are able to interpret circumstances and to act upon them--nothing is *ever* brand new. Qualities of framing, of the background, differentiate the design but without necessarily calling attention to themselves. In looking from the outside, though, as we can do with this story of teaching and of science, we should be able to abstract the qualities of the frame. What composes the frame in this teaching--what leads to the decisions made by me in teaching this unit? What leads to the decisions made by the children as they design their experiments? For me decisions come out of my ideas of the science and of the children which existed before we began the unit but are continuously reformed as the unit progresses. This is both in and out of my control: it is also shaped by the materials and the children. Similarly the children's decisions come from preconceptions they have about bubbles and about school, transformed by the discoveries they make as they work with the materials, each other and myself. As Heidegger also implies, it would be a mistake to view decisions as only reflecting what we know. They also symbolize what we don't know and what we think we'd like to know. This theme--that actions and decisions reflect assertions of knowledge as well

as uncertainties--threads throughout the rest of this thesis. It will appear many times in the stories that I tell. It is the basis of my assertion that statements of knowing, by the children in explaining the science, by myself when making choices in teaching, are also statements of not-knowing--places where learning can take place.

The act of design is purposeful, it expresses a need, is symbolic of that need. The actions in this class should be interpreted in terms of needs. The articulation of these needs is again enabled by qualities of the framing background. The things the children and I say about what we are trying to do, what we want to do, are expressions of our interpretations of both the background and foreground. Examining expressions of need exposed to us in the act of design allows us a pathway back to the background. It gives us a tool to explore selected components of the frame. When we examine the things the children are trying to do with bubbles in this chapter we can rediscover the qualities of their knowledge which has been buried as well as their ideas and theories that are on the surface, that they are working on *now*. The design, the thing within the frame, can act as a frame itself for the elements of the background. It causes their differentiation from the continuum. Similarly with the act of teaching. As I write about what I am trying to do with the science and the children, I expose the hidden assumptions, values and beliefs which underlie these needs and desires.

Design as a verb--a method--should serve both cyclical, symbolic time and progressive, historic time. As expressions of needs it does the former. As we act to realize these needs it does the latter. This is interesting because what is actually realized can only partially (if at all) satisfy the needs it stems from. Or it may do something entirely unintended. This very much happens with both the teaching and the soap bubbles. Sometimes I plan for this but usually only partially so. For example I planned that in our initial experience with bubbles I would "find" what the subsequent classes would be about. What I actually found was much more sophisticated than what I had thought would occur. This happens in teaching because actions do not occur in isolation. It happens in the science because acting on one set of variables locates others. So design, and method, are both controlled and uncontrolled. They represent both what is known

and what can be known. They are both atemporal and integrally of the substance of time--looking backwards, forwards and at this very moment. Do we have to look at a cross-section of time to see a design or a method or is it also recognizable in particular moments, actions?

I had planned this unit about soap bubbles during the summer to be a unit about design.[12] Design in the sense that Schon (1989) writes and talks about as an interplay between materials and the person which is shaped by metaphorical images of purpose. I picked soap bubbles as a vehicle for this because to understand soap bubbles as a phenomenon is very abstract, non-intuitive. It therefore presents interesting design problems for me as a teacher. How do I design this curriculum and this teaching? How is this design process an evolving one that is interactive between people as well as between a person and things and tasks? I also picked soap bubbles because children can almost be counted on to have some experience with them. But this experience is usually very constricted and proscribed. What I do in this unit is and isn't. How it is constricted and proscribed by me, the children and the materials is the point of this being a story about design.

This unit, which I claim to be about design could be described as about involving children in the scientific processes of experimentation. By saying this I would satisfy the demands of local and national science curriculum requirements. The unit is, though, much more than the simplistic view of experimentation often advanced as science in schools. For example what is often called experimentation in schools is really *demonstration* of what is previously known--it is artificial. To be true experimentation there must be a potential for discovery of new things, for surprise. Experiments are designed--they address particular end points--but still they also represent questions, the unknown as well as known.

This story (and the stories in the other chapters of this thesis) are written from transcripts of the class. In transforming those transcripts to a story I have reduced and edited what was said

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[12]This unit was taught in a first and second grade combination class. The classroom teacher was Kathy Valentine. For a full description of the school, class and children, please see Appendix I and II.

by the children and myself and also descriptions of what we did. In doing this and in choosing to focus on science content (rather than control issues, say) I have, strangely enough, deleted much of the patterned activity of the class. I find this strange because if this is a story of design, and design as a noun is a pattern, then I have deleted a large portion of that design.

The repetitive acts I am talking about are things such as turning out the lights to get the children's attention, the mental processes I go through to decide who to call on and when in class discussions, descriptions of speech patterns or activity patterns of individual children. These small patterns enable and compose the larger design. They are microcosms of my dialectic between the atemporality and temporality of patterns. We recognize patterns because they repeat in time, they become a quality of the passage of time but they also punctuate and differentiate particular moments in time, they exist for themselves.

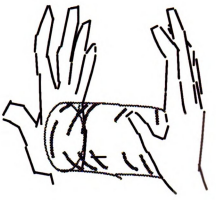
The first class: Figuring out what to do.

November 7th

The children come in from recess and we discuss what we will be doing now in science class. While they had been outside I had made up the tubs of bubble solution. I have decided that each table of three or four children will have one plastic wash tub of bubble solution. I've made the solution with dishwashing soap and water. I say that we are going to work with bubbles, sticking various things into the bubble fluid. First though we set up the room by putting down pads of newspapers on the desks. When we are ready, I give them the bubble solution and ten minutes to experiment with it. I give no other instructions than that. They are restricted to stay in their own pods and to using only their hands to make the bubbles. I have given them no implements. This is purposeful: I wish to maximize the children's sensual contacts with the material and I want this contact to be just between them and the soap solution (and of course other children in the class--there was much discussion in all this) without anything else added in.

I stop the whole thing and by pods have them dry off their hands and go up front to a learning circle. In this first conversation I am exploring the terrain of things that the children observed about the bubbles. I have certain possible directions that we might go from this first activity laid out in my head and I want to see which of these things the children have located for themselves and if I push a little bit, very gently on those things, how the children respond to this. I am trying to locate *what* about soap bubbles the children are actually going to be able to pursue and discover given that in the teaching that I do with this age group I am disinclined to actually *tell* them information to explain the things that we observe. The areas that I have outlined in my head that we might be exploring are bubble shape, bubble size, colors in bubbles, why bubbles form in the first place, why they pop. All of these are touched on in this first conversation. We end up settling in more or less on the first one over the next few weeks. This is in large part due to Thomas and his techniques of design which are very sophisticated, I think, and to Danping whose explanations for the shapes of features of the bubbles seemed to me both simple--derived directly from what could be seen--and correct. Both of these qualities--of the design process and of the postulated explanations--are very important to me. They are coherent with choices I have already made about what my teaching looks like. That is, most importantly, that my teaching is based upon what the children can do so that my role can remain one of facilitator and shaper.

I start the discussion by asking what people were able to see when they were making bubbles. Thomas said: "Well, something I made, I put my two hands . . . first I blew a bubble, then I caught it in one hand then I put my other hand on top then I got this long string." He mimes this with his hands. I name what he has made a cylinder. Other children have tried similar things and start discussing this. I get up and draw what I think he has made on the board.



I quiet the room and ask Thomas if this is what he means. He agrees.

> Thomas: And it was not two [bubbles], sometimes people catch bubbles like that but what I do is sometimes I catch one and put it in the other hand, sometimes I catch two and put it . . . *together, he shows us with his hands* . . . and then you see the silver coin in the middle but you didn't get a picture of that . . .

I start to ask Thomas about this silver coin but he wants to talk more about how he made the cylinder. He says that it requires two hands. A bubble in just one hand is "fat out of my hand but when my hand goes on it, it goes straight up." When he puts another hand on the bubble it elongates into a cylinder. This is the essence of an explanation of why bubbles are the shapes that they are--they are fluids which take a shape imposed upon them. I repeat his description of how he made the cylinder and ask him to confirm that.

> Thomas: Yes but what I think is funny is, see, it was sort of fat when I just had it . . . here I'll, it was sort of like this and see here's my hand and the bubble goes like this when I'm not have my other hand out but when I put my other hand over it, it just goes zip!! . . . *He does this with the bubble solution--I have brought a tub up to the front of the room* . . . But it's fat then it starts going up It turns into a straight person, like kids playing, they get in line so fast, like when they are playing, they're all fat and then when they say line up, it's just *whup*!

I ask if any one else has done anything like what Thomas is talking about. Timmy says that he did something like this without making the silver coin and he found when you pull the bubble cylinder too far it stretches and then pops.

In this first short part of this class's conversation we have started talking about the shape of bubbles and why they break but in a more complex way than could have been suggested from

my abstracted list at the beginning of this paper. The discussion about shapes is also about the intersection of shapes and the discussion of popping bubbles is combined with consideration of size. Now Andy adds in that he saw Kwanhyo blow a bubble that fell to the floor and, rather than breaking, bounced. The conditions which make a bubble break aren't purely those of size.

Emily adds her observations about bubbles breaking, that you can only stretch them so far and then Suni says: "I had one, I had one, see I catched the balloon and then I put the other hand on it and stretched it and kept stretching it, then I had one balloon and then when I stretched it, I had two." I asked him if this was like Thomas's, he made a cylinder and then when you pulled it far enough apart you got two. Thomas interjects: "Yeah 'cause it broke." I say: "Oh, so, but it didn't break and there was nothing, it broke and you had two bubbles." This particular phenomenon, that bubbles can divide into two or more *or* break, is certainly something that I knew about but not something that I had thought about or had connected up. That I do that or that others in the class do that is caused I think by the social qualities of how we are discovering things--in class with others and then all together again as we talk about things and put ideas together. For me this means as we talk about the things we have done and what we think about them we hear new ideas, different ways of thinking than those we have constructed alone. This has an implicitly critical quality--as someone says something different from my own ideas, I compare and assess. That, though, is dependent upon my ability to listen and truly hear (understand) what the other is saying. This combined with a desire to do new things or think new thoughts rather than justify my own or replicate others is the essence of the creativity integral to the concept of design I am attempting to foster in this class and describe as a component of teaching. I think this can only be achieved through conversation around topics in which the children are genuinely interested. This though has a cyclical quality--the children also become genuinely interested because of the conversation.

An'gele tells us about her technique of bubble blowing: "Um, when I was doing it, I just would just dip my hands in the water, I had two hands, I went like this, and I got like a little crystal ball, a little circle in my hand like this . . . " She shows us:

Then she tells us that she was able to make a cylinder like Thomas described using her other hand. Then Cory says : "When I put, um, one in my hands and then I took it out, I blew and little tiny bubbles came out of my fingers." Each time a child says what he has done I draw him out a bit in his description. I do this because I want to develop the language that the children are using and I am conducting this search for something that can be developed into a theme so I want to increase the "dwell" time on any particular observation or statement to see if it is developed further and if it resonates with others. I talked in the introduction to this chapter of how a design stands out from a background. I am looking for this design to begin to emerge. I listen to the things the children say about what they have done and in response to each other for repetitions in ideas, for echoes that pull one idea into prominence over others. I am looking for the emergence of a foreground over a background.

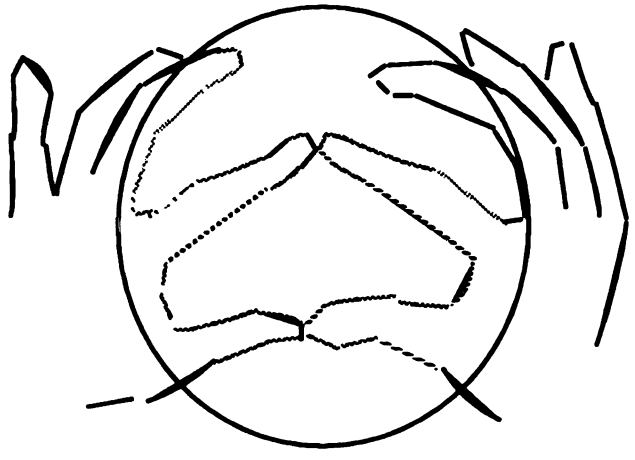
The language that I am using to describe this is deceptive; it implies a passivity but in truth it is the combined interactions in conversation between us all, the desire to communicate, that causes the emergence of a theme. Part of my role is to recognize the commonalities in the statements the children make and work to construct the conversation to contain that theme more prominantly--so that over time separate ideas and observations become part of a whole and the children begin to work together on common ideas and questions. For example, after An'gele and Cory describe to us the mechanics of making bubbles for them and describe what they were able to make, Sakti says this: "I blowed a bubble like this and I held my hand like this and I blowed it and it kind of went like this and then it was this big and it popped." I repeat: "It popped? Did it

ever become separate from your hands? Did you ever get it so it was like separate from your hands or was it always attached to your hands?" She says that it remained attached to her hands. Her comments are connected to and add to all the other children's observations. It's this that gives me a feeling of a common topic for us to pursue. Both the children and I are playing a role in developing and creating this but it's a complicated pattern of playing off each other.

Shumshad says that when he pulled his hand out of the water a bubble was made between his fingers and even an enclosed spherical bubble, held in his hand, followed the edges of his fingers. What he actually tries to describe to us is how the bubble film travels up the sides of his wet fingers, clings to his fingers. A bubble not held this way was shaped like a crystal ball. This is an addition to Thomas's early description of how to form a cylinder, a free bubble is round but it will cling "sometimes" to a surface and be reshaped by that surface.

We continue talking about technique and I try to suggest an exploration of bubble size, one of my original ideas about what this might all be about that hasn't been mentioned yet. I don't want things closing down on one topic yet. This is in part because all the various things I have listed in my mind that we might be exploring--size, source, color, shape, etc.--are connected and I know that in order to develop understanding of any one it won't be done in isolation of the others. To think about shape we are going to want to think about size for instance. The variables are connected and we are going to want to recognize and develop these connections to be able to theorize about explanations. Another reason that I don't want the discussion narrowed too soon is personal. There are certain things about bubbles that I find fascinating and I wouldn't mind us pursuing those because then I could think about them further. I pursue my own little research projects through all the units I willingly teach. I choose the topics of these units--bubbles, music, patterns--because I wish to explore them myself. I also bring this attitude, I think, to how I work with the children--they are objects of my explorations also. I say all this because if design is a purposeful interaction between materials and person, it is also a process of exploration and discovery.

For bubbles, I am particularly interested in color. That isn't though what is going to happen, at least not focally at the start of these classes. It does happen, we have conversations about color off and on through this unit and in interesting ways, as intertwined with explorations of other variables. At any rate at this point I think we should talk a bit about size and I want this discussion to happen connected to a discussion of how they actually made the bubbles. The size of a bubble depends upon how much air you blow into it and also on how large the initial film the bubble comes from is. I say to the class that I saw Ho Sook making bubbles a different way from the description others have given. I demonstrate this.



Then I ask how were those bubbles different from bubbles made the other way like An'gele had shown us. Ho Sook says that they are smaller. This is not so, they are larger and Paula disagrees. She was also blowing bubbles this way and hers were much larger. Many children debate this.

Next Teton says that he saw rainbows when he made a cylinder. I ask what he thinks might make the rainbows. Paula says: "The bubble soap, when all the bubble soap . . . and the lights . . . when the lights come down, it seems like all these rainbow things are swirling around."

Teacher: You saw them swirling around?

Danping: You know what? When I was looking at the rainbow . . . first you know when I'd put my hands together and then I'd go like that [*blow the bubble through her hands like Ho Sook and Paula did*] and then I'd see the rainbows first . . . they'd be thick and then they'd be skinny and then they'd curl everywhere.

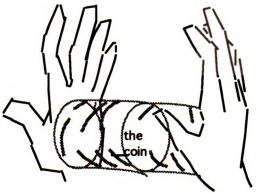
I ask her why she thinks they did that and she replies that she saw it occur as the bubble stretched. I repeat the whole thing putting the two sets of observations together to emphasize the implied causality. "Danping is saying that at first her rainbows were real big and then they got skinnier and skinnier and started to swirl around and that was as the bubble got bigger."

Now I blow a bubble and ask what they see. Shumshad says: "Um it was kind of like a bag that you made." Suni says: "Like blowing a real balloon but you were blowing that." Andy adds that as I blew, it got bigger and longer and Teton says that at the top of the bubble he saw a large rainbow that changed like Danping told us about. Cory adds: "Yeah it went skinny skinny and then it went longer longer and then when it got to the, um, end it showed the colors, it was purple, green and black." Thomas tells us that he saw the rainbow go up and move especially when the bubble was about to break. Then Emily and Benjamin try describing how the bubble changed shape as I was blowing it.

I blow another bubble and the children continue talking about the shape changes while I blow it. Then Kwanhyo says: "It was going on your hand like this and then it went like this, it curved and then it was going on your hand like this . . . " I say that then it broke. Sueh-yen says that it was like a ghost and that it "turned it bigger and bigger and then it was moving and then it popped." Cory says that before it popped, it looked like "fire and smoke on the back." I blow another and then another. The second pops and generates the first question that we pursue by experimentation and observation. I ask what they saw. Paula says that she saw it stick to my arms before it popped. I ask if anyone saw it exactly when it popped and Cory says: "Yeah it went all over you, first it went down and then it touched the bowl and then it went phoof!" Next I ask if it popped all over or just in one place and that break spread. I want them to look harder and harder and when no one can answer this I blow another bubble. Cory says that it popped in one place and others say all over. I blow another. Now Danping describes what she was able to see. "Um it went sort of like a circle and then it went a little bit down and it went off one this . . . [*she gestures with her hands*]." Cory adds: "First it went down then it popped, then and it went in one place 'cause it only went down, all of them went down, it went . . . " He gestures with his

hands and I catch on: "Oh 'cause it like everything fell?" Shumshad describes it perfectly: "Yeah like raindrops."

Next Cory asks me to try to make Thomas's silver coin construction. I do this while Thomas tells me how.



I ask if the children can see the coin. Thomas adds: "Well it's really not a coin it's really just a line that's circled." I stretch the bubbles until they break, then have to do it again. Cory exclaims: "The rainbows are going very fast!" I notice: "They are as soon as I made it stretch, the rainbows went really fast." Cory: "It's from the lights!" I make another.

Thomas: Now hook it! There's going to be a coin now see all around that . . .

Paula: Now turn it the other side it looks like one of those lamps that you put fire in . . .

Emily: The coin was invisible!

Thomas: See!!

Dan: Oh I see it . . .

"I see it!" everybody is shouting. The bubble pops and I do it again, Thomas tells me step-by-step how to do it this time. Finally we get the cylinder made and a "coin" in the center. Thomas: "There see that round thing, it's clear but it looks like a coin." I agree and point out that the intersection is flat. It pops and we make another. Lots of children start talking about this, describing what they think it looks like. Cory for instance says that he thinks it looks like a snow man.

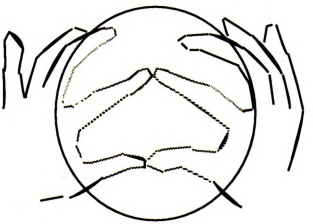
I have Thomas come up and sit in the center and make the coins himself. He has problems getting the two bubbles to reattach. (This is an interesting problem, by-the-way: two bubbles don't always want to "stick" to each other. I don't know why this is but I think [because of thinking about it in all these classes] that the surface of the bubble gets dry--they have to wet each other to attach to each other. Now I know that doesn't make sense--after all a bubble is made from a liquid--but anyway that's where I'm at in my thinking. I'm also not sure if my private research should be in this at all except that there is a lot of parallel thinking for me when I'm teaching.) I get Thomas to talk as he is working, to say the thing that he is making or trying to make as he does this. This has two effects--to get him to slow down and to focus the audience. Once he's made one I ask the kids to direct comments and questions to Thomas. Cory asks him how he makes it--when he puts it together. Thomas does another play-by-play as he makes a second. Then he does a third. I ask Cory why he thinks that it makes that flat surface in between the two bubbles. Cory: "I think if it touches something else it can turn flat. Or it got squished in the middle and it didn't pop." Thomas: "This is what I think, the way the bubbles attach is I think the way it happens, the way the bubbles attach. You see my hand makes the bubbles go out and these bubbles go together." Andy: "Well I think when it goes together the other bubble sort of pushes it and makes it flat when they come together and it makes the coin." Then Thomas says that he doesn't know if it should really be called a coin because it's not that "but that's just what he named it." I say that's ok because it is flat so it looks like a coin; it tells us that its flat, it's a good description. Andy says that he agrees "it looks like a coin."

Timmy shows us that if you do what Thomas did and pull and pull on it the bubble gets longer and longer. I ask how far they think he can pull his hands apart. Then I ask what they see happening as he does pull his hands apart. Kids say that it is getting skinnier and skinnier. Thomas says that means it's going to break soon. Then he makes the coin and Emily says that she wonders what would happen if the coin were on the side and I ask if they think it would be any different. Kids say yes but don't say how. Timmy makes another. This time he blows a large bubble and puts it into the palm of his hand before he starts to stretch it and there are three coins.

I ask why there are three coins. Cory says because there are bubbles on his hands. I ask how many bubbles there are. Some count three, I think because of the the three coins. Or they are counting the coins and then say three bubbles. Others count five or six (these aren't attached though and making coins).

An'gele wants to make a big bubble to show us. She makes one and it bounces off the floor. She gets coached by Emily and Paula who used a different technique. An'gele is blowing this way:

Paula and Emily used this method:



which produces a bigger bubble because the initial film is larger. An'gele makes one finally.

I start to end class by asking them what they think they learned from doing this. Thomas says that he learned that bubbles stretch and he's learned how to do that. Cory has learned that

he can make it very big. I ask what they are going to do next time. Thomas says that he is going to make one that goes over his head like a space man. Cory says that he is going to try to make one that goes up and will fly around the room. I ask them to think about that for next time.

I wrote that when I use the word design I can mean either design the noun or design the verb, designing, or sometimes I can mean both. I think in this part of the story of this unit what is portrayed is designing not so much a design although I think as the teacher a shadow of a design already existed in my head that was gaining solidity as the class progressed. For sure I found things in this class through the discussions about the shapes of bubbles that I could locate as things that we would at least partially focus on in the next few classes. There are, though, designs (the noun) to be found in this. There is the way that I am teaching--the questions that I ask to focus the conversation on descriptions of things made and of how the children went about making those things, qualities of the conversation itself that I model and develop (for example, the subject of the silver coin--the science grows out of what people have discovered on their own). This is a design because it follows a pattern. I conduct conversations in certain ways in which there are rules of behavior. I develop the science over and over again through this conversation which always starts with observation, moves to explanation and further experimentation, driven by questions rather than answers. There are also the "things," types of bubbles and observations expressed metaphorically, that the children produce in the conversation. These are the results of their interactions with the bubble solution and other children contextualized in the task I have given them. These things are designed because they are made purposely, either to fulfill my task, because a child sees someone else make one or possibly because of a developing interest in something previously known or discovered accidentally. It's the way I teach that these done things become works-in-progress, designs become incomplete, become symbolic of partial acts of designing.

The act of design though does appear to be an interaction among materials, the person and metaphorical images of purpose, as Schon says, when we examine the bubbles the children

have made. Thomas's coin for example which he made because of the qualities of the soap solution and of his own acts. These were shaped by his person, his past history, which were in turn developed by his growing personal aesthetic. Thomas spends a lot of time designing and competing Lego constructions. I believe you can see this--he made bubbles and the first thing he did with them was try to attach them together. People who play with Legos don't just gaze at them, they try to build things with them. The idea of building something is certainly purposeful, and transporting this idea to working with bubbles is certainly metaphorical. What do bubbles and Legos have in common? Not very much from my perspective, quite a lot from Thomas's. For myself as the teacher engaged in the act of design, I have ideas about what we should be doing in these classes and these ideas start to take on concrete shapes as I interact with the children and the soap bubbles through the children. It's purposeful because I have a purpose: I want the children to engage in experimental design where they find out things and develop ideas. That purpose is metaphorical to me because it's shaped comparatively with other things that I have done in science, things that are like and unlike this. Designing experiments in crystallography is like and unlike this. It gets more and more similar, though, as we go on.

In the next class we continue to discuss bubble shapes but now the children start to postulate theories to explain those shapes. I act to keep the children cognizant of their role in shaping the bubbles. Unlike other observation-based science we have done (for example the unit on music described in the next chapter), in a fundamental way, the bubbles take the shapes they do because of what the children do in forming them (as well as because of their own intrinsic properties). This is why this unit is fundamentally about design. Recognizing the role of the experimenter is paramount. Discovering the intrinsic properties of bubbles comes through either the success or the failure of the design of the experiment (both can tell you information and augment your understanding). There can be no illusion of the experimenter's passivity. I try to keep the children cognizant of their role. This goal is what shapes many of my decisions in the whole of this unit.

The second class: The beginnings of science talk and explorations.

November 12th

I start with having the children set up their tables. Then I ask them to all try to make the cylinder and coin that Thomas and Timmy had shown us. The operative statement in this is that I ask them to try to do something particular. I set a problem in which what they do as well as the qualities of the bubbles play a role. Timmy tells the children how to do this. I give them ten minutes to do this. Then I have them come to the front in a learning circle to talk about it. I also bring up a basin of bubble solution in case we need it.

I ask: "How many people made their cylinder and the silver coin? Were any people not able to make them? Kwanhyo you weren't able to make them?" A number of children have had some problem making the silver coin. My intention in asking this question, which I do many times in the subsequent classes, is to find out about these difficulties that the children have in making their creations and to find out what things the children do about those problems. This isn't particularly to help the children to achieve their original visions but rather to see how they alter their mental designs because of difficulties or the strategies they develop to try to circumvent the problems and also hearing the things they have found out about the soap solution in the process of running up against difficulties. In this instance the children talk about their difficulties and exchange hints and techniques.

Cory describes the way he was able to make the bubbles. "When I was blowing a cylinder, when I got very far it, um, they were both big bubbles and when I made the cylinder it was a big cylinder and inside of it, I looked, and inside of it it looked like there was a circle inside of it." Thomas exclaims: "That was the coin." Cory, however, says no it wasn't, it was a "flat part." Thomas says again "that was the coin." I ask Cory to describe his bubble again and agree that was the silver coin. Then I ask: "Why do you think, you guys why do you think the silver coin is flat. I mean the bubble is round but the silver coin is flat." Cory says: "Because when you

stick it together it makes something flat" and Danping adds: "It squashes each other." I ask her what squashes each other means.

This is more than just a description of something she has seen. It is an idea about why what she has seen is the way that it is--why the silver coin is flat. She has to be clear about what she is talking about for others to understand and for us in the class to be able to go any further with her ideas. Because this topic of the silver coin and the shape of the silver coin seems to keep resurfacing and because things can be said about it that are both derived from what the children can observe with the bubbles and connect with other more fundamental scientific principles about pressure and directional pressure, I have pretty much decided what I want the class to pursue when she makes her statement about the two bubbles squashing each other to make the coin. This has become a really interesting cut on the question I had originally thought we might be interested in about the shapes of bubbles. A free bubble is round because of the pressure of the air inside it pushing out equally in all directions. This isn't at all obvious--why is the air pushing, for example? It has suddenly become obvious because in Thomas's construction there are two bubbles pushing against one another so in some parts they are round but where they connect they are flat. The roundness becomes understandable because of the flatness. It's obvious the flat part is caused by the bubbles pushing together, so the pushing that goes on elsewhere is pushing the bubble film out and round.

Danping says: "Because the bubbles is squashing each other and it makes . . . like this goes like this and it just squashes this, it's almost like two bubbles both put in one but it just squashes it and lays down flat in the middle." Cory adds: "Like a flat nose." Next Thomas tells us: "I can explain it better because it's sort of like . . . see this? This is what it's like. It's flat but it's round because it's skinny, you can see in both sides but, but what we mean by it's flat is it's very skinny like this . . . but it's also round." I ask: "Why is it round?" and Thomas replies that the coin is round because the bubble is round and it is inside the bubble. This is where I get the next refinement in my ideas for the subsequent classes. In the future we will begin talking about the shapes of bubble films and the shapes created by their intersections. The aspects of design we

will participate in are around trying to control the placement of those planes and predicting their intersections.

Thomas and, in a minute, Danping are saying that the shape of the bubble controls the shape of the intersections between the bubbles. This gives me an idea from crystallography in which the shapes of crystal faces are controlled by the places of the intersections of different faces. (The relative angles and sizes of those faces are caused by something else though that bubbles don't share so again this is a partial metaphor.) I don't immediately act on this idea though, I have to let it build up pressure for a couple weeks. At any rate my next question is to ask why the coin is flat. Thomas says: "Because it's inside the bubble and if it wasn't, I wouldn't have called it a coin for one thing, I would have called it an I don't know." Well, here's an example of false historical causality. I respond by summarizing the whole thing although I ignore Thomas's last bit of logic. "So Thomas says first of all that the silver coin is round because the bubble's round and when they come together it's still going to be round and Danping says that it's flat . . . " Thomas breaks in to state: "It *is* flat!" I continue: " . . . Danping says it's flat because the two bubbles are pushing on each other."

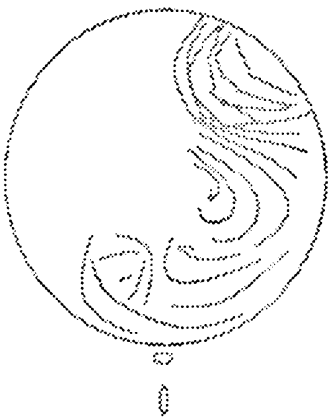
> Thomas: Right.
>
> Danping: I know why it's round because the bubble is round, right? And the edges are round so when you squash them it's going to make a round coin, it's not a square coin. That would be if it was a square one. 'Cause see if the bubbles are round then they squash them so it's round when they squash them.
>
> Teacher: Hum, Cory what were you saying?

Danping has just made a very nice elaboration on Thomas's explanation for why the coin is round. It adds to my growing ideas about bubbles as metaphorical crystals but I want us to stay on the question of why the coin is flat because we are very close to making sense of that I think.

> Cory: Um that there's no air inside the flat thing so it makes it flat. I think that there's no air in it.
>
> Teacher: Oh I thought when you first started to say that . . . I thought you said that there is no air inside the bubbles.

Cory: There is. But inside the flat thing there isn't. There's nothing.

This is a pretty important concept. Children this age have very interesting ideas about what air is and one of the places that they form their ideas is in blowing up things like bubbles and balloons. Having some idea about what is in the bubbles and where it comes from is important if we are going to think about shape and size and that they have any control over those things. I ask what other people think is inside the bubbles. Emily changes the subject, though, and says that she saw an "invisible line" which squiggled around the bubble. We will get back to what is in bubbles later. "It wasn't really invisible, it was hard to see but it, like on the side, on the sides, this was, it was on the side and it would be like a rainbow and right here there would be like lines that would go [*she traces a wiggly line with her finger*]." I say that I have seen something like this also. Then she says again: "The bubble had, like, little lines in it and then on the side it was like rainbows and then in the middle it was like a line and it went like this a whole bunch of lines and it was going like this very slowly or something." This is what she is talking about:



I spent quite a lot of time with Danping and Ho Sook looking at these lines on their bubbles. There are two kinds of "lines" on the surface of the bubbles. One is formed by excess fluid flowing down the sides of the bubble to the bottom where it drips off. The second are interference color bands. The actual colors of these bands is dependent on the thickness of the bubble. The thicker, the brighter the color. When the bubble is very thin, they appear as black or

grey lines. The speed the lines move is variable and is controlled by the flow of fluid over the bubble so the two types of lines are connected. This flow is more or less downward to the base of the bubble but swirls around. Maybe this is like Brownian motion? Anyway Ho Sook and Danping and I talked about how it seems to do with the "water" fluid on the bubbles and this is what Danping means when she now asks Emily if she is talking about the water. Emily doesn't understand this though.

Emily tries to explain what she has seen to Danping, Ho Sook and the class. "Here's the bubble . . . [*she indicates a circle with her hands*] . . . and then inside would be a little line about that big, you can barely see them and they're so white that they're like invisible and then like on the side there would be like a rainbow." Danping announces that she knows what Emily means and I ask her if what Emily has just described is the same as the water that Danping and I had observed running down the outside of her bubbles and dripping off the bottoms. Danping says: "No I think that she is talking about the lines that are in the bubble." I ask from what I have observed myself: "Are they the same lines that sometimes look like they are colors and sometimes look like they are black and white?" Danping says that she isn't sure.

Now Shumshad changes the subject back to the flatness of the coin. He says that he thinks the coin is flat: "Cause maybe there's something sticking, sticks on and that makes it flat." I ask him what he means and he replies that two bubbles stick together making a flat coin. I ask him what he thinks of Danping's idea that the bubbles *push* together to make the coin flat. Danping repeats her theory and adds: "And they're round so when you squash the bubbles together so the coin is round." Shumshad thinks that's pretty close to what he's been saying and then he tells us his theory why the bubbles are round. "You know why the bubble is round? 'Cause maybe there is some air inside it." I ask what the children think of this idea.

Cory: Yes there's air in it.

Suni: Yes there's air in the room and it's inside the bubble

Timmy: The air gets mixed in the bubble and then when you blow, when you blow the bubble it comes out.

Shumshad: You know I think, what it is inside it, 'cause you know that sticky thing? It sticks the air in the bubble and that's why if you . . . blow it then you know when it turns around right, and there's that sticky air that will stick on it, that's why it makes a bubble.

I really don't know what he means by sticky air so I blow a bubble that we can look at while we talk more about this. I want them to associate the act with the bubble.

Emily: Did you see the lines in there?

Teacher: There's a bubble why is that round?

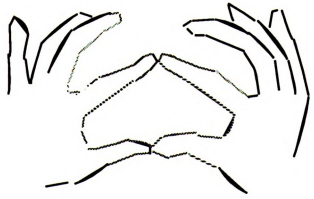
Cory: 'Cause of the air that's in it.

Andy: The air is pushing. When it's going around, it's pushing.

Teacher: Ok hold it, Cory says because there's air in it makes it round and Andy says because the air that's inside is going around and around and pushing.

Danping: I think because your finger was round and you blow it so . . .

I ask if my fingers were square would it make the bubble square. Some say yes and some no. I make a bubble An'gele's way:



and point out that the hole between our hands from which the bubble forms isn't round. Andy says that it *changes* to round and Danping adds: "It first went like that [*elongated*] but then it went to round." Then Danping says that even though the hole between my hands is more or less triangular the bubbles become round because "the bubbles down there are round so when you blow it, um, the littler bubbles get big so they're round." In other words the bubbles already exist in the soap solution and in making them large we are just enlarging them.

> Timmy asks if he can say something about how the air gets in.
>
> Timmy: 'Cause I think when people breathe, how they breathe out and then the air's in the room and then I think after you put it in your fingers like this and it's in there, I think the air comes here and it stops here and then when you blow, it goes out with the bubble.
>
> Teacher: 'Cause you're blowing it out?
>
> Timmy: No because there's air in the room I think and then when you have it like this, the air comes in towards it and then when you blow, blow the bubble the air goes inside it when you blow.

Timmy is saying that when you blow you aren't blowing air into the bubble rather you are making the opportunity for air from the room to go into the bubble. This comes up again.

Finally Tity says: "When I made my silver coin it wasn't a flat circle." This is the only time someone observes this. The next few classes we concentrate on the shapes of the intersections between bubbles. These are and aren't really flat. Whether they have a curvature is dependent on the relative sizes of the bubbles intersecting. This is really hard to observe though and we never talk about it again.

Then we return to why bubbles are round. Cory says that it's because you blow into it like with a balloon--you blow into it and it gets round. The air that gets into it makes it get round. If you blow too fast the air will just go right through it and pop on the other side. I ask him if this is the same as what Andy said about the air going round and round and he agrees that it is. If the air goes straight the bubble pops. Emily agrees with Timmy that it's the air in the classroom that goes into and makes it round. I ask again if it's the air that you blow in and am

corrected that it's the air from the classroom. I ask her if it's something about the air itself that makes the bubble round or rather like Andy and Cory have said the motion of the air. She says it's the air, the air from the classroom combining with the air from me combines and makes a "weird" sort of air that goes into the bubble and is round. So I ask what would happen if I were to blow something else, not classroom or my air into it, would it still be round. Danping says that all bubbles are round. I ask her why and again she says because the little bubbles in the bubble soap are round.

Now all this is interesting and I table pushing on it for the moment. I choose rather to ask the children to clarify their statements so that we can all be sure of them. Not to have the idea that the "placement" of the bubble film is at an equilibrium point between competing forces is a problem but one we will work on. Their idea that the bubbles already exist in the bubble solution is interesting and their idea that air can have shape is wrong. Neither of these ideas can't really be addressed by the directions we seem to be heading in our interactions with the bubbles. Neither effect what we are doing so there is no reason for me to want to work to confront them.

I ask if they all think that even when they can't see bubbles that there are still bubbles in the bubble soap. They all say yes and Danping adds that these are what we blow up when we make the bigger bubbles. Andy says that he thinks the air inside is going around because of the movement of the color bands. He and Emily start talking about this. Andy says that these bands form right from when you start to blow.

An'gele says that she knows why you can put your finger into the bubble. She says that it is because the wet air in the water hooks on to your fingers so that you are able to go through. This is quite right, the bubble needs to be able to "wet" a thing that it clings to otherwise it can't and will break. This is why two bubbles sometimes will and sometimes won't connect together to make the coin. We work on this a bit more and the concepts behind it come up again and again. We go into this further starting with the next class when I ask the children to use and make implements to make bubbles with. How this works and the shapes of the resultant bubbles is determined by how the bubble solution is able to wet the materials we are using for construction.

Now though Emily asks what would happen if you have one dry hand and you try to put that hand through the bubble. I tell the children that wet things can go through and dry things will break the bubble. We demonstrate this.

Then I say that I thought Danping's idea on why the coin was flat was a good one--I thought so although I wasn't sure. I send them back to their seats and I ask them to blow a bubble and look for and at the lines Emily talked about and then to make a column and see what happens to the lines. They all start talking about how the lines start moving faster and faster as I stretch it. Emily points out how when I touch the bubble all the lines speed up and start to move towards my finger "like a magnet." They do this until recess.

In this class, although we have continued to discuss bubble shape we've added in more sophisticated observations about size and color. The children have also started postulating scientific theories to explain what they are seeing. I want to make sure that they connect the things that they see to the things that they are able to do. I want their view of experimental design to include themselves as the lens former: I want them to see themselves as active in the process of making observations and formulation explanations about the science not start to fall into the fallacy that they aren't part of the process of seeing.

In the next class I decide that they should experiment with bubble size. To do this I give each child a lunchroom tray with a quarter inch of bubble solution on the bottom and a straw to blow the bubbles on the surface with. This allows the entire surface of the tray to form a bubble. The bubble can be very large because this surface is much larger than anything they can form with their hands. I also want them to use the straw because that distances them from the bubble. They are further away and therefore they can look at the bubble differently. Using a straw also makes the act of blowing more focal I think.

I want to slowly introduce tools. In the original task the only tools were the children's hands and the solution. In the process of coming to use tools as tools a person has to stop focusing their consciousness on the tool itself and place it on the outcome instead (Polanyi, 1966).

At the beginning of using a tool, the tool itself is at focus. By having the children just use their hands in the bubble solution at the start I wished to focus them on the properties of the bubble solution and their role in forming the bubbles. Now I can let them play with a new tool and let them develop new ways of seeing the bubble solution through this tool after, of course, they've explored the tool. The point of using tools is that they allow a person to see particular aspects of the things being worked on. This can be passive looking like through a lens of a microscope or it can be an active shaping like a saw and wood. Mostly we do want to think about what the tool shows us about the object (subject) but (at least in science) we should also be mindful that the tool is selective and we can look backwards from what we see in the object to the tool and say things about the qualities of the tool.

This is also true of teaching. In the introduction to this story I talk about the aspects of this class I have deleted in constructing this narrative. Many of these "things" such as turning out the lights to gain control of the class or thought processes I go through to decide who will talk when, are tools of teaching which enable our explorations of bubbles and design. They also shape what happens in the class--things could happen differently if the tools were used differently or if those tools weren't used and others were. These are my choices because I want the class to look a particular way.

As a class we had to learn to recognize these actions as tools, as symbolic of something else. The children had to learn the meaning of "lights-out" and to respond to that meaning rather than to the lights being off. They had to learn the conversational patterns of the class. These had to become background but in such a way that they could still delineate, articulate the things we should be paying attention to--my next instruction or a child's statement of an idea. We can look backward from the outcome and ask about the background patterns that enable the processes of the class, the designing of the class. That's not to say that I do that while I'm using those tools or that there aren't many and multiple levels of asking. For example, deciding who will talk when can get at particular thoughts about particular children in a context or can go further back and ask why I feel I need to be in control of conversation (to shape the science, to control behavior, to

hear different children). We can also ask how do these tools shape the science in a small sense--determine what we are doing--and in a large sense--determine the concept of science itself we are developing.

For the next three classes I continue to keep the exploration of bubbles "open"--exploring other, different variables in turn rather than closing in on one particular direction. We talk more about bubble color, discussing and experimenting with this to some depth. We spend time thinking about the conditions that make bubbles pop. We continued discussing the shapes of bubbles and intersecting bubble films. Finally I start to narrow our explorations down to this last by having the children write about this question of shape and try to construct particular shapes with the bubbles. The arguments to explain phenomenon become increasingly complex and concern the shapes formed by intersecting planes.

After November, I ended the first part of this unit in which the children made bubbles free-form. In the classes during December and January I gave the children three-dimensional geometric constructions that I had made out of straws and paper clips to dip in the bubble solution. I did this because I felt that at this point we should focus in on one aspect of the bubbles: their shape and the shapes made by the intersection of bubble films. The children used my geometric shapes for a week and then I set them the task of designing in their notebooks things that they would like to make for themselves out of the straws, predicting what they thought these constructions would look like after being dipped in the bubble solution, then attempting to make these things so that they could try them out. This turned out to be quite an interesting process to watch and participate in. It led to many discussions about the process of design as well as about the products themselves. As far as what the children discussed and thought about for the actual bubble shapes they were able to make, I think they explored what effect the shape of the external frame had on the resulting bubble film. There was a general feeling that the external shape controlled the shape of the bubble. This is true but not as simplistic as it initially sounds. The shape of a bubble depends upon if you are looking at a two-

dimensional or three-dimensional shape (if it is two-dimensional, the bubble film will follow the outline, if three-dimensional the bubble will be a complex result of intersecting two-dimensional films), a shape with no irregularities (irregularities will warp the two-dimensionality), a perfectly stationary shape. Discussions of the process of design centered on purpose--why design?--and the frustrations of translating designs, from paper or from your head, into reality. This is very much what Schon is talking about I think when he calls design a metaphorically shaped process of dialectics between person and materials.

In the next phase of this unit we focus much more on this process of design, both in what we are doing and in our discussions. The science we talk about follows from the things we are able to make much more than the things that we design follow from the science. This is not the usual way we are taught to think about the processes of science (i.e. Popper). The point is the designs (noun) and the process of design (verb) control the science and the class (teaching).

I return to my narrative about the class in February. The children have been working by now for two months with the straws, paper clips and bubble solution. The children have become deeply involved with the problems of design and many of our discussions start with this: what have the children been able to do? What were they trying to do and what were the problems? From this we moved to discussions of the science of bubble making but not in this first class. In this class we talked about problems of design and what children did about them.

Discussing problems of design

By now everybody in the class has been able to make at least one thing with straws and paper clips and most have tried it out in the bubble solution. I ask what kinds of things that they have made, I ask if they were able to make the things that they designed and whether or not they found that easy. Some respond yes and some no to the question about whether or not it was easy. I ask who found it hard and ask Teton to tell us why he found it hard. I call on Teton

particularly because his design was extremely interesting. He wished to make a dome with a series of arches made from the straws curved by utilizing the extendable elbows. He is the only child who was interested in the design phase in using this property of the straws. Others did use this property but not in a planned way. Rather they came to use the elbows during the alteration of their designs during construction.

This to me was what this whole thing was about, an interplay between design and material in which the properties of the material could be altered spontaneously because of the difficulties in achieving the design. Schon talks about the design his students were engaged in as an interplay between aesthetics, the intellect and emotive qualities of the individual with the qualities of the material available for construction.[13] Those students are engaged in the actions of design as they play with the materials. In my assignments, the children's initial design is in the absence of interaction with the materials. I feel that by doing this I have generated a problem for the children.[14] They are trying to make something in particular. When they go to the straws and paper clips and finally the soap solution they are trying to use those things to make their design. This can be very frustrating and usually involved either altering (or attempting to alter) the properties of the materials or of the design. In the end it could mean a compromise, radical alteration or, for some children, complete abandonment of one design for another or for just empirically playing with the materials to try to make something. There was also a lot of discussion going on between children, between the children who were able to turn their designs into real objects and those who were experiencing greater degrees of frustration. The reason that I did it this way was because I wanted the children to be thinking at the initial stages of design about what it was they were trying to make with the soap bubbles, not the straws so much. My idea in doing this was that I knew there would be big surprises in what they actually did make if their constructions were three dimensional.

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[13]Donald Schon (1990) The Theory of Inquiry: Dewey's Legacy to Education.

[14]Dewey's (1933) in *How We Think* suggests a concept of what drives inquiry. (The question is inquiry into what?)

The final step, trying out their constructions in the bubble solution, was always filled with discovery and surprise. They never got what they had anticipated except those children who made simple two-dimensional shapes. Now this could have gone three ways (I figured): children could have then altered their constructions to *try* to make something in particular with the bubble films, they could have just been interested in what they did make or they could have again worked empirically with their constructions and the bubble solution to try new things out. With the straws they mostly did the second thing. In the next part of this unit, where I give them wire to make their constructions (which is much more free-form and easily altered) virtually everyone that I could see did the third thing. I decided to go to wire because I found their use of the straws very limited and they were just difficult to work with. Wire lends itself to accidental forms and also to three dimensions much more easily.

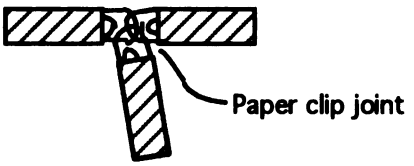
But back to Teton. I have asked him why he thought it was hard.

> Teton: Because I was trying to make something and and I got one in my head and I couldn't make it so I had to make another one but that one didn't work. Only two pieces worked.

I asked Thomas next. Thomas tried to make huge complicated things. Remember that Thomas competes in Lego design contests. He did a lot of making initial things and then altering them and building on additions. Again I ask him if he had a hard time.

> Thomas: Well sort of, I don't remember, well I think I had a hard time, I don't really know why.

I ask Andy. Andy: "Well first I was going to make something different but I found it too hard so I made this, it was hard too but I didn't give up." I ask him to show kids what he made and ask him if he drew it first or if he had just made it. Andy: "I made it." Teacher: "You made it first before you drew it?" I ask him what was hard about his first one and he says it was just hard to make. Cory says that his was hard to make because he "had to make two stuck together." He points out Suni's which has three stuck together. He is talking about the joints made by the paper clips.



Some of them wanted to make things with very complicated joints with many straws coming off of one point. I ask Cory why he found this so hard. Cory: "Because when I was looking at this, I didn't know how you put those paper clips together so I did it like this . . . "

I show the children some shapes that I have made and also Suni's and I return to what Cory said about the paper clip joints. I show them Thomas's construction in which he made a different kind of joint in which he bent the paper clips. I ask if anybody else bent the paper clips. Paula says that she did it at home and that she didn't know it would be alright to do at school. I also show people how Thomas and Teton had bent the straws at their elbows so they could get curves.

I return to asking different kids why they had a hard time making their constructions. I ask An'gele. She says: "Well some, that one thing was the hardest if I can find it, oh here, that was very hard because I was having problems. First I was trying to make the tetrahedron at the top, see? First I made the tetrahedron and then I put all these on and it turned out . . . I don't know how I did it, it was very hard." Teacher: "It was hard to get it to look like you wanted it to look is that what you are saying?" An'gele: "Actually at first I wasn't even trying to make that, at first I was trying to make a tetrahedron and then it came out and I said well that's neat and I kept it." Teacher: "So what you are saying is similar to what Teton was saying you couldn't make the thing that you drew so he ended up making something else?" An'gele: "Actually I was really trying to make a tetrahedron but I couldn't but it doesn't matter."

I summarize this discussion. I say that I have heard three things, that Teton said that it was hard to make the thing that he had drawn, Cory and Suni saying that it was hard to use the paper clips and materials, and An'gele saying "I was just trying to make a tetrahedron and it was hard to get it to be shaped like a tetrahedron and when I tried, it came out wrong but I liked the

shape that it was so I kept it." I restate this "So actually what happened was that you were able to make a shape that you liked better." She agrees.

Sakti shows us her's and says that she found it hard to have a joint with three paper clips and one with two. I ask if she is saying that it was hard to *make* it this way or to *know* that it needed to be made this way. She says that "it was hard to know that it would need three paper clips there."

The children have been talking about the struggles they found in trying to implement their designs. These struggles arise because of a lack of knowledge about the properties of the materials they were working with and an inability to articulate, to specify and describe, the exact qualities of the desired construction. In their talk, the children indicate various strategies for dealing with these difficulties--when they discover what the properties of the materials they are working with are, the design changes to accommodate this. The children could "discover" how to specify and enact the steps needed in construction because of their vision of the end product. Or (as most do) they change their vision of the end product. In each case there is an interplay between design and implementation--the two are inseparable. The final test of whether or not a construction's faults make it undesirable comes when the child tries to use it. The only child in the above discussion to actually try her design in the bubble solution was An'gele. Note she is the one to say: "Actually I was trying to make a tetrahedron but I couldn't but it doesn't matter." When she tried it out, the undesired thing that she had made was suddenly desirable.

I get back to those children who had made something without designing it first. I ask if this was easier or harder. Cory says that it was easier. Cory: "I didn't design mine because I had it in my head." I ask him how that is different from designing it on paper. Cory: "Um, because it's different because it's in your head and there's no paper in there and you just have to make it." I ask him if he did have an idea of what he wanted though first and he says yes but he was able to just make it. Then he drew it. Dan also says this so I ask again if they already had an idea in their head how this was different from designing it, other then just writing it down. Thomas says: "Oh I think I know, designing it means like building it but designing it really means that you have a

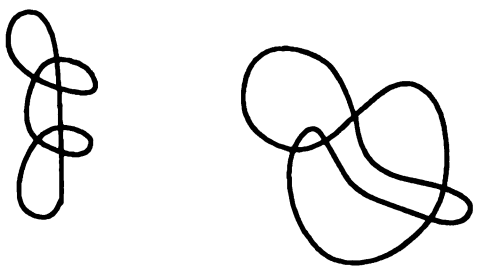
picture and it's easier to design it in your head because you can see what it might look like but if you try to draw it it might not look like it 'cause it's easier to design in your head because when you draw it's *real* hard. Tity says: "And you don't know what it's going to look like later." Suni says: "You can see it in your head and you can try to draw that as best as you can." Thomas: "But you might draw it wrong." Suni: "It takes time." I ask him if when it is in your head it is a design and he says yes because "when it is in your head you can think about it and remember it." Thomas agrees that a picture in your head is a design "but you have to have it in your head for all the time that you are making it."

In the next two classes we moved from talking about specific strategies the children developed for dealing with their design problems to talking philosophically about the meaning of the term. In each instance, the children can be heard to be weighing their designs and the problems they found in implementing them against the effects they achieved. The decision to keep something that has not come out as desired or to continue to work to achieve a pre-determined end is made by weighing the original "vision" against what is actually achieved. The final value is placed when the construction is *used*. When this happens, no matter what the qualities of the construction, something new is seen. The question is how much is this unexpected result valued by both the children and myself. This is what determines whether or not new science is discovered.

In the next class I give the children flexible wire and plastic aquarium tubing to create bubble constructions. This is, on the one hand, easier to work with, hence designs are easier to make, but the material also lends itself to greater degrees of unexpected results when dipped into the bubble solution. I invite through this material a heightened level of play between the potential to control and the realization of the unexpected. In this way I hope to stimulate both the process of design and experimentation and the discovery of new science.

February 25th

Today I introduce the wire and also thin, flexible, plastic tubes that they can use to make bubble constructions. I tell them I did this so that they would be able to make curvey things. I had made a couple shapes: a sort of pretzel out of pipe and a helix out of wire.



I suggest that they can use the wire and pipe or those and the straws too.

Tity asks how they are to know how long a wire they will need and I tell her that is part of designing it.

I ask them what they think the helix would look like when dipped in the bubble solution. Cory says he doesn't know, "Maybe there might be nothing." An'gele says: "I think it would look like all circles because that's mostly circles but that little wire that goes through, that might pop one of the bubbles you would have to get that wet first before you can make them." Thomas says that he thinks it will look like something that he can't describe but he thinks that "it will cover this and cover all these also and cover this end and it will be like this is all glass and this is holding all the glass up." Cory repeats "there might be nothing." I ask him why he says this but he says he doesn't know. Then he says that he sort of agrees with Thomas because there is something inside. Danping says that it will look like a "piece that goes around, I mean the inside part, it will go like this, it will kind of twist around." I try it. Many children start to call it a slide. Cory says it looks like "sort of glass inside of it." Suni says it looks like a glass of water.

I ask what they think the pretzel shape will look like and they all say a circle. I try it. It is a series of intersecting planes that curve. I say it reminds me of the silver dollar. I point out how the shapes are moveable because the construction isn't rigid. I do this and get the bubble planes to move in and out of each other and make different configurations. An'gele says that it reminds her of a fan. Andy says a flower. I say that this would be an okay description of a prediction when they are writing.

I ask them to go back to their seats and start designing what they would like to make with the materials that are now available to them. Then I ask them to make predictions about what the bubbles will look like before they try them out.

They spend the rest of the class doing this.

I have given the children new materials with new properties to work with now. These materials are both easier to use and harder to control. I invite the unexpected in our results. The children respond to this with a reduction in their struggles over trying to construct a particular design. Rather children now seem to spend much more time reworking their constructions as they try it out in the bubble solution. The acts of design, construction and empirical work with the construction are compressed.

The new constructions as I have said are much less controlled. When a child makes an apparently two-dimensional heart shape out of wire, it is rarely two-dimensional. It is always warped in multiple directions and asymmetric in outline. The wire itself once bent never becomes smooth and straight again--it retains little kinks and crenellations. All of these irregularities have repercussions when the constructions are used in the soap solution. The most obvious manifestation of this is in a change in the children's attempts to describe their creations in our subsequent talk. Rather then using geometric terms which assume a symmetry, the children in the next day's conversation resort to metaphor. This is fertile scientifically. Metaphor is a form of language use that is fundamentally comparative. It invites discussions of similarities and differences both descriptively and functionally. The new object--how does it *look* like a water

slide and how not? How does it *act* like a water slide and how not? This talk is embedded in the conversations in the rest of the unit and it is instrumental in the increased intensity of our talk about the science rather than the design facets of the unit.

Discussion of science increases.

February 27th

I ask if anyone has finished their design and tried it in the bubble solution. A couple have like Cory, Danping. I find Danping's creation (a helix like the one I made) and ask her what it looked like when she dipped it. She says it looked like a piece of glass. I ask what other people think it might look like. Timmy says a slide. Emily says a water slide. Cory says a bubble slide. Sueh-yen says a bubble can. I ask Danping to dip it in. When she does the children see a rainbow at the top of the helix.

Suni says that when he heard Danping say that it looked like a glass, he thought she meant that the bubble would be all over the shape (I think he means like Sueh-yen's "bubble can"). He says: "I think that is what it will turn out to be if you don't have this middle part. I think it will be like a big piece of glass if it doesn't have this thing in the middle." I ask him what he means and he says that it will just have a bubble around the outside not in the inside. I say that we should try that. (We do later.)

I pick up Emily's who has made a heart out of the wire and ask what the kids think that would look like with bubbles. Kwanhyo says that she thinks it will look like a "piece of heart." Thomas says: "It will look just like that (the heart) but with glass over it." I ask Emily to try it. When she does Thomas says that is what he meant. Cory says that there are rainbows inside of it. Many kids exclaim over this. The prominence of colors in all of these constructions with the wire is because of the irregularities in the constructions that the children make. It is really hard to bend these wires that they are using without introducing kinks and curvature changes which are not regular. Also planar constructions like this heart are not planar but are usually warped in

irregular ways. These two things 'cause the bubble surfaces to be bent in a number of different directions. This is not an effect that we were able to get with the straws and paper clips. Anyway when the bubble films are bent in these ways the children see through the films easier and the films are under anisotropic tensions so that the light is refracting differently and the children are better able to see the effects of this. Cory and then others start naming the colors that they see. Then Cory notices that the rainbow disappears and "once the rainbow is gone the bubble pops." The bubble gets thinner and the colors are dependent on thickness and disappear as the bubble gets thinner and thinner.

Then I pick up Thomas's construction which is out of the pipe material rather than the wire. He has made a series of curves which he has put together into a sort of dome not unlike the design that Teton was trying to make out of the straws. His construction though is huge, bigger than the plastic basins that we have the bubble solution in. He has also been doing the kind of adding on to his construction that I noted in the part of this about the straws. Thomas says that he doesn't know if it will work because maybe it is too big to fit. I ask him if this is what he had originally designed and he says yes. Now this is not what he had originally drawn but as he altered his construction while he was making it he also went to his drawing and altered that. He was very careful to do this with each step of his changes. I think this is interesting because often the children didn't build what they had designed but usually they waited until they had completed a structure that they liked before they re-drew their design. After Thomas tells me that he made what he designed I ask if other people were able to make exactly what they had designed. Some say yes and some say no. I ask Teton and he says not really. He says that he drew his picture and continued to think about it as he worked. Again note how the acts of design are a dialectic between construction and realization, materials and their properties, vision of the final product and results.

I ask if people can predict what they think Thomas's construction will look like with bubbles. This marks the beginning to the children's talk in which increased and fertile use of metaphor can be seen. Cory says "nothing or lots of circles and a rainbow inside." Alyosha says

"like a circle on the bottom and whatever those are (Thomas suggests circles) and from those on the both sides, they go all the way up there." Cory: "It would look like a butterfly." Shumshad: "It already looks like a rainbow." Dan: "Like a wood basket where you put wood." Thomas: "Nothing I don't think it will fit in." Then he tries it and gets a lot of it in. It makes a very complex set of intersecting curves. Kwanhyo: "It looks like a glass basket, the top of it." Cory: "Whenever he moves it, rainbows come, but it only works for the sides." Teacher: "Do you have to move it to get the rainbows?" Thomas says no, Cory says yes. An'gele asks if he could dip in the other part that he missed before and I ask what difference she thinks that would make. She says that she thinks it would look like a rainbow. "And maybe it would go up and down and also across." I try it by dipping in one side and then the other. I ask if it did what she thought it would and she says sort of. Cory asks me to do it again because he says that he saw the bubbles shifting inside the construction. "There was a crystal ball right here and then at the back of the wall, it was weird." Tity says that it looked like a sunset "because these (the curved tubes) look like a half of the sun." Suni says that he saw the back wall and crystal ball also and that he thought they looked like "a sun and the sun's baby."

Next they continue on designing, building and testing their constructions.

Much of the children's description of these new constructions makes use of metaphor. The increased complexity of the new design has stimulated metaphor use--the shapes aren't given to easy description. Working on the science means developing language, agreeing on meanings: developing a community in the discourse community sense. At the start the use of metaphor enables difference/similarity comparisons which is fertile scientifically--it invites conversations about what a child does mean, exactly. Also the use of metaphor has implied explanation embedded within it, these words are not purely descriptive. I think this is because the metaphors are functional words as well as descriptive. The words the children use--saws, rainbows, baskets, glass, slides--imply something about the way the object looks and also how the object is made and how it can function. Again this echoes Schon's ideas about the use of metaphor in

engineering and urban design.[15] This is where and how they become fertile ground for scientific discussion.

In the next class the children continue to talk about their strategies for the construction of their designs. Note they are actively reworking their constructions as they try them out in the bubble solution. Their use of metaphor goes from being descriptive to becoming generative scientifically--I have a role in this though. I think because there is an increased discussion of the science, rather than of the acts of design (which was primarily individualistic), there is a coming together of ideas and people working together on one phenomenon. There would suddenly seem to be a community talking together about shared questions, profiting from differences and similarities.

Discussion of science and the role of metaphor.

March 3rd

We start class looking at some of the constructions the children have made. I ask if people found it easy to make the shape that they designed and I get a lot of no's. Cory says that he had trouble because his was too big. Andy says his was hard because he didn't really know what to make. Then he says he made something and then drew it. I ask if some people found that they tried the thing that they had made and then altered it when they tried it in the bubble solution. Tity says that she made a heart and then when she tried it it didn't work so she changed it so it looked like a wing. She says that Shumshad told her to make it smaller but she didn't want to. She says that she thought it didn't work because it was too big. I pull out a very large construction and ask if the kids think it is too big to make a bubble. Some say yes and some say no. Suni says it looks like a helmet. Paula says it looks like a basket. This is An'gele's. She

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[15]Schon, D.A. (1984) Generative metaphor: A perspective on problem-setting in social policy.

originally made a chain of hearts but after trying them in the bubble solution she changed the design so that the hearts were nested inside each other. It also has a handle. I ask her what she was thinking about when she made it. She says that she couldn't make it come out like Tity's and it's not finished yet. Suni says that he tried to make something similar. He thinks it will look like a glass over it.

I ask them what they mean when they say it's going to look like glass. Suni says "like a bubble that's kind of like shiny and you can see through it and the bubbles shine just like glass." I dip it in and ask Suni if that is what he had predicted it to look like and he says yeah. I point out part of the bubble at the top where the wire is all crinkly and the bubble shows a lot of curvature changes. Kids say they see a rainbow.

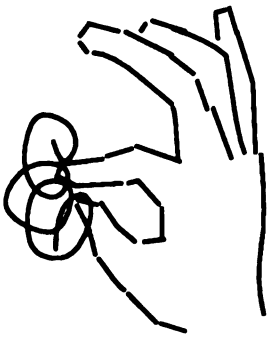
In the second half of this discussion, the children start to have inspired ideas about the science. Please note how this is tied up with the use of metaphor and experimentation. The science is dependent both on how observations are described and how they can be acted on. This is at the core of Schon's ideas of metaphor as generative in design problems. The metaphors embedded in design capture aspects of the problem the design is constructed to address. In implementing the design other aspects of the metaphor and of the problem become highlighted. This is generative.

We look at another construction that no one claims. It is a spiral with no central axis.

Suni says that he thinks it won't work as it is made, you have to somehow close off the ends. Emily says that she thinks it will make another water slide. Thomas says that he thinks it will look like "well this is just a prediction but I think it will be covered here and it will be like a cone but this won't be filled because it's not connected but this would sort of be like a can I think." I

ask if that is what Suni meant when he said it should be connected. Sueh-yen thinks it will look like the helix. I ask if at the top where whoever made it had put a sort of circle but not quite closed it off there would be a bubble. Some say yes and some say no. Sakti says yes because it's a loop. I ask if she thinks the loops in the spiral will make a bubble. She says that she doesn't think so, it will make a bubble at the top but not further down. I try it as it is. Nothing happens and I ask why. Thomas says because air is getting into it. I ask what he means by that. Thomas: "I think bubbles trap the air inside but if there is a hole in the bubble it will just pop. Like if you, if there's a little hole, it blows up like a light bulb, if you make a little hole in a light bulb it will blow up, on or off." This is a very interesting metaphor to examine in this context. The science that we have been working on all these months is coming together here as are the children on this one question and set of ideas. For the next few paragraphs of this discussion there is apparent a coalescence of children thinking and working together--a community.

I squeeze the rings together:



and dip it in. Suni says he knew this would work. I ask if they think that the pieces of wire have to actually touch each other to get a bubble. They all yell yes at me and Suni says that is what he was trying to say before. I try just getting them real close without touching and try it. It doesn't work. I ask why doesn't it work. Thomas says because too much air is getting in "like a light bulb." Alyosha says that is the same thing with balloons. "If there is a hole in a balloon all the air will come out." I remind Suni what he had said about the spiral making a tube and ask why he thinks that didn't happen. Suni: "See if you connect both of these then it will make a tube." He

wants me to make circles at either end. He does this and Cory points out that it is littler. We try this and it makes bubbles on the two ends but not in the middle. Suni: "I think I know the reason, 'cause see this is smaller and these are different sizes than these two, they have to be in the same order." Shumshad wants to make a loop in the middle and he tries it and gets bubbles in the loops. I point out that there are still no bubbles between loops.

Suni wants me to try a piece of the original wire which forms a slinky sort of shape. I get one. He thinks it is important that the loops are all the same size. The kids think that would work. Thomas says it won't work because "there's no support, it can go up but it can not go sideways. If it went sideways it would be hard for it. It's not too easy to go sideways, I don't know why but I don't think it will work." I ask Suni what he thinks of what Thomas said and he says he disagrees, he still thinks there will be bubbles along the side. He then says that he isn't sure if the bubbles will be from the inside (like the helix) or on the outside. Shumshad says that he thinks they can't come from the inside, it won't work from the middle unless I squeeze it. Danping says: "It will turn out nothing because it doesn't have a thing in the middle so I don't think . . . the bubble will just follow the inside part. So it has nothing to follow."

I try it and nothing happens. Thomas and Suni say that there wasn't enough things to hold it and there has to be another part. I ask about Shumshad's suggestion. Danping says she thinks it will work because then it will have a circle. I try it and it does work. Cory says to let it go (he thinks the bubbles will extend?). I do and the bubbles break. Cory says that he thinks he knows why it won't make a bubble without the inner axis. "Because maybe the water is slipping out and it has nothing to hold it in." Cory suggests connecting the wire loops with another wire. An'gele says it didn't make a bubble because just like everyone keeps calling the helix bubble a slide, "maybe the bubble keeps sliding down into the water and if you blink your eyes you can't see it."

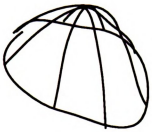
There is some talk about their strategies for the construction of their designs. They still remark on the frustrations of trying to realize an ideal design but much more they are actively

reworking their constructions as they try them out in the bubble solution. The children seem much more ready to abandon initial ideas about their construction as they find new and interesting things in what they have made. As the children talk about their designs now they are actually talking about the results they obtained when they tried them in the bubble solution and they talk in metaphors. Their use of metaphor goes from being descriptive to becoming scientifically generative. This is enabled by me in a manner analogous to the way I described searching for a theme during the first conversation the class had about bubbles: I am listening for commonalities in the things the children say but now not just commonalities within the class but also things that resonate with my stores of scientific knowledge. If I hear a number of children saying things that are fertile scientifically, I work to make the science come out. I do this through questions rather than explanations: I pose questions. I want the children to continue to offer their own ideas and explanations and share them with each other. I think because there is an increased discussion of the science, there is a coming together of ideas and people working together on one phenomenon: the core of a community in an idealistic senses: people talking together about shared questions, profiting from differences and similarities.

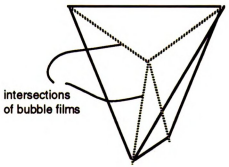
In the next class there is even more explanatory scientific theory making by the children. Note their theories about how bubbles work are intimately tied with statements about the design of the experiment. There is an implicit recognition of interrelationship of the design (which they have made) and resulting bubbles. The things that they have seen and are trying to describe and explain they know that they have made--the result must be explained by a combination of attribution to their own actions and the qualities of the bubble solution itself. There is an implicit appreciation of the interdependence of the phenomenon and themselves as active shapers of the results. The results are dependent upon what *they* do. Again note the evidence of a community with the children working on the same idea and talking in a manner about their construction and ideas that has been developed and validated through the organic process of the community itself.

March 5th

We look at Andy's creation. Children say it looks like a hat.



I dip it in and say that in one place the bubbles seem to go straight across but in other places the bubbles come together like in the tetrahedron.



I ask why in one place do they do that but not in other places. Thomas says that it's because there is a triangle. I ask him what difference that makes and then if he is seeing a triangle in the wire (because I didn't see that). He says yes and shows me where and I ask if he means a part that is curvey and he says yes but that doesn't matter. Suni says that the wires are like a triangle and it's because the wires come together into three that the tetrahedron effect is achieved. Abeni says that she thinks the straight part of the bubbles are because there the wires are straight but in the other part the wires come together. Suni says that if the wires went differently and made a different shape so would the bubbles. Shumshad has noticed something and poses a question

about it. He asks why in one place do the bubbles curve up. Suni says because there is "no gravity over here, I think there's . . . it doesn't feel a lot of gravity that holds it down so they just try to stick up and stick together so they make a kind of a hole." Cory says that they stick up because of the wire and that's the way Andy made it and he tells us to look very closely and we will see that the wires aren't really straight, they're curved. He points out that we need to look from different angles. It can look straight from one angle and curved from another. Then he says that "maybe the bubbles have to hook on to something so they have to go to there (creating the curve)."

I break one of the bubble films by mistake and ask if anyone noticed what happened when I did that. Cory says that the intersections between the bubbles which defined the shape we were talking about moved. We do some more of this, popping different ones. At first we get a triangle and then as we progressively pop bubbles we get the circle. Shumshad says that when he pops it, it causes the intersection between bubble films to move down. We do it again. Shumshad says that the triangle bubbles hold the bubble creation up and when they break it goes down. Suni says that he thinks it wouldn't do that if the wire shape was a square. He seems to be saying that the shape created by the intersection is created by the wires being too close together and with a square the wires would be further apart. Cory says that he thinks popping one effects the others because "if you look very close, I think the bubbles go over the wiring, they hook onto the wiring."

Suni suggests that if there were a wire across the bottom of them it would hold the circle even with the other bubbles. Then the bubble would be able to "hook on." Shumshad suggests that we pop the bubbles from the bottom first rather then from the top like we had been doing. This changes the whole thing. The intersection moves up, different bubbles get differentially bigger and in the end we have windows in the upper spaces between the wires. Shumshad says that he thought when he did this that by popping one of the bottom films he would have popped them all. He says he thought this because the film he chose to pop was touching all of the others.

An'gele says that she knows why one part pops before another part. She says that one part "has better gravity and plus this part was sort of harder to make and this part is bendy and it's harder for the bubble to go bendy then straight." Alyosha says that the bubble intersection is in the position it is because the bubbles hold it up and the air is pushing it up. Suni thinks that something funny happens, a funny shape is formed when just one bubble is popped.

We start again making and testing the wire creations.

In this class the geometric and metaphorical descriptions of the bubble construction is closely tied with the children's explanatory scientific theory making. Their theories about how bubbles work (that there is a play between gravity and the frame of the structure which determines the placement of bubble intersections, that the existence of the bubble films themselves are dependent upon the ability of the bubble solution to "hook" on to the wires). Explanation of phenomena is intimately tied with statements about the design of the experiment. The children as they work on these ideas are talking together--there is an increasing sense of ideas shared and growing because they are being shared. Again I feel that this is a manifestation of the community developed around a purpose and shared activity in the class.

In the next, our final class about bubbles, we re-focus on why there are colors, in rainbows, holograms, bubbles--the science of diffraction and light--the principles in each context are the same. The class moves from a consideration of bubbles to thinking about the applicability of their ideas to other phenomena. Being able to do this is because a design has both a background and a foreground. The apparent and obvious part of the design is the foreground. That is composed of the things we have been doing: working with bubbles, talking about that phenomenon. We can move though from this design to another by recomposing the foreground from other parts of the background, by rearranging the components of the foreground to accommodate those. In the class and the teaching the progress of this follows the same pattern of our other explorations and conversations: we move between observation, metaphor, explanation, doing things, use of tools and of the community. These and their interrelationships compose the

pattern, the design, of the teaching as well as of the community of the class itself. Community, because it reflects the pattern and design can be dynamic, its focus can shift and move.

The last class: A consideration of background as well as foreground.
What this can mean in science.

March 26th

This is the last class we are going to have about bubbles. Kathy and I have planned a field trip to the local children's science museum for our next class. At the museum, there is a special exhibit about holograms and lasers. I wish the children especially to work with this exhibit and draw some connections to our work with bubbles. For this reason we spend quite a lot of time talking about what holograms look like and discussing examples of holograms the children have seen (i.e. Princess Leia in *Star Wars*, on credit cards). We examine examples on my credit cards.

I ask what they see when they look at the holograms on the cards. Abeni says that it is shiny and has rainbow colors. Tity says that it's silvery all over. Sueh-yen saw that it reflected light. He also saw that the bird changed shape as he moved it and the background reflected his face. I ask the kids who hadn't seen *Star Wars* if they now had an idea what a hologram was. Shumshad says that it looks real and it moves. Emily says that it's *not* real though.

I ask where they thought the different colors came from. The children say the light. I say that the light isn't different colors is it? Dan says that yes the lights are different colors. He points to different lights in the room which are different levels of white. Emily says that the light sort of reflects itself to make colors. Thomas says that we could do an experiment with a prism, the light may not be different colors but the prism can show us. I ask him if he is saying that the white light can be many colors and he says that it can be the colors of the sun. I ask what are the colors of the sun and he starts to list: blue, purple, ... Other children start to disagree. Others agree and continue to list the colors of the spectrum. I ask Thomas if he is talking about a rainbow and

he says yes. He says that the white light can make the rainbow light and with a prism you might be able to see it.

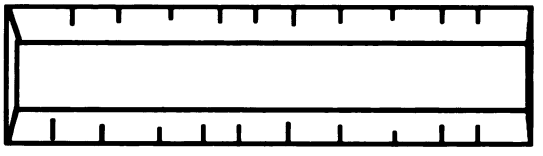
I ask what other people think--how did the hologram get the colors in it. Paula says that the colors in the rainbow come from white light. Then she says that on the hologram the colors come from the light reflecting on the silver pattern. Emily says that there is "an invisible rainbow and it can go through our school roof and it can go through anything and when it touches that, that silvery piece it would shine 'cause you know how a rainbow is like this and a sun is right up here and it moves around in a circle, it could reflect 'cause if they were on opposite sides it could just go like that and it would still go down." I ask if the invisible rainbow comes from the sun or if it is always in the sky and we can see it 'cause the light goes through. "It's in the sky 'cause the light goes through." Danping disagrees with Emily. "I don't think there's such a thing as an invisible rainbow. I think on the credit card there's sort of like a plastic piece that's cut out like an eagle and they put some kinds of things on it and then when the light shines on it it just comes out like a rainbow." I say but the light is white. She responds: "I know but when the light shines on the plastic I think they put something on the plastic to make it shine, so it makes it shine like a rainbow." I ask her if she is saying it's something in the plastic and she says yes.

Shumshad agrees with Danping "a little bit." He says if they cut out a piece that's silver and put some kind of "medicine or something that's kind of shiny and then they put a plastic piece on the card and then if you move it, it will go.

Suni gets back to the colors of the sun. He says he disagrees with Thomas, there isn't any blue on the sun. "They have a different name and they're not colors like blue but my Dad . . . well actually I really forgot those names." Thomas says that "the colors came through my window and I saw blue." Suni repeats that it might look like blue but that's not what it's called, "it's not really blue." Thomas asks "well what color is it?" Suni says that when his Dad showed him this that he thought it was blue too but it has a strange name. I ask him if he is thinking of indigo. He says yes. He says that there were "some other colors in the blue parts too." He says that "all the colors mixed make the sunlight, make white light." I ask how the colors get out of the white light. He

says that they separate but he doesn't know how they do that. Then he says that the sunlight isn't really white light but is yellow.

Cory says he agrees with Suni and reminds us of what we did last year with the rulers.[16] How he looked up through the rulers and saw rainbows around everything. I let them try out the rulers.



Clear plastic ruler

I ask what they saw. Alyosha says that he saw a blue line under the thing that he was looking at. Danping says that now she disagrees with her idea from before "now I know how they make the rainbow, I think on the plastic they just fold a little bit so if they fold over here and over here then these two will be different colors, if they didn't fold any this whole piece of the bird would be a different color." I ask if she is saying that the rainbow is made because of the way the plastic in the ruler is formed.

Sakti says that she saw different colors when she looked at the light. Meiying did also. Kwanhyo says that she saw a rainbow all across the room. Thomas says that he was disappointed because he didn't see as many colors as he usually does. He only saw red and blue. I say that they aren't very good prisms.

Suni says that he has just figured something out. "If you put light through glass you can see the colors because glass makes the color of the light separate into other colors that are mixed to make that color, that's what I think glass does." I ask him why the glass in the window doesn't do that. He says that there isn't too much sun out and I say that it doesn't even when there is a lot

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[16]In last year's science class I had given them small clear plastic rulers to use to measure plants. These rulers have beveled edges so that if held up to the light and looked through objects appear to be surrounded by an aureole of the spectrum. Cory is remembering this.

of sun out. He says that it works on his window at home. Danping says that it needs to have corners. Abeni says that she thinks the thickness of the glass or plastic has something to do with it. I point out that the rulers aren't very fat. She says that different parts are fatter or thinner. Emily says that you see the colors only when you look through the places where the thickness changes. Tity says that you can see colors by looking through the edges too.

Cory saw a prism at his Grandmother's and she told him that if you don't keep it in the light the rainbows might go away. He says that she said this because once she kept one out of the light too long and then when she did put it in the light there were no rainbows. You have to keep them in the light to get rainbows. I ask him about the rulers and he says he doesn't know. I ask him why we don't see rainbows all the time and he says he doesn't know.

Sueh-yen says that the rulers and the prism have three sides and he thinks this is important to make rainbows. Shumshad thinks that the reason he couldn't see a lot of colors with the rulers is because of the little lines that measure. Emily says that if she crosses her eyes everything is outlined blue or sometimes yellow. This also makes it hard to see. Alyosha tell us about a rainbow he saw in Yugoslavia that happened after a rainstorm. He thinks that it is light shining through the water from the rain that makes the rainbow.

I ask why we can see colors in the bubbles. Emily says that the light reflects in it. I make a bubble for them to look at. The children start exclaiming and calling out the colors. Others say that they can't see the colors. I ask why there are colors and Abeni says it's because like the hologram, the light is shining on it and that makes them or it might be electricity. I ask if the colors are the same everywhere or different in different places. The children say different. I ask if they are moving and children say yes. I ask if in some places the stripes of colors are spread apart and in some places close together. Children just stare at this one.

Then they start working with their constructions again.

Conclusion.

In our final class about bubbles, we focus upon one particular aspect, a fundamental aspect, of the science that we have been studying: color. We extend our ideas about color, formed through our interaction with the bubbles as well as from other places, to new phenomenon. Being able to do this reflects the complexity of the initial explorations: they didn't address simplistic and confined questions but rather larger, more fundamental ones. These explorations (I use this word because it contains both what we did--the substance--and how we did it) addressed particular observations and questions in the foreground but always contained the potential to address new things. We can move from one exploration and set of questions to another by recomposing the foreground--what we are explicitly examining--to contain the elements of the background--those parts of the science which were not focal until called upon.

A design, in teaching, in classroom interactions, in science, is composed of a background and a foreground. Our perception of the design is both through a cognitive differentiation of the two but also because of an interplay between the two. They are mutually dependent upon each other to construct our perception of the whole. We can understand and interpret the pattern because the background sets off the foreground. It is the interplay of background with foreground that gives the foreground meaning. How we construct the foreground is really a question of why we construct the foreground. The construction of a pattern or a design reflects the things we wish to do--our needs and purposes. The pattern and design also reflect who we are, what we know right now. It contains the potential to be a tool as we construct our future selves. As we try to realize the future we can act to reconstruct the pattern by recomposing the foreground/background relationships. Our implicit awareness of the background has to become explicit for this to happen. We explicitly perceive the foreground but circumstances which cause us to question the pattern can make us aware of the background. This defines the role of the teacher.

In this unit, the children explore qualities of bubbles. They construct a pattern in the science and in the things they are doing. Because I can perceive the pattern, recognize the science that is useful and important embedded in the things the children say, I can design the teaching, the things that we do together, and also how we talk about those things. I want to do this in such a way that we maintain the potential for reconstructing the pattern. In the background of the pattern is the more fundamental scientific questions and the potential for knowledge of which I must remain aware.

This pattern constructed through the design of the teaching which contains both the science, the way we are doing the science, the children's interactions, defines the community in our classroom. It contains all the elements of idealized definitions of community: people working together around a shared purpose, people developing a shared language and methods of acting in service of this purpose. This community is also vital: it can grow, change, shift focus and direction. This is a manifestation of the interplay or potential for interplay between foreground and background that I am trying to maintain. We return to the idea of patterns and of communities in the following chapters. I wish to develop and challenge the definitions and uses that I have tried to illustrate here.

CHAPTER 3

PATTERNS AND UNDERSTANDING

The last chapter was about design, design in teaching and design in doing science. It was about how the acts of design precede science or teaching and act as lenses or as molding agents on what can happen next. But design is also interactive--it occurs as a dialectic process between person, objects and purposes. It occurs while the science and the teaching are going on. A design is recognizable within a context, it is formed out of that context. The act of design--designing--can't be de-contextualized. The trick though is that designs, the noun, give the appearance that they can exist separate from context, can be abstracted. Designs are metaphors for what can be done with them. They are then generalizations, simplifications, they only capture some aspects of the context from which they are derived. They are recognizable as entities because they are abstracted, partitioned. In many instances this is the cumulative effect of patterning. We recognize a design because of the repetitive quality of the patterns it contains. The repetition of a design, though, also creates a pattern.

Repetitions and relationships create a pattern. The choices behind repetitions and relationships define the act of design. In this chapter I will describe another unit of science teaching, this time about patterns themselves, first examining patterns in the abstract and then applying patterns to an exploration of music and sound. This is, at least in initial approach, an inversion of the unit I described in the last chapter. In the last chapter we started by examining design and thought about how the teaching and science came from it. In this unit we start with observations and recognize patterns and then explore the design--the reasons behind the

observations we are able to make. A pattern is made up of repetitions and relationships in the science and also in the class--the things we do in class, both scientific experimenting and in just ways of talking, repeat. This, in turn, reflects relationships between people and science and also constructs relationships. This defines a classroom community, a culture though that changes as the dynamics of the relationships alter.

The community that develops in this classroom is not static, instead it changes and evolves as the topic of conversation and the ways of talking change. The medium for the construction of the community is the science that we are doing (Hawkins 1974a). At different times this science is being looked at and thought about in very different ways. For example, we start our examination of music through an observation-based study of sound producing devices. We proceed to an experimentally-based exploration. Finally we intellectually examine what music is and then think critically about this. Each of the modes of acting, thinking and communicating with each other develops as an interplay between people; people wanting to communicate their own ideas and also hear and understand each other's. This is the essence of a community--people interacting with each other for a purpose, out of a need (Sartre, 1963; Schwab, 1976). The purpose evolves because it develops as people interact, therefore the ways of interacting evolve also.

This chapter is about this process in science and the children's involvement with the science, not as much in teaching[17]. The next chapter (Knowing--Chapter 4) is about teaching.

An outline of the unit on music and patterns.

This unit on patterns and sounds and music had three stages which are separate and also interconnected and interdependent. The first stage, in the fall, was about patterns and seeing--

[17]The teaching in this chapter occurs in the same first-second grade combination as the last chapter. For a complete description of the school and class as well as a list of the children's countries of origin and pseudonyms please refer to Appendix I and II.

seeing patterns and developing language to talk about those patterns. It was at a more fundamental level about discussing what the word pattern means--what is and isn't a pattern and why. The second stage began again in the spring when I started the unit on sound and music. This stage was about exploring how sound is made. It's about patterns because in order to do this the children looked and listened for patterns in the things that we were using to make sound. It was also about patterns because in order to do this in a way that illuminates the qualities and genesis of sounds, the children had to interact with the xylophones and rubber bands that we were using in a systematic manner which was a pattern in itself. The third stage was a return to the first stage in a way, although the vehicle was different. In the fourth stage we explored the definitions of the word pattern in music and more broadly.

What this synopsis doesn't capture is that in all of these stages what was focal for me and what I was trying to make apparent in the children's discussions/arguments was that a pattern is a man-made construct that captures some aspects of a phenomenon and leaves out others. Seeing, hearing, acting in patterns involves choices--conscious or unconscious that can be articulated and talked about either before a choice is made or afterwards when it becomes apparent that everyone hasn't made the same choices. This is why talking about patterns is also talking about perspectives--having a perspective, taking a perspective. It is these differences in perspective that drives the development of a community--the children share their ideas about sound and music, both learning from each other and developing the ability to articulate their own ideas.

Back to talking about the stages though.

In the fall the children made patterns using pattern blocks and then talked about those patterns, developing descriptive language which ranged from simple stuff like, "it's a red hexagon," to metaphor and statements involving mathematical progressions and relationships. I chose to have this beginning abstract and "man-made," artificial, designed. Then we went on to look at pictures of things made by people, like buildings and bricks, and "natural things." I put "natural things" in quotes because these are pictures--they are framed and chosen. To see

patterns in these things is a reductive process--seeing some things in a foreground and putting other things into a background. It is selective just as choosing how to shoot the picture is selective. In looking at these patterns which are both made and not made by whoever is seeing them there is a new element (as compared to the patterns constructed by the children from pattern blocks): These patterns don't have limits, they extend beyond what we can see. Even when they do have edges and borders in the pictures, it is usually obvious that these borders are arbitrary and chosen--the pattern could extend on. These patterns can be simple repetitions or progressions but all are created by relationships, relationships between the elements of the design. The idea was to help the children articulate both the content--the "thing" repeated in a descriptive manner (I mean not to name it) and the way it was repeated--the relationships.

In the spring when we started with music and sound, my idea was to use the children's ability to perceive patterns and talk about them in an applied way that enabled and suggested scientific explanations and explorations. So we started with an exploration of a xylophone. I simultaneously asked the children what patterns they could see in the instrument and hear when the instrument was sounded and invited the children to do things to try to relate observed patterns to other observed patterns. Then we did this again with rubber bands. The children, with my help, quickly began to relate the things that they were able to observe and postulate these relationships as explanations for the phenomena. Because they were also acting on these relationships--testing them--and doing this in public we together developed systematic ways of going about this. The children suggested that certain patterns of observations were related and then they tested those relationships out publicly. Through this process of public demonstration, communication and discussion of results, these explorations got more and more systematic. In doing this the relationships that the children were working on became further reduced--separate variables were located and tested. In some senses the relationships the children held between each other also became reduced--for the purposes of communicating their experiment the children had to act and talk systematically and unambiguously. The children listening had to

suspend their own ideas and think within those of another (connected thinking not critical thinking although in the end there is always an interplay of these).

These variables and the relationships between these variables became the focus because of how the children were interacting with the musical instruments. The children were now talking about how sound made vibrations and these vibrations were characterized by amplitude and different periodicities and these in turn were effected by thickness, tightness, length of the materials which make up strings and bars of xylophones. They were also talking about how what they did when playing the instruments effected these variables. This is done by acting systematically on the instruments themselves so that variables can be isolated and studied alone. It also gives you the illusion that you can pretend, you, the experimenter, aren't part of the system, especially if you can conveniently forget that you made up the variables--extracted them from the continuum--to begin with.

This is, however, one of the reasons I chose to embed this exploration of the power of patterns in a study of music and sound (rather than just sound, say). Most people would not have a problem that the aesthetic choices, criteria, made in creating, listening to, judging a piece of music don't represent a fundamental. My point is that these same choices have parallels in the criteria, the variables, used in the study of sound. These are just as arbitrary and should therefore be subject to debate and justification. And this justification can be rational or irrational; it can be on a basis of usefulness or on a basis of aesthetics. Or some combination but it ought to be articulatable even though when we do make these choices they most often haven't been articulated by us. We are just acting on reflex (Heidegger, 1967).

Well anyway, because this is why we are looking at music and sound, not just sound, my next move was to return us to talking about music so that I could work with the children to articulate the foundations under which the choices they were making to specify variables could be examined. I asked the children what was the difference between sound and music and also effectively what criterion they would suggest for judging a sound as music. The children all seemed to agree that judging something as music was an interplay of context and the presence of

certain components. These components were pattern, beat and rhythm. In exploring what the children meant by these words in the context of "music" that they created to demonstrate their ideas, we found that these words were, in themselves, intertwined and interdependent--that their meanings overlap and slide into one another. That to differentiate between them was arbitrary, a choice of the user based upon what they were thinking and trying to do. This became a conversation about design--that patterns and music are designs. Both are also arbitrary, made, reflect choices, although it is unclear when the choices have to be made in order to call a design a design. This takes us back to music is music because of context. We talked about bird song--was that music? The children argued that maybe it was, if they applied their criteria of pattern, rhythm and beat but maybe not if they applied their criteria of context, purpose and design. What is the purpose of the bird singing--is it music or communication. Again perspective--they as listeners might call it music but the bird who makes it might not.

Beginning our explorations of patterns: What is a pattern, how is it constructed, how is it used?

For the first six weeks of this school year I taught a unit on seeing and using patterns in science. Many people, in writing about science and about doing scientific research, write about patterns and the role that patterns play.[18] Patterns are constructs which arise through descriptions. They are characterized by variables, constants and operations. They make connections, see similarities, describe relationships, create regularities. They are made: created, imposed, manipulated, by people through selective vision. Seeing patterns is a simplification; it dichotomizes reality into the regular and the irregular, the explained and the unexplained. Using patterns involves an interplay between the reg and irregular. Explaining phenomena is often

[18]For more information on the explanatory and comparative powers of patterns in science the books *Patterns in Nature*, Stevens (1974) and *On Growth and Form*, Thompson (1961) are particularly helpful.

through correlating patterns in which case this interplay is especially important. It becomes a test of the patterns: every use (application) of a pattern is a test of the validity of its simplifications.

Patterns order observations and can be used to explain those observations. The function of correlating multiple patterns is to explain. Because they contain variables, patterns can be applied to other observations in the hope of ordering or explaining them. To write about the role of pattern in science, though, presupposes a role for irregularity. Patterns, both seeing and making them, are compelling in science because they cause one to see the totality of a phenomenon in new ways. The parts of the phenomenon that don't fit the pattern become both invisible and are thrown into sharp relief. I think pattern is compelling because the act of bringing order to disorder is infused with romantic mystery and with power. But the parts that are left in disorder are even more mysterious and maintain the phenomenon's own power! The phenomenon asserts its own reality through its irregularities: the components that exist and which we can't explain. We assert *our* reality through the imposition of patterns, the recognition of regularities, the creation of explanations. The dialectic between the person and the phenomenon, the pattern and the irregularities, the explained and the unexplained drives the scientist. The imposition of theories--generalizations, patterns--enables seeing the phenomenon in new ways because of the abstracting qualities of the process and the fact that it is situated in the flow, the activity of applying the patterns. When the qualities of the phenomenon that don't fit the pattern become important, the assessment of the phenomenon or the pattern itself should be revised.

It's because pattern exists as an overlay on the surface of the real phenomenon that irregularity and regularity coexist. There is more to the phenomenon than can be described by the pattern. Recognition of that causes a scientist to apply existing patterns to new phenomena and to discover new patterns. The scientist is the creative agent in the dialectic between pattern and irregularity which intersects within the phenomenon. There are two different ways that patterns are looked at and used. A person can look at the pattern and the object through the pattern, using the pattern to give one new ways to see that object in order to continue

contemplating the object. The pattern is a tool to enable seeing the object itself. Our use and creation of pattern in the fall is for this purpose. Or the pattern is a tool for doing something with the object. Our exploration of patterns in the spring in looking at sound and music involves this. This means that the irregularities, the features of the object which don't fit the pattern or have been generalized so that their particulars are lost are probably not looked at again. The first stance suggests that the irregularities will sooner or later *be* seen and will cause the pattern to be revised, reformulated, thrown away. We return to the first way of using patterns when we embed our exploration in an examination of music--what do patterns tell us about music, what don't they tell us that we want to express? I think this is contained in the writings of Dewey (*How We Think*), Dewey and Bentley (*The Knowing and the Known*) and Levi-Strauss (*The Savage Mind*) on commonsense versus scientific ways of knowing and thinking: The use of imposed patterns or generalizations in commonsense ways of being are as a tool for doing things not as a source of contemplation in themselves--neither contemplation of the pattern nor of the new way that it gives you of looking at the thing that it's applied to. This is also described by Polanyi in *The Tacit Dimension*: when an object or an idea becomes a tool used to do something else, the tool is no longer examined for itself. There is in fact a dialectic between the two which, in effect, causes the continual reassessment and re-evaluation of the pattern itself.

If there is an interplay between the two ways of using patterns, this interplay is framed by, caused by a person's purposes. A person's purpose causes them to *use* the patterns as tools. This use of them for a purpose forces the continuous re-evaluation and evolution of those patterns. I weigh the qualities of the phenomenon that I've used to structure my actions, through an examination of those actions against the results. The results are framed by the assumptions of the patterns but also those qualities not contained within the pattern--the irregularities. This is a sort of a statement of the experimental method. I think it is demonstrated in what the children do in the second part of the unit on music particularly when asked to explain some observation. They apply patterns experimentally in attempts to predict outcomes and hence to explain those outcomes.

I also think generalizations in science are a form of metaphor. As such they define comparatively; by saying something is like something else and unlike something different. They act to highlight certain features of whatever is being classified but obscure other features. Any phenomenon is a continuum of qualities but in order to name these qualities they have to be separated out, pulled out of the context of the whole. But because these labels are in reality only a facet of the whole out of context, the act of labeling refutes itself when seen within the whole again. In other words, other features of the whole contradict this partitioning, if you can see them. But the creation of the categories with which we "see" phenomena or people too is the source and fundamental of hegemony, of manifesting a power structure/relationship between phenomena, and it's only by developing a sense of critical consciousness--recognizing the partial quality of those categories--that we can "see" anything else in the continuum. The point is that these categories and generalizations can be inclusive metaphors--defining what is within to exclude what is without-- but they also have the potential to be generative metaphors--helping us to see in new ways, to be starting points in our explorations of the phenomena--that enable science to be a creative act (Schon, 1984).

The first and second grade science curriculum focuses in many ways upon the development of observation and classification skills. I thought that by combining these curriculum goals with the study of patterns--both in the abstract and as observed in nature--it would be possible to explore the intricacies of how to describe sensual observation with words and how to link these descriptions to explanation. This is a fundamental component of science as I have experienced it. To this end we started the unit using pattern blocks[19] to construct patterns and then work on developing ways to communicate those patterns to each other. First students developed language to describe the shapes and, then, language to describe relationships between shapes. For example, to build a hexagon out of two red trapezoids the children had to specify

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[19]Pattern blocks are plastic or wooden geometric shapes which are sized and proportioned so that they fit together nicely and it is possible to make one shape, say the red trapezoid out of a number of other arrangements of the other shapes, one triangle and one diamond for example.

both number, orientation and placement of the pattern blocks. Finally the children discovered that to describe complex patterns they could use metaphor: a pattern of four yellow hexagons surrounded by red trapezoids could be described as a "honeycomb with the honey leaking out."

The children described patterns often with body movements and hand gestures which are a way of reducing or simplifying what they have seen. To turn this into words can be thought of as a further reduction (but an ambiguous one--words have multiple meanings, for example see the final discussions of pattern, beat and rhythm). Being able to turn the whole into parts that the children can talk about is fundamental to science. Examining these parts, trying to qualify and quantify, define these parts and think about the relationship(s) between parts, involves thinking about differences and similarities (defining frame and overlaps) and thinking critically about what can be done with those parts and relationships. Many people have written,[20] about the links between symbol systems, communication, audience, purposes. In this literature, the authors talk, in different ways, about tacit knowledge and articulated knowledge and how these are created and used to exist in this world, socially, individually. All of these authors suggest that how knowledge is created has a lot to do with communication, first with the object then with another, both for a purpose.

After working with the pattern blocks for some weeks we viewed slides of close-ups of leaves, flowers, bricks, things with repeating patterns. This replicates one of the ways that I learned to do science--as an undergraduate I majored in geology and had a minor in art history. Learning to see analytically and critically in my art classes has always been very important to me in my science. Looking at things in two-dimensions, in a picture, can be very helpful in learning

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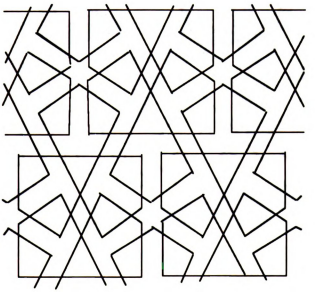
[20]Lakoff G. (1987) Women, *Fire and Dangerous Things: What Categories Reveal about the Mind.* Lakoff G. and Johnson M. (1980) *Metaphors We Live By.* Polanyi M. (1966) *The Tacit Dimension.* Derrida J. (1976) *Of Grammatology.* Moi T. (1986) Helene Cixous: An imaginary utopia. in T. Moi *Sexual/Textual Politics: Feminist Literary Theory.* Norris, C. (1982) *Deconstruction: Theory and Practice.* London: Methuen. Kristeva J. (1973) The system and the speaking subject. *Times Literary Supplement* 1249-52. Moi T. (1986) Marginality and subversion: Julia Kristeva. in T. Moi *Sexual/Textual Politics: Feminist Literary Theory.* Moi T. (1986) Introduction. in T. Moi ed. *The Kristeva Reader.*

to do this. It seems easier to me to abstract content from form and process in two-dimensions. We also worked with xeroxes of Turkish tile mosaic patterns, coloring in different components and talking about the relationships between those components.

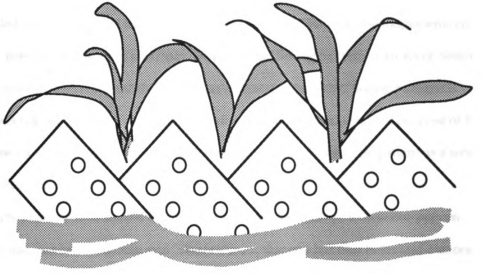
Looking at the pictures of objects and then at objects themselves, the children noticed varying levels of articulation of the components of the picture and this is what enabled them to see a pattern: seeing a pattern involves differentiating foreground subject from background. For example in the following picture of a Turkish tile mosaic:



to be able to describe it we can talk about it being a series of lines but that isn't very informative--it doesn't differentiate it from any other series of lines. We can say that the lines form shapes like squares, kite shapes, stars and diamonds but that doesn't tell us that it is a pattern. To describe the pattern we could say that it is a series of squares which repeat along three axes which meet at 60 degrees to each other. The squares are composed of four kite shapes, two large and two small, arranged in a fourfold rotational relationship (two-fold rotational relationship to like shapes) to one another around the perimeter of the square. The intersections of the three axes of squares is marked by a six pointed star made from the vertices of the kite-shapes. The overall symmetry of the design is three-fold. To make this description I have focussed on the squares and arranged

my descriptions of the other shapes to help me talk about the squares. By doing this I have defined a foreground and a background. I could have done this by starting with a different shape and building up the picture from it or I could have started with a description of the symmetry--three-fold rotation with three two-fold rotational axis intersecting at the threefold axis and then arranged the geometric shapes so that they became derived from this.

Here is a drawing of one of the slides that we looked at.



To describe it we could say that it is of bricks and plants or we could describe a pattern and say that the bricks repeat in a certain way or the plants repeat in a certain way. To talk about this repetition would involve focussing on certain parts of the picture and excluding other parts. The bricks repeat in shape and orientation but not in the number of holes shown. The plants repeat because they are all the same type and are spaced evenly but each has a different number of leaves oriented in different directions. To make a pattern, to say that something is regular and repeats means defining the characteristics that are regular and do repeat and ignoring the others. This is an example of how a pattern can be seen because of contrast, the repetition of a component sets it against a background--but it is also true that the application of a pattern creates its own contrasts by defining certain features and obscuring others, by taking features out of context, generating a "background."

In order to see a pattern in this picture we make abstract generalizations about shape. We make an idealization about an observation. This is an example of using metaphor to describe and simplify (to call a plant a plant is an example, recognizing the ideal in the real). There is a tension in this process: A pattern can incorporate more and more detail making it possible to reduce/ignore that detail. Again we are defining a foreground and a background both by substance and by relationships. Recognizing relationships that are important--mean something, are not just descriptive--and knowing what qualities of the object can be ignored and what must be included are fundamental judgements in doing science. They are also judgements constructed from our previous knowledge and from our purposes. Seeing patterns is an act of design. Making generalizations has much in common with seeing patterns. Seeing patterns is in a sense generalizing about what I do see--ignoring individual differences. And the purpose of this is so I can see the similarities between the components of a pattern and see the pattern as a whole--see the whole to re-see the parts in a new way.

The children also started to use mathematical relationships to describe pattern progressions. For example, Suni said "The bricks . . . that one has four holes and that one has three holes and that one has two holes, four minus one is three minus one is two, I think the next one will have one or four and the pattern will start over." The children began to talk about how they could use the patterns to predict how things looked that weren't included in the picture. The children are working on being able to see changes as a pattern because they can quantify--use counting and numbers as a tool to describe both the object and the changes in the object. Then they move to predicting through extrapolating. There is also a quality in doing this that is a form of experimenting with ways to include previously excluded qualities of the pattern into the pattern. I said above that in order to say that the bricks repeated we would have to ignore qualities of the bricks that didn't repeat like the holes. Suni is attempting to include those.

This anticipates the next step in which I encouraged them to extend their observations of patterns to talking about how the patterns have explanatory power in science. The explanatory power of patterns rather than the descriptive is through correlating what appear to be

unconnected patterns and in postulating reasons why they are correlated. The bricks repeat in shape and orientation and the holes repeat in another sort of pattern. Those two patterns are associated spatially, is there a genetic connection and does it tell us something fundamental about the bricks or maybe about the forces that constructed the pattern? Are these in reality the manifestations of one, more fundamental pattern? And what about the repetition of the plants--is that linked to the repetition of the bricks?

An observation can be called a pattern because whatever is observed is observed to repeat. Can it be assumed to repeat some more? An important point about patterns is that while many are in reality contained, limited things, an inherent assumption to the idea of pattern is that they can extend infinitely. Although to create patterns we need to be able to generalize and categorize, generalizing and categorizing construct limitations, what I have been calling borders or edges. But what I think is pointed out in this discussion of the science of pattern making is that in order to generalize or categorize, a pattern must be assumed. This pattern making assumes that the process is uncontained, infinitely extendable. It also assumes the validity of the generalizations used to create the patterns but in fact the pattern and the generalizations generate each other; are in an interdependent relationship rather that one independently supportive.

Finally, I used the patterns to make comparisons. We examined a collection of dried leaves--maple, tulip tree, sweet gum, poplar, cut-leaf birch--that are similar yet different.[21] We also looked at crystals and fossils to think about patterns and what they might mean.

Starting to explore music through patterns: Constructing relationships.

April 14th

I started this part of our exploration of pattern by asking the children to remember looking at the musical instruments at the science museum (they had just visited Impressions 5) and then I tell them that I want to explore music and sound for the rest of the year. I say that I

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[21]Stevens (1974), Thompson (1961).

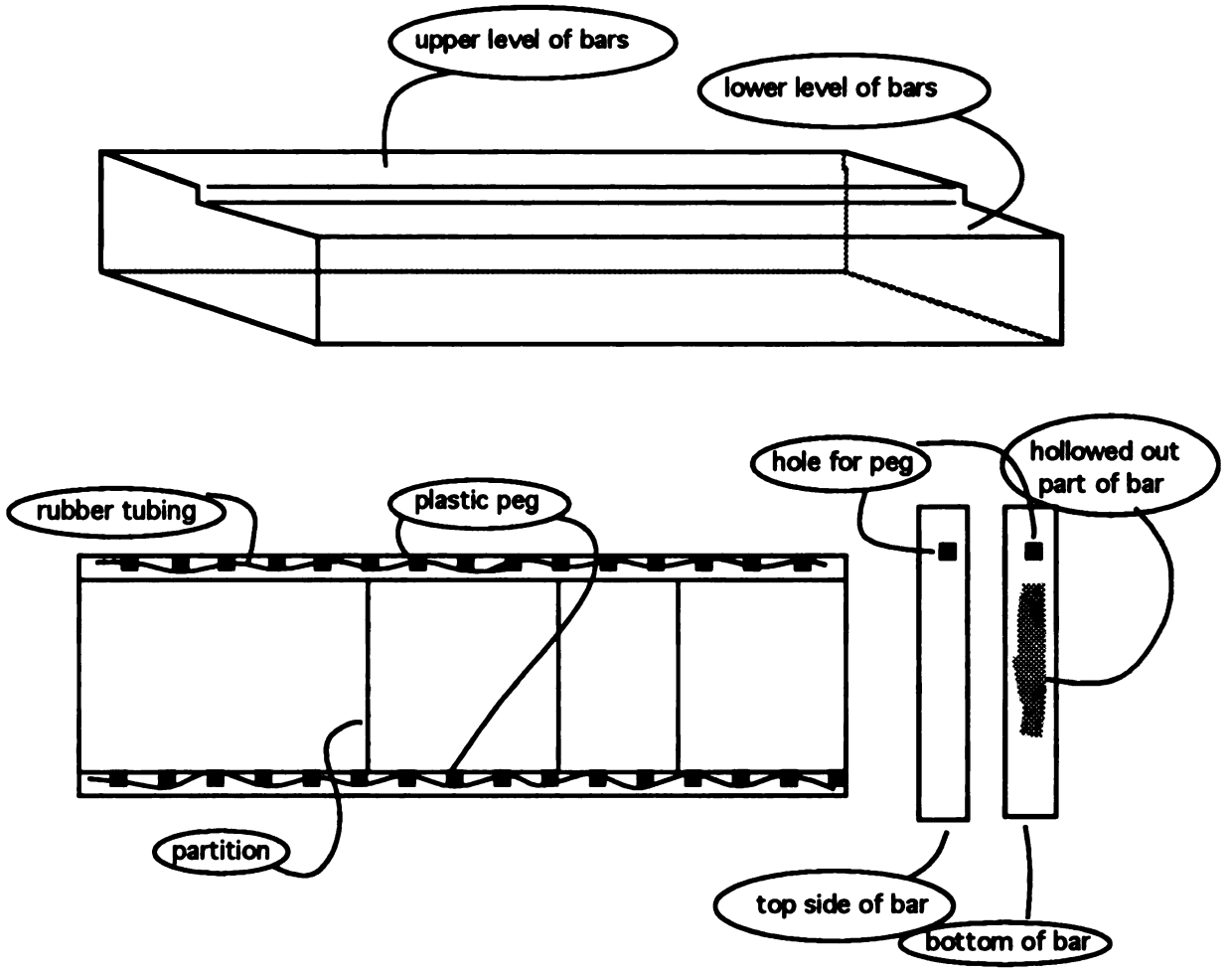
want to do this because music is to me " a lot of patterns." I ask the children if they play or know anyone who plays a musical instrument. We have quite a long discussion of this in which virtually everyone names someone that plays something. Of the children in the room Thomas has just started playing a keyboard and Sueh-yen is on Book 4 of Suzuki in violin. Suni also says he plays the flute. Then we go to looking at the xylophone.

I start by asking if anyone sees any patterns. Suni talks about the grouping of the bars of the xylophone. He says that there is "one long one and then three and then two." The bars in the xylophone are of the pentatonic scale--this pattern in the way the instrument looks is related to the scale. I take a turn at describing it: "There's one of these, then three, then two, then three. What kind of pattern is that? What would come next if that's a pattern?" I'm thinking about the bricks here when I ask this. Suni replies: "One." I repeat this and other kids start agreeing and disagreeing and counting sequences. Then Emily says: "Two." I suggest three.

There is a lot of debating going on over this. The children seem to automatically assume that the pattern extends in both directions. *See notation discussion in the next to last class (the 28th).* They don't question that assumption. I ask why the bars might be grouped in that pattern and Suni says that "maybe they just put it like that." In other words he thinks the pattern is *made* not something natural. So I suggest that maybe we could move them around and make different patterns. I do this for a bit and then I ask if the children have noticed that the bars have letters written on them. The children all have noticed this (probably because Mrs Veenstra, their music teacher, calls the notes by name when the children use these xylophones in music class--music as it is taught at Spartan is very hands on and the children get to try out a number of different musical instruments and observe a number of others being played by visitors). I go on: "Maybe we should write them down. Suni can you write them on the board while I say them. C a big C Big D big E big G big A Big C big D big E big G." We talk about patterns the children see in this. Some children think there might appear to be patterns but they are created by me or whoever made the xylophone. Finally Emily suggests testing to see how the slats marked with the same letter of the alphabet sound. "Why don't you see if the two C's are different."

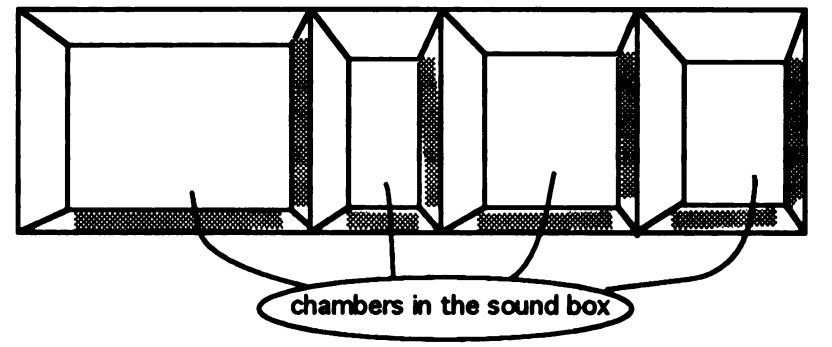
I ask if the children think the two different bars with the same notation written on them sound different. Many children respond that they will sound different and some call out that one is "high" and one "low." I start playing the pairs, low and then high. I say as I do this large and then small. Many say that the smaller is higher. The point of this is to demonstrate a correlation between two patterns--in size and in tone.

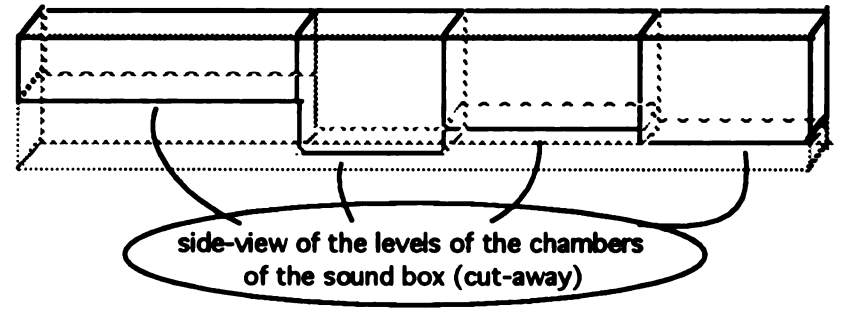
I go back to asking about what patterns they can observe now. I am also trying to suggest in this introduction to this particular unit a dialectic between observation and experimentation. The children start to note different qualities of the physical design of the xylophone. This xylophone has two rows of pegs, one empty with no bars, this is nice because it lets us examine the sound box without the bars in the way.



The actual shape of the two parts of the sound box are a bit different for each row and also within the row each is segmented with differing lengths partitioned off and each partition is at a different depth--like the parts of a lock--I don't know why this is or if it corresponds to the intervals in the pentatonic scale we were just talking about. Maybe it has something to do with how xylophones are often played two notes at a time? Or maybe it's to limit resonance effects? Anyway, different children point out the physical qualities of both the xylophone and the keys and finally start observing (or constructing) patterns in their observations. For example, the zig-zag pattern of the rubber tubing, the differing number of plastic pegs on different rows. Finally Cory describes a pattern that a number of others have also noticed and I ask him to try to speculate why that pattern might be there. I do this purposely--this unit is about observing patterns but not passively; it's about thinking about reasons behind observed patterns and then experimentally testing those reasons. The children have to have it in their heads that there might be reasons before the experimenting can start though. I am not saying that reasons aren't formulated *during* the experimentation also, I think they are--as patterns are correlated--but I want to initiate the idea that we are working on *reasons* not just observation now. In the fall we were concentrating on observation and description. Cory's response is to further detail his observations to emphasize that there are two different patterns in the plastic pegs. He doesn't wish to speculate though on cause and effect.

I return again to asking for observations, now about the sound box. Suni says he sees a pattern: "Well see it's like one big square right there, well like a rectangle, and then like, um, a littler rectangle and then another big square and a rectangle and another rectangle." I ask him why it might look like that and why is the top of the instrument different from the bottom. At first Suni says he doesn't know then he says that "they made it a little different." Alyosha directs us to look at the bottoms of the holes inside the sound box.





Alyosha: I see a pattern, see there is these two . . . I think there is these two over there too.

Teacher: Alyosha said that he thought, he was looking like in this square [*inside the chambers of the sound box*] in here, see there is like a step in here and he thought that that was in there too but it's not.

Thomas: Yeah it is!

Teacher: What do you mean Thomas?

Thomas: Well there are steps right here that goes like this and then there's a big dam and the water goes higher here and a bigger dam here and the water goes higher . . .

Teacher: Wait let me see if I can say it, okay? so that everybody can see. In this one here, it's like a big space here and then a step and then another step, so there's two steps and three, um, things here and then up here, it goes up again to get to here and there's a space and then a step and then it goes up again to get to here and then up here there's a big space and then it goes up like a dam, like this is like a dam of water . . .

Thomas: Like um . . .

Teacher: . . . to get to here and it's up higher and then it goes up again and it gets to here.

Thomas: So it's like this water would be falling all the way down into here and all the water would be trapped here.

Teacher: What Shumshad?

Shumshad: But I think this would have the most because it's more deeper down.

Teacher: Would have the most water? [*Children nod and murmur yes.*]

Shumshad: Because it's the most deepest down, see this one is not as deep, it's not as deep as this one, you see I don't know, but if you put these [*the bars*] on there, this is low and this is high, this one makes lower sounds and this one makes higher and those make medium.

First Alyosha points out that the bottoms of the parts of the sound box are of different heights then Thomas describes them metaphorically like levels and dams in a river. For some reason this metaphor seems/ed particularly important to me--that's why I repeated it to the class. First of all I like it when the children use metaphor to describe things that they see--I think it is interesting because it enables subsequent comparative talk. Metaphorical statements invite why questions from me and also seem to invite other metaphors and then exploring how those metaphors are applicable in different ways--they highlight different things about whatever we are examining--can get much more explicit. Second this particular metaphor was interesting, I think because it made me think that Thomas was saying sound is like a fluid, I thought that was really quite worth thinking about. Often the mediums that transmit sound are fluids but also I think in a lot of ways sound has the properties of a fluid. For example, it fills its container and that seems to be particularly applicable to thinking about sound boxes. I go from Thomas's metaphor to Shumshad's observations and ask if they are trying to correlate the two: "This would make a lower sound and this would make a higher sound because, are you saying because this is deeper?" Shumshad says that "Maybe it would be true . . . " I ask again:

Teacher: So would that be true here, this is the lower sound and this is the higher sound?

Shumshad: I think I need this to tell you. See if you do this and if you do this and try it, it will be low and if you do it on that and try it [*he does both--takes one bar, rings it in one place moves it again and rings it*] see that one is more higher.

Shumshad is the first child to have made a conjecture and then formulated an experiment and tried it in this part of this unit on pattern and music. His interpretation of his results however are in opposition to the rest of the class's. "NO IT'S THE SAME!!!" many children call out. I repeat Shumshad's hypothesis and try it. To me it sounds the same in tone but different in resonance.

Cory: It's the same because the wood is the same.

Emily: The wood is the same long.

Shumshad: Or maybe you need a little one for that.

I think this is a classic response of a scientist to an experimental result that has not come out as expected. Shumshad has immediately started to incrementally modify his experiment. Oh maybe if I try it just a little bit differently it will work . . . Danping makes a new claim by correlating two different patterns of observations. "I think because the wood is the same length it will make the same sound. Not just because you put it in different spaces." I turn Shumshad's conjecture into a counter-argument by restating the observation on which it is based. "Well what Shumshad was saying was that it was the deepness of this. This is shallow, this is deep. You don't think that makes any difference?" Danping has her own, different, observation which she thinks correlates to Shumshad's. "I a little bit disagree with that because, see, I think that if you have lots of them of course it will make a different sound but if you have one, if you put it over here, like, if you have these space right, if you stacked these space up, I think it will still be the same space even though it's skinnier."

Danping is claiming that the volume of each of the spaces in the sound box is the same, that the ones which have larger rectangles in outline have shallower floors. Very interesting but just like Thomas's metaphor we don't pursue it. I think that the reason that we don't is because we haven't gotten to a place in our talking about sound yet where enough children in the class can talk together about these ways of thinking. I think there is a development of this over the course of these classes and that comes about because there is a community that develops through that dialectic process between observation, generalization, explanation, fed through experimentation and conversation. It's that I am working on getting off the ground. I think both Danping's and Shumshad's conjectures are very interesting in and of themselves but the class wasn't at the point yet that could be acted on.

So I continue on pushing the experimentation. I say: "Let's listen to it again and see if they sound the same or how they might sound different. Listen to it on the deep one . . . ." I do it. Children call out that it sounds lower, it sounds higher, it sounds the same. I ask a couple of

the children all of whom say that it sounds the same. I say: "You know to me and I don't know if I'm right or not but I do think they sound different but I don't think they sound different lower or higher I think they sound different louder and softer." Thomas agrees with me and we try it again. This time all agree. Actually I think I am trying to say here that it has a difference in resonance not volume or tone but I really don't know how to express this--with the deeper hole the tone was fuller but however it is I said it, I purposely introduced another variable.

Cory doesn't agree with me. He also thinks that only the size of the bars matters. Then he adds in a new variable of his own--how hard the bar is struck: "Maybe you're doing it harder over here and softer over here." I invite him to try the experiment and then Shumshad critiques him: "But he used this part instead of this part [*metal part of pencil rather than the eraser for second try*]." Suni thinks much more along the lines that I was thinking in. "I think I know why, see, this has more of the sound, the sound can go much more deeper and it makes it much more louder, but this is not that deep so the sound doesn't make it so loud it just makes it soft but this one if it was just like this one on this side it would have the same tone, exactly the same tone." Notice that he is again constructing an explanation by correlating more than one pattern of observations. He also introduces a new word, the first that we pursue the meaning of in the context of this unit. I ask: "What do you mean by the word "tone"?" He doesn't seem able to articulate what he means by tone, though, and I drop it. This is okay, we're just working on starting to develop the language here and part of this process is introducing new words (concepts), trying them on and maybe keeping or discarding them. The point is when I hear new words that I judge *might* become important I give them a little air time by keeping the talk on them not just letting them pass by. The next big word that we will pursue is vibration and that is also introduced by the children in this lesson but not chased after for a bit.

Next Shumshad takes over the experimenting again: "Maybe this makes a deeper sound, maybe this makes it harder and this makes it softer, let me try this ... *raps with knuckles on wooden bars on floor, gets different tone* ...." It suddenly occurs to me to wonder if the bars are hollow and I ask whether or not they seem to be to anyone. I am also quite honestly participating

in this experimenting I do have a lot of questions about this too. I say: " Is it hollow by the way? Turn it around does it look the same or is it flatter?" I am asking about the concave side of the bars. Some say the same some say different. Thomas responds with a theory: "The tune, this is what makes the tune, how it's carved under here 'cause these two are different, they're different sizes but also these two are cut differently." A number of children engage in this discussion. Again the referent point for their theories (explanations) are the patterns in the things they observe.

In each instance of our talk, the children make statements suggesting explanations for the sounds the xylophone makes. Their explanations relate to things they have been able to observe about the xylophone--the primary basis of their explanations are observations up to now. Periodically I stimulate observation and explanation by making an observation of my own and then waiting to see how the children use that observation--do they extend it into a pattern, do they use that pattern to construct or support a theory about the sound? Making a single observation is not enough to construct an explanation; the children have to be able to make the same observation repeatedly in differing circumstances to be able to see a significance to it. In other words they need to be able to make the same observation about the object in instances where other variables are changing. I try to stimulate this.

The children reach no consensus, however, about what causes the tone changes and we return to that a number of times. Right now though Meiying wants to show us something. Meiying speaks very little English yet her "talk" is quite animated. She hits one bar sitting on the ground then holds the end of it and hits it again. The results of doing this are really quite dramatic. Lots of children start exclaiming. Danping yells out: "It's dead!" This is the first of a couple new metaphors to describe the sound. Again each seems to capture something about both the qualities of the sound and also something important about the physics of this phenomenon. I think this is an example of changing the wavelength of the vibrations in the bar and also causing them to not resonate; it causes them to damp out. First though Tity, Suni and Cory critique Meiying's experimental technique. I like this, I want them to satisfy themselves that the

phenomenon that they are observing is real. I encourage them to do this by allowing them to retry the experiment until all are convinced of the validity of the results. Then more children try to describe what has happened.

> Abeni: When you hold it the sound gets more . . . *makes gestures, I say different? she nods . . .* and when you don't hold it the sound is more . . . *she makes a face with eyes wide open . . .*
>
> Danping: Um, I'll, see, see I think when you tap it, it makes sounds, the regular sounds, but when you just hold it, you kind of like kill the sound or something.
>
> Teacher: Huh, interesting word, listen to it again, Cory could you hear a difference in that?
>
> Cory: Um hum, when you hold on to it, when you went like this, it's like the sound was captured, with out it, the sound would just go free.
>
> Teacher: Yeah you're saying sort of the same thing as Danping, Danping used kill and you used capture, why do you think that would be, why would it sound so different?
>
> Andy: Well because I think when you hit it, the block vibrates but when you hold it and you tap it, it doesn't vibrate.

There, the first seriously, scientifically magical word for this unit. I don't ask for a definition yet, instead I ask Andy why the effect takes place hoping that he would continue to use this word. This is like fishing, I want them to take the bait good. I want them to get into using the word and maybe have different children use it differently and then start a discussion of what it means. I ask: "Why would vibrating make any difference for sound?"

> Sueh-yen: Because you're like squeezing it's neck or something like that and then when you, I can't really say it, but when you tap it with holding it, it can't breathe.
>
> Suni: Well the pressure of your, when you have the pressure of your hand, you might squeeze it down and when it gets down, it gets something, it's something like, when you have a frying pan and you turn it over and you hold the metal part and it just sounds like it goes dong dong dong but when you don't hold on to it, it makes a bell sound.
>
> Teacher: Huh did other people hear that? When you hit a glass too . . .
>
> Cory: It's almost like that . . . *points to Kathy's bell--one of those one's where you hit a button on the top and it swings a clapper underneath . . . .*

We do the same experiment with the bell--ding it, then put a finger on the side and ding it again. I ask: "Is that the same, you killed it or you captured it or . . . Okay I agree with you it does seem to me that it makes it vibrate when I hit it but what difference does that make? Why should it vibrate, does it have to vibrate to make a noise?" What makes the noise? Timmy: "I

think that there's a little thing underneath and when you hit the top it hits the side of it." I turn the bell over so everyone can see the underside. By the way, Kathy's bell has been a source of fascination in the room, when they think she isn't looking there is often one or two of the children trying to surreptitiously check it out. This is harder than it seems because if it rings by mistake, or if the temptation gets overwhelming, everyone gets yelled at. I start to ask what people think of this, how they think the bell works when Meiying suggests a new experiment on the xylophone. Rather than holding the bar as she did before, she suspends the bar on the tip of her finger. She tries it first at just one end. When I strike the bar with and without her finger, the children pronounce the sound the same. Cory puts a finger under both ends and lifts it off the sound box and we try it. The children say that it sounds the same. Then Cory puts his fingers on both sides of the bar. We ring it and he says it sounds the same. Then he squeezes his fingers, pressing on the bar, and we get the damping effect from before. Alyosha: "I think when you hold it, when you hit the wood, it shakes and the music comes out when it shakes, and when you hold it, you don't let it shake, so no music." Now in this statement Alyosha is connecting the wood's ability to vibrate with the occurrence of the musical tones. He's not saying if the vibration causes or is caused by the music. That's the trick with correlating patterns, there is the appearance of an explanation when no causality has been established.

An'gele has an addition to this in which she explains how she thinks music is emitted from an object. She explains it as a story. "Okay so there's a house and there's a roof and maybe somebody's playing music inside and then they get it too loud and it sort of vibrates and that makes all the noise and it comes out, I think that's how it works." To me this is a bit like Thomas's metaphor of water and a dam in the sound box. Both involve filling a place up with sound until there's too much and then it comes out. Both are examples of children using their experiences to try to make sense of a new phenomenon.

We return to the children making conjectures about what effects the sound. First Shumshad suggests that it might matter where on the bar you strike it; on the middle or one of the ends. He thinks this might matter because the hollowed out part on the underside makes the

center thinner; different parts of the bar have different thicknesses. Some think this will matter, some think not. For example Suni says: "If you hit it on the thin part, it makes like a sound but I think if you hit it on the thick part, it makes like, just like, um, thunk." We discuss this some more; do the children think the sound change is because of where the bar is hit or how it is held.

Then children suggest that the different sounds of the different bars might be due to their being made of different woods--they are different colors. Some start talking about whether or not the size of the bar effects the loudness as well as the tone. The size of the hollow on the underside of the bars is brought up again. Thomas arranges the bars by size and by their notation and notices the correlation between this and the sound the bar makes. We end the class with all these observations and variuos ideas about them in the air. I ask the children to return to their seats and write why they think the pieces of wood make noise when they are hit and why is that noise music? I want to see what they got out of all this discussion about how the noise is made and effects on the quality of noise. Assumed in our discussion is that these two things are linked. I also want to know how the children might define music since they are referring to striking a bar of the xylophone as making both a sound and making music.

In this first class, the children make many different sorts of observations about the xylophone and about sound. Often times they are able to make the same observation in different places: for more then one bar of the xylophone, when the bar is held in differently, for example. This lends itself to the construction of patterns. This is the first step to attempting to construct theories to explain a phenomenon. Each time a similar observation is made under different circumstances, other aspects of the phenomenon have changed--the other variables, which could be used to describe the whole, have changed. For example the xylophone has many wooden bars--the children see the same thing over and over. Different bars, though, sound differently, are in different places, are somewhat different colors, make new sounds when moved or held in special ways. This lends itself to experimentation: it stimulates the children to try to do things to see if they obtain the same or different results. They can either extend a pattern or limit a pattern in this way. Also by doing things they are able to try to connect patterns. When two patterns can

be connected, correlated, it lends a great deal of support to an explanatory theory. For example, many children seem to think that hitting the wooden bars made the sound. There are two observational patterns here, one around the bars and sound and one around hitting and sound. They are connected by what the child (or I) do. That's an experiment.

Asking scientific questions intertwined with experimentation: Working within the emerging patterns.

April 23rd

I started the April 23rd class by asking about the questions that I ended class with last time. "Why do you think [the wooden bars] make music?" This question is the foundational question driving the observations the children are making and the experimentation I am trying to encourage. The children return to the variables they had located in the last class: the length of the bars, the hollow underneath, how it is hit, the construction of the box, if the bar is on the box and where. Finally Emily starts to try things out. This is my goal in this class, that the children start to take over control of the experimentation. I would like this experimentation be driven by the children's own questions and ideas. I assume that different children will have different ideas about things to do and different explanations of the phenomenon. These different ideas should fuel the exploration.

Emily takes a bar off the box and hits it. Then she and Cory debate whether or not that results in a change in sound. Cory reminds us of his and Meiying's experiment last time where he held the bar tightly and hit it and the sound was "dead." Then Cory says: "But it's different with your hand ... *claps his hand* ... see hold my hand really hard ... *I hold his hand, he hits it again, no difference in sound* ... it still sounds, I don't know why that happens, it's not like these [*the wooden bars*]." This is very interesting I think; why is the sound different when you hit the wooden bar and your hand? And why don't the same things effect the sound? Cory is asking a great question. Also *he's* asking the question. This is different from making conjectures and then

trying experiments to demonstrate those and when they don't work as expected the conjecture turns into a question. I summarize what Cory has done and said because I really want the children to pay attention to this new point. Cory adds this explanation: "[It's] 'cause of the vibration, it doesn't not make the vibration when you're holding on to it 'cause it's not just one whole big, it's not just one whole thing. Like if my arm was cut off it would be one whole big thing."

Cory's explanation for the phenomenon that he has pointed out to us is more an inspirational leap then the children's previous explanations. As I have been noting the children's other conjectured explanations are of the form of correlations between patterned observations. For example correlating the progression in wooden bar size with the tone of the sound the bar makes when struck, correlating the loudness of the tone with how hard the bar is hit. A similar inspirational leap occurred when the children were talking about the sound box and about the damping process of the sound when the bars were held tightly. In both of those cases the "leap" was both reflected in and furthered by the children's use of metaphor. To say the sound box was like a series of dams and therefore the sound was like water filling that space to different depths and then flowing both caught something Thomas saw in the object and shaped and transformed it through that expression. Cory's idea isn't like that. Cory just suddenly seems to jump between two things.

Children agree and disagree with Cory. Benjamin says that the bar of the xylophone is different from your arm because it's an "instrument." Meiying points out the difference in size between the bars of the xylophone and that the effect of holding the bar and hitting it is larger for the larger bars. Emily disagrees, she hits a bar in the air, on the xylophone and on the ground and claims that it makes the same tone in all three places. I am not sure what she is getting at, I think possibly she is saying that the difference we hear isn't attributable to the bar, rather the bar has a particular tone which is effected by the place that it is played. Suni responds: "Well see I disagree with Emily because see, um, on, um, this part when you put it down here . . . because something like the ground is kind of hard and it kind of makes the sound go away, see on this side there's

really, it's like the sound is louder because if the other side is touching . . . like this side it would be the vibration, the sound would go like not so high, it would go kind of not that much just a little, so I think Cory is right."

> Emily: Well but if you went, see that gets higher [*louder*] when it's on the ground 'cause it's so small.
>
> Suni: Yeah but there's a difference between this, isn't this rubber?
>
> Emily: I know but yeah it's got to stay on the rubber to do it but the vibration . . . *hits the sticks together* . . . 'cause that makes a sound too.
>
> Suni: Except you're holding this part, except this part where it makes the sound much better and it needs some space. It needs some space for the sound waves to come out!
>
> Emily: Yeah I know!
>
> Suni: Watch Emily, see, see when you put it here . . .
>
> Andy: It has the holes [*the chambers in the sound box*] . . .
>
> Suni: . . . yeah on the sides here, to like go inside and make the sound. But there's no space here [*on the floor*].
>
> Emily: I know but if I go like this . . . *she holds it up in the air* . . . it has a whole bunch of space down here.

In this conversation the children are suggesting ideas to each other (not to me), both arguing for particular points of view and changing their ideas as different qualities of the xylophone are demonstrated to them by each other. This seems very important to me, by taking control of the conversation they signal to me that they have found an aspect of the phenomenon that we are examining that is engaging--the children have found their own purpose for the conversation. Again developing this sense of a common purpose is central to the development of a community. The conversation is grounded in both what they observe and what they can do--the experiments they can design to try out their ideas--but motivated by their ideas and the sharing of each other's ideas.

We balance a bar in the air on the tips of Suni's and Cory's fingers. Emily rings it. Suni says: "See the sound waves go under it but if . . . " I interrupt: "It's still nothing like the sound down here though." The children keep trying different combinations of different sized bars and ringing it in different places both on the xylophone and in the air and on the ground. Shumshad

arranges them on his legs so that the hollowed out part rests on his thighs and rings them. Emily tries the largest bar over a deep hole in the xylophone and over a shallow hole. She says that "it would just need a little more space like . . . 'cause this one would be down here and that's a really low one, but if you put this one over here, it gets a lot of space to breathe so it makes a really good sound." Suni again talks about "sound waves." I never do ask him what he means by waves. Too bad. Paula says that when the bar is over a part of the sound box that is deep, it sounds hollow.

> Danping: See I have something to say about when Emily put that thing on the floor, see when you put this thing on the floor, the floor's a little bit hard and when you hit it, it's very low and then when you put it back on the box . . . *she does it* . . . see the sounds more lower, I mean louder.
>
> Suni: Because it has something so the sound can go . . . *hands to indicate out* . . . well because it has, like I don't know what to call it, hole, and see if it went, because if it was right down here, it wouldn't make the sound, see when Emily did it down here, it made like, um, a little sound that you couldn't even really hear it, but when you put it here, it sounds, um, higher because most of the sound waves could go inside and make the sound but if you just put it here there's not, there's not enough space for the sound waves and I think that's why it doesn't make a sound so loud.
>
> Teacher: An'gele?
>
> An'gele: I think I know why it was making a different sound because, like, see, because this one is lower and this one is higher. See, put your hand in this one and you can still see it, put your hand in this one and your hand is gone, and you see, probably you could do this [*I have stretched rubber bands across some of the empty pegs*], see how high this is and then this one, this would be low, now if I do this . . .

She moves some of the rubber bands which I had stretched across the empty pegs in the top half of the box. She takes some of the rubber bands and moves them to different pegs so they are over other levels of the inner chambers of the box. She claims the sound change is due to this. An'gele moves some of the rubber bands and sounds them over different places and levels of the sound box. She thinks the differences in sound she gets is due to the differences in the depth of the chambers. (She ignores the changes in length of the rubber bands as she stretches them to different pegs.)

An'gele has started to work with the rubber bands. That is what I had planned that we might do today. I thought that by using rubber bands we could work more on experimentally thinking about how what we did effected the quality of sound produced by a thing and also be

able to see the thing vibrate. I definitely wanted to have more discussion about vibration but I didn't want it to be about something abstract and without a common experience between the children. Vibration, to me, is the central concept to talking about and understanding sound. Defining vibrations and the various variables that can characterize vibrations is a powerful tool to making sense of the things that the children can observe about sound. But to do this the children need a place where they can generate both the observations and the questions that will lead to those variables. For example amplitude and frequency are both components of the vibrations that they should be able to observe and alter in playing with the rubber bands and they should also be able to observe what effects changes in those variable will have on the sounds of the bands. My idea was to have the children play the rubber bands by holding them between their fingers of one hand and their teeth. But before we got to that I wanted to do a little bit more with this discussion of effects on the sound of a bar from the xylophone being played in different places. So I ask: "You know what I did notice was that if I had these just like on the floor, just the pieces of wood with out the hole [*sound box*] underneath, they still sound different. Listen to the wood, just the wood without the hole ... *do it* ... you've got to listen very carefully ... *play them* ... the wood by itself without the hole, they do sound different. What do you think Thomas?"

Thomas: Well I think they do sound different.

Teacher: Why do you think they sound different?

Thomas: Well they're not vibrating as much but there's more places for the sound waves to move.

Teacher: When it's here or down there?

Thomas: There [*on the box*] they can go way down and bounce around everywhere but there, they just hit the ground and bounce up to that.

Teacher: Uh huh ...

Thomas: And here bounce out of the hole to our ears.

Now I go to the rubber bands. Each child takes three and goes back to their seat and tries them out.

Encouraging experimentation by questioning relationships.

On April 28 I start the class with the children working in groups. Each child got one rubber band this time. They played them in turn while the other members of the group watched and listened. Then the group compiled a list for presentation of what things they saw, what things they heard, what patterns there were. When the children present their lists, I start to compile a larger list on poster paper at the front of the room. Sueh-yen starts with: "The rubber bands make both sides sound different, the rubber bands vibrate, the rubber bands go up and down, the rubber bands are different sizes." I ask, "How do you know the rubber band vibrates."

Sueh-yen: Because when you ping it, it vibrates.

Andy: Yeah but you have to stretch it to get it to vibrate.

Sueh-yen: Yes . . .

Andy: 'Cause see it's not doing anything [*if it isn't stretched first*], all it is, is just moving, it's not vibrating.

Now I can ask what they mean when they use the word vibrate. Suni says: "Well see I think they mean you have to stretch it out instead of like he's, he's just making it fall or something, you got to like make it . . . stretch it, that's how it makes the sound. Sueh-yen then adds: "Because when you pull it far and let go . . . *he wiggles his hand up and down.*

Teacher: But what do you mean vibrate then?

Sueh-yen: Like it's moving really fast.

Tity: Oh I think I know what he means.

Sueh-yen: Like that . . . *moves his finger back and forth* . . .

Then Sueh-yen with Tity's help says that it's the rubber band going fast. I ask if that means that anything going fast is vibrating like me when I'm driving in my car. I am really just asking anything at this point just to keep the children talking. Not enough has been said at this point to do anything with. Children say that no, I'm not vibrating. Cory says that "what makes the sound is the vibration . . . " I ask again, "But what is vibration?" Emily repeats Sueh-yen's non-verbal definition by gesturing with her hand that vibration is movement back and forth.

An'gele: I think I know what they are trying to say, it vibrates when you go like this [*does it*], like when you finger goes down and then it pops up and then it goes up and down sort of air hits it, and then it starts making noises.

Teacher: So it, the rubber band goes up and down [*yeses*] and air hits that and maybe that makes noises?

Shumshad: I think they mean, I think they mean , but this is just a guess, that it makes sounds, that's what it means, like this . . . *he gestures in the air.*

So is it the noise that makes the vibrations or the thing that makes the noise making the vibrations which are noise? I ask: "So are you saying vibration is the same thing as making sounds? An'gele said it's when it goes up and down, vibration is when it goes up and down."

Shumshad: I don't mean that, see you know what I mean? When you pull it, it makes a sound that's what I think vibration is. But I'm not sure. You know on the top of houses, like your house but not on apartments, there's antenna's, well maybe there's sort of an antenna that makes the TV go on, I think that's what it means.

Teacher: So the antennas make vibrations?

Shumshad: Yeah . . .

Teacher: An'gele said that it's when things go up and down like that, Shumshad said that it's the same as sound and it has something to do with the antennae on the top of houses.

Benjamin: I think it's the same as sound.

Sueh-yen: I agree with An'gele.

Teacher: You agree with An'gele, Sueh-yen? How about Cory?

Cory: Um, I think that what like vibration is, like, that something hit it, I can't really explain it real good, but if I hit metal it makes like a vibration, 'cause it makes a sound and I think it's a vibration, it makes a vibration.

Teacher: So if you hit something, if you hit something it makes a vibration, but hitting something isn't a vibration.

Cory: Yeah and you hold on to it and it's going like really fast and it's going up and down very fast.

Teacher: Jiggly . . .

Cory: It's going up and down very fast!

We go back to the lists that the groups have compiled of their observations about the rubber bands and Suni reports. This time I have the class discuss each thing Suni reads out from his list. Suni's list is of a form where each statement is attributed to the person who has made it.

The first thing he says is from Teton, "I think Teton is the loudest because he's got the thinnest rubber band." I echo his statement and ask if others thought the thinnest rubber bands were loudest. Trying to make a discussion out of this was premature. I had assumed that Suni was presenting claims about the rubber bands that his group had come to a consensus about and I wanted these "claims" to start to appear more problematic--I was assuming that other groups didn't find or conclude the same things. It turns out that Suni's list actually represented an argument among his group members rather than a report of a consensus achieved. This might be why each statement was ascribed to a particular person. Other people in the class were ambivalent about whether or not they agreed or even had shared Suni's report. Cory claims that his was loud and demonstrates. It is also thinner than other people's bands in his group. But Andy (also in Cory's group) says that Cory is pulling it longer then other people, making it tighter. Tity thinks that his plucking strength or size could be varied.

In other words the children weren't ready yet to start thinking about one variable at a time. I am waiting for them to be ready for this because then we can start more systematic experimentations around sound. The experimentation that I have been talking about which the children seemed to develop naturally in which they relate two separate patterns by doing something is not systematic. To be systematic, other variables have to be held constant. For example to "prove" the tension determines the pitch of sound when a rubber band is played, the rubber bands played must also have the same thickness, be plucked the same amount, be held the same way. I think that in order to do this what is needed is that the children recognize the variables as separate (or separable) from each other. In other words they need to set them apart from the continuum of the phenomenon. That the children are not doing this is demonstrated in the next paragraph. On April 30th, the class after this when we discuss Suni's list some more, the children do come to do more systematic experimentation. That is an important step.

I go back to Suni's list. He tells us next what he had added, "I think Suni is the same loud as Teton." I ask if it was as thick as Teton's. Suni says no but demonstrates that it sounds the same. Then he reads what Dan said, "We could hardly hear Dan because he had the thickest

rubber band." Shumshad breaks in before I get a chance to. "Dr Osborne you know why? It's because he . . . " Shumshad indicates that Dan played his without pulling it tightly. I ask him if that is what he means in his demonstration and he adds that maybe also Dan didn't hit it very hard. Then Shumshad wants to try using Dan's band but playing it differently. Suni breaks in though to read the next thing on his list. "We could hear Shumshad better than Dan because we couldn't hear Dan at all." I ask why they thought they could hear Shumshad so much better. Suni says because he stretched it out. That was the last on the list so I summarize what I've written up on the chart: "Suni said that Teton's was loudest because it was thinnest, Suni's was as loud as Teton's but it was thicker, you could hardly hear Dan's because it was the thickest but on the other hand he didn't stretch it very far, so they said two things, a thin one is louder and one that is stretched further is louder." I start to ask children what they think of all this and whether or not they saw anything like that in their experimenting. I ask Andy. First he says that it's interesting and that he agrees with it. Then he says that he thinks that if the band is thinner, it will be louder because it is easier for it to move, to vibrate. Shumshad adds that when they are thinner, it is easier to stretch them. It looks like the debate is about to start up again when I end class.

In the previous classes the children have been working on defining and explaining a phenomenon by constructing patterns. Defining a phenomenon means recognizing it and naming it. Describing it follows. It is described through generalizations--recognizing pre-existing patterns in it--but also linking these patterns up in new ways. It means seeing how this phenomenon is like and unlike what already exists. This defining and describing the phenomenon is linked to explaining because of this final construction of new pattern. It occurs through linking observation to question-asking. That process, in turn, causes the extraction (articulation, definition--the other sense of the word) of variables which characterize the phenomenon. To say that these variables characterize the sounds and musical instruments means to define how they are related to each other. Recognizing that there are these variables and that they are related is just the first step. After this comes working out how to act on the variables to

elucidate their relationships. Acting on variables in science must be methodical. It is patterned. Method and pattern are linked. In the next two classes the children work on this.

The development of method: Communication and community.

I start April 30 thinking that we will finish compiling the chart at the front from the other group's lists. I begin by reviewing what we already have and then I ask the class if they can see any patterns in what is written there. We didn't get more than a minute or two into this when Shumshad started talking about the substance of the statements on the list and suggesting things that he also thought about playing the rubber bands. Shumshad starts us out by stating that he thinks that even if you stretch a rubber band tightly you still have to pluck it hard to get a loud sound. He reminds us that Dan wasn't doing that. I question him for a bit about this so that it becomes clear to others that he is differentiating those variables.

I ask the class whether or not they think it makes a difference how hard they pluck the rubber band. Most seem to think it does but also think that there are other factors which might make more of a difference. For example Andy agreed that how hard you pluck the band matters but how thin the band is makes more of a difference. Suni also thinks this: "I think it's because of the thinness because if you stretch it too long, it might break but if you stretch it just right it will, um ... maybe it will make, um, and if you pluck it right it might make a louder sound." I ask Sueh-yen about his violin, whether or not plucking a string hard makes a difference to how loud the tone is. He says that it does make a difference, "When I pluck really hard it goes louder and then when I pluck really soft it goes softer." Then I ask him: "Are some of the strings on your violin thicker than others?" He responds that the thicker ones are louder than the thinner ones. This wasn't what I thought he would say and it starts us off on a discussion of the difference between louder and softer and higher and lower when describing musical tones. I had felt that there was a little bit of confusion over this developing in our last couple discussions. This is

important because the discussion which Shumshad, Suni and Teton are about to start hinges on having a shared understanding of the difference between those two pairs.

Shumshad begins: "See can you give me a thick rubber band I'll show you why. See if it's thick it doesn't matter, it will make, I don't know." He does this and then I tell him to do it again so everyone can see and then ask if the only difference is in the loudness and the softness. The class says no. Andy says how thick it is and Timmy says how long referring to the rubber band not to what Shumshad did or to the results. Shumshad has a new idea before I can pursue this though.

> Shumshad: I'm not thinking about lower or higher but maybe, I'm not sure but if you play a different thing it will make it different sound . . . *He demonstrates--he plucks first with a finger, then with a pencil . . . he and Teton do this, they move to the front of the room at this point*
>
> Cory: I don't hear it.
>
> Emily: It depends on what you pluck it with.
>
> Shumshad: I think it depends on how hard you do it.
>
> Teacher: How loud depends on how hard?
>
> Shumshad: Yeah but it depends, this makes a louder, lower sound see? But maybe on this side it will make a higher sound. [*They are trying first one side of the rubber band now and then the other.*] I think it's higher.

I remind them again to be sure that everyone can see and hear them and also ask them to clarify whether or not they are talking about lower and higher or softer and louder. "Shumshad, can you make the claim you just made over again and be careful when you use . . . are you talking about the noise being louder and softer or are you talking about the pitch, the tone being higher or lower?" Shumshad plays the two sides of the rubber band over again calling one lower and one higher. In doing this though Shumshad comes up with a new idea. He and Teton try it out for a minute then show us: "See it makes a different sound if you play it in a different place . . . *he is having Teton play it closer and further from his fingers, they have it set up that either one of them holds the rubber band stretched between two hands and the other plucks it* . . . okay see? Okay this side, this side. See higher higher higher, oh I mean not higher higher higher but lower medium higher." First I get them to clarify just exactly where they have been playing on the band. It's

been first close to Shumshad's finger then away a bit, then at the middle of the band. Then I ask them to do it over with a thinner rubber band. I ask them to do this just because I think the thinner ones are easier to work with. This is somewhat more effective, more children can hear what they are doing as well as see it and people start responding to what they are doing and saying. Andy says that it changes to being louder and An'gele to higher. I say I can't hear any difference at all. Tity says she thinks she knows why it might work. Shumshad also has a theory: "I think I know what is happening, see if you hold it like this, see this part of it is different, see it's different, so I think this part is different, so this part plays different and this part and this part, see this different, see this has a different part of this finger and this has part of the different finger so I think it will make a different noise." He is holding the rubber band looped around his fingers. On one hand the band is around the base of one of his fingers and on the other hand it is toward the middle of a different finger.

Teacher: What do you mean it's different, how is it different?

Emily: I didn't understand a word of what you said.

Sakti: Yeah!

Shumshad: Well see this part, this part is in the middle of my finger, so I think they're different parts!

Teacher: Well how are they different what do you mean that they are different?

Shumshad: Not fingers but they have lines that are different ways, like some lines of that goes like this and some are like this so I think that they are different kinds of fingers, so I think it will make a different noise, you get it?

Teacher: No I don't get it! But I'm hoping that I will soon . . .

Shumshad: See this blue thing . . . *points to vein in his wrist* . . . it's the blue thing in your body that the blood goes in [*kids talking and looking at each other's wrists*]. So see?

Teacher: Wait a minute let everybody catch up with Shumshad, everybody's looking at their veins, now what about veins?

Shumshad: Now see some veins are different, now see this vein and this vein, then this vein? So I think on different fingers there would be different veins.

I ask for clarification and Shumshad explains how his different fingers have different rings (in the skin, patterns of markings in the skin) on them. I start asking children if they

understand Shumshad's conjecture and if they can put it in their own words. I think what Shumshad is doing is very interesting: he is demonstrating the dialectic between theorizing and experimentation to us. He has made an observation; that the thicker and thinner rubber bands make different types of sounds when plucked. But he also wants to make a claim that plucking each differently alters the sound. In experimenting with these two observations he comes up with a third, that the sound varies with how hard the band is plucked. In playing with this he discovers that the two sides of the rubber band make different noises. Then he and Teton experiment with playing at different places on one side of the band. Finally he comes up with a theory; that something happens when the band is held between different fingers that cause the sound to be different. He has done a lot of leaping around in this and I want to make sure that the class is with him. Suni says that he can explain what Shumshad is up to. He gets about two words out of his mouth and then runs to the front of the room to try out the experiment for himself. The three of them now start telling each other what to do. After quite a bit of this Suni announces, "It's not veins, it's your finger prints."

> Teacher: Okay would you tell me, all three of you who are doing this what it is you are trying to prove by doing that?
>
> Shumshad: Oh I'm not sure but I just did something wrong see this side of this wasn't any different, this side of this, which is different, so I think it's the same thing with the thumb.
>
> Suni: Well let me explain this, see what we mean is, okay like if you hold a rubber band with two fingers, two thumbs, I mean, and you hold it like this and then somebody plinks it, it will make one sound but when you change a finger and make a sound then you're ... you plink it and it makes a different sound. I'll show you. Get the stuff together!! Okay watch this, okay it makes that sound ... *He plucks the rubber band again.*

Cory suggests they pluck it harder. They do it and the sound is louder. This gets incorporated in the original experiment where the fingers holding the rubber band are changed.

> Shumshad: See it depends on how hard you pull it.
>
> Suni: And it depends on what finger you use.
>
> Shumshad: See if this is my finger and this is my finger and this is both ... *they do it* ... see they're different fingers.
>
> Teacher: Okay all of you guys stop, stop. Stand up there in a line and stop fiddling around and don't all talk at once. Okay whose going to speak Shumshad or Suni?

Suni: Teton!

Shumshad: Teton, say something you haven't said nothing.

Suni: Yeah!

Teton: Okay I'll explain it, it depends on the size because if there are like our thumbs are one size and they're both the same size, both of our thumbs and if you change a finger they're not the same size, look . . . *He shows us his fingers.*

Teacher: Now listen to me, I saw what you guys were doing and everybody else saw what you guys were doing. It seemed to me that not only were you changing what was holding the rubber band, you were changing how far apart you held your fingers, you were changing how hard you plucked the rubber band, there were all sorts of changes and all of them might have made a difference in the way the rubber band sounds . . .

Science isn't just fun you know, it's disciplined. In order to make sense of the phenomenon their experimental actions has to be patterned. In this way variables can be located and isolated. Results can be ascribed to changes in those variables. All of this hinges on the construction of a pattern--in the observation of the phenomenon and in the method of interaction with it. The need to do this in this class has grown organically out of what the children are trying to do and also communicate. The construction of patterned action is necessitated as much by what they are working on in thinking about sound as in how they are trying to communicate it to others. The patterns of method in science and in communication are linked developmentally with the growth of the classroom community. A community is defined by shared discourse and activities.

They try it again, trying hard to only change the finger they have the band rapped around. Finally Suni announces, "It's different, it's different, there that proves it." The three of them run back to their seats. I call them back up front and tell them that they need to explain to the class what they have done, what they think it shows and ask people what they think of it and whether or not they agree and why. I tell them that I personally don't agree with them but "I'm not totally sure I know what you are saying." Suni says that he'll explain: "Well, see we had a rubber band and then we did one thing with fingers that were the same and then we plinked it and it sounded like something. Then we changed the finger except kept one [*only changed one finger*] and we kept it the same distance. Then we plinked it and it made a different sound, so if

you changed fingers, it can make a different sound but you have to keep them the same distance." I ask him if they plucked it the same way each time and they say yes except for Shumshad.

The manner that Shumshad, Suni and Teton are interacting is a very visible expression of the interactions of members of a community. They listen to each other and try to think inside each other's thoughts and then, occasionally, one or the other contributes a different idea, one that is implicitly critical. This manner of interacting is fundamentally creative. It can only happen socially when people are honestly interested in each other and mutually engaged in a common pursuit. The way the children listen to each other, as well as the way that they criticize each other, is a measure of respect. I think this develops because of a genuine interest in the subject matter and our explorations and a respect for each other constructed by me and enforced by me. I model this way of acting and after a while the children adopt it because they have found that the things that each does are interesting and of value.

Shumshad states: "But Suni sometimes you pluck it and you do this much and sometimes you do this much, so it would make a different sound, see you pluck it, first you pluck it this much and then ....You can not go like this always, the same length, you can sometimes go like this and it will make a different sound."

Suni: Yeah except we want it to be the same so it can make the, so we can prove it!

Shumshad: Okay do you have a ruler and I'll hold it and then let's see ...

That's exactly what I wanted to hear. Now we are ready to construct a systematic experiment. We get a ruler and they start their experiment over again. They measure the distance between their hands and then the depth of the plucking with a great deal of discussion of who does what. Also Teton insists on metric. The three of them work out that they will stretch the band 14 cm and flick it 3 cm. They are going to do this first with one pair of fingers, then with different fingers. They explain all this very clearly to the class. I suggest they ask the class what it thinks before they go on.

Suni, Teton, and Shumshad take questions from the floor. Thomas thinks the flick should be larger so now it's five centimeters. Suni explains again even clearer. Emily disagrees with

their statement of what the experiment will prove. Suni says " we're not sure we're just testing, we might be right, we might be wrong." Emily: "In my opinion, I think it won't make a difference." Suni explains again. An'gele wants to make sure of the experimental design. Finally they try it and I have them talk it out while they do it. We can't agree if it is different so they do it again this time twice because Shumshad thinks that will make it easier to hear. Emily thought it sounded the same. An'gele different and so did Sakti. Timmy the same. Alyosha different. The group different. I poll: it's about 50/50. Then again and it was 5 the same and 7 different. So they try it again. I hold the rubber band this time--there is no difference in diameter of my fingers. Different took it.

> Emily: I sort of disagree with you guys, I'm going to need the chalk board.
>
> Teacher: Okay.
>
> Emily: Okay, here's your thumb and here's you finger and here's the rubber band and you pluck it and it makes one sound and then the next time you do it, and it even makes a different sound or the same sound.
>
> Suni: Well to us it made a different sound.
>
> Emily: Well most people thought it sounded the same. It probably . . . well they were either right or wrong but we don't know that right now.
>
> Suni: Right.
>
> Emily: So I have an idea so we can find out . . . well one thing we can do . . . *tries it with two fingers and one finger rather than changing the fingers* . . . lets see if it makes a different sound.

Emily repeats so others can see. This is also the first hint that someone thinks it different diameters of the fingers that matters not just something magical about the fingers themselves. Shumshad coaches her on how to present this to the whole class. The argument in this class progresses from arguing that one idea *versus* another is right to being about method. The result of the argument about method--what to do and how to do it– is that the children's methodology becomes systematic, patterned, disciplined. When the method is agreed upon, the argument can return to being about ideas. What are the methodological variables and how do they effect the sound? I make everybody go back to their seats and try the experiment in their groups.

This development of a method for acting and a method for communicating are very important in the construction of a community. They are the tools through which a common language is built. They cement a common purpose. A method is a patterned way of acting; it enables people, observers and participants to anticipate what will happen, to know what has happened. It is a tool in interpretation. Because a method is purposeful action and because it is patterned, it is a design and it is designed (both senses of the word design). Method, the concept, is contingent upon human agency and human interpretation.

Method, experimentation, making sense of phenomena.

May 14th

On May 14 Thomas brought in a small-bodied guitar with metal strings to show the class. He has mentioned to me before that he might be able to do this and I encouraged him. A guitar is perfect for us to look at at this stage of our explorations. The guitar strings clearly vibrate when they are plucked or strummed. One can control the vibration and the resultant sound with the keys without worrying about changing other variables (such as the string length). The guitar lends itself to systematic experimentation in which only one variable at a time is altered. He starts the presentation off: "Last time we were kind of tangled up and we couldn't decide whether to pull it tight or not [*he is talking about Shumshad, Suni and Teton's experiment*], well this I can get to sort of do the same thing ... *turns key on the guitar after plucking one string--at low end* ... okay when I pull this it sounds like that because it's two different ones [*strings, he plucked two strings together*] but if I do this, listen to the same ... *plucks them again after loosening key, kids laugh say it sounds different, higher, lower, flat* ... 'cause I loosened the strings too much." I ask him to explain what he has done and he says that by turning the key he has loosened the string or it can tighten the string also. He continues to do this until he gets the string so loose it won't make a noise. Then Tity asks him to pluck a skinny string, he does this and says that makes a different noise because it's a different string. I think he says this because he is trying to make a point about how

the tightness of the string effects the tone and he wanted us to concentrate on what he was doing with the one string. But he does continue on to say (referring again to the last class), "And we were also tangled up with how wide and how thin they were, well I have these and they're different, rats you can't do that one [*he has loosened the highest string so that it won't play at all now*] well this one is real high ... *plays the next one up* .... It sounds higher and it's thinner and this big one right here starts lower because it's fatter [*a lot of murmuring]* okay now I'm going to loosen this skinny string so ... it's a bit hard to ... I hope I can loosen it if I don't tighten it ... *loosens key and plays, kids are murmuring* ...." Then Thomas describes to us how each string has a different thickness and each sounds different. He plucks each one as he describes it. So I ask him if he would say that those different sounds come from the different strings because they're thicker or thinner. He says, "Um hum ... *continues to play the strings* ... and if they're loose or tighter."

In this class, as Thomas demonstrates on the guitar, the class again runs through the variables we had been examining with the rubber bands. Different children suggest trying different things with the guitar, stating what they think will happen. Thomas tries them out and people suggest counter-theories to explain what actually does happen. Both the theorizing and the experimentation are grounded in each other. They are also grounded in observations of the design of the guitar. There is much debate about various features of the guitar--for example the frets, the bridge, the hole. Different children, as they call attention to their observations, suggest theories to explain their presence and also suggest ways to test them out.

For example Shumshad notices the hole in the body of the guitar and suggests this makes the sound loud. (Remember this same discussion in the xylophone also.) He suggest covering it to test this. This in turn causes much speculation on what causes the sound we could hear. There was definitely a correlation between the sound and whether or not the hole was covered but that still didn't tell us what caused that. This as well as playing with the strings returned us to a discussion of vibration, now, however, much more sophisticated.

Finally we concentrate on the strings, loosening them with the keys as we play. One becomes loosened to the point it no longer plays. I ask Danping why this has happened. "Because I think

when you loosen it you sort of just let it go by itself and then when it goes by itself it's sort of very loose and I can't say it . . . I mean when it could go anywhere, it just could go . . . I don't know . . . ."

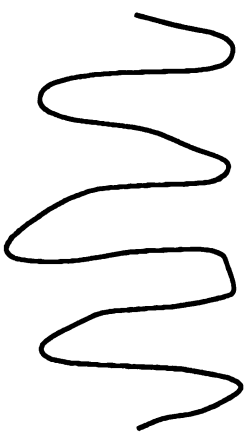
> Teacher: If you loosen it, the string could go any way? Any where? Is that what you said?
>
> Danping : Yeah but I don't know how to say it out loud.
>
> Alyosha: I think, see when you let it go and when you let it go loose, then it goes on the side longer and then it, it can't vibrate very good when it goes on the sides, when you go like this when it shakes, when it goes out, then it looses control of itself.
>
> An'gele: I think I know why it makes that noise. Because when you pull the string it's like, see how straight my finger is, now it loosens up and it gets to do whatever it wants to do, it's like I'll use an example, like if your Mom said you have to stay in your house and then she said you're free to go any where you want.
>
> Danping: Then you just go anywhere.
>
> Teacher: That's very similar to what Alyosha was saying and it's a little like Danping, you're saying that when it's loosened up it's free to move any old way it doesn't have much control, is that what you're saying?
>
> An'gele: Yes.
>
> Danping: I think when you loosen it it's out of control.

Shumshad makes a very subtle point next. He says that it's not really the string that changes the sound, it's the keys--by turning the keys you control the tension of the string therefore you control the sound with the keys. Then he says, "See if you can loosen it, it can go this far but if you tighten it, it can go only this much . . . *he indicates the amplitude of the vibration on the string changes* . . . ." I ask him: "Are you saying that if it's tight, it vibrates just a little bit and then you loosen it, it vibrates a lot?" He says yes that would be true as long as it didn't break.

I ask about the effect of the thickness of the strings. I remind the children of their conjectures about the thickness of the rubber bands, that they had said that thinner rubber bands make higher sounds. I say that that seems to be true here too. Why do they think that would be? All of this, about thickness and thinness and length is to work further on the idea of vibration and how it effects sound. I want to get at ideas of amplitude and frequency and I know that both the stiffness or the tension of the string effect this and this is in turn affected by both tightness, length

and diameter. With sound, the amplitude is proportional to the loudness and the frequency is proportional to the pitch (variable and effect). Greater stiffness or tightness of the string will decrease amplitude but increase frequency. Greater thickness increases the mass of the string, decreasing frequency and pitch. These are the correlations we are working on--the observations and phenomena that are related through patterned action, through methodological experimentation.

Andy says that he thinks that the little ones vibrate more because they're thin, that's how they make high sounds and the low ones that are thick don't vibrate much therefore they are low. Now what does "vibrate more or little" mean? Is he referring to amplitude or frequency? Benjamin adds that the fat ones are heavier and the thin ones lighter. This is proportional to the stiffness. I ask Andy what he thinks of this and he says that what Benjamin has said "has to do with how they can bend." Danping disagrees. She thinks that the thick one vibrates more than the thin one and she starts to draw a picture. Meanwhile I say that: " I can think of ways that that's true, for instance what you guys were saying about how the fat one is less controlled and it vibrates like that ... *I draw* ...

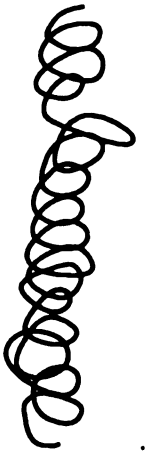


and the thin one vibrates like this":

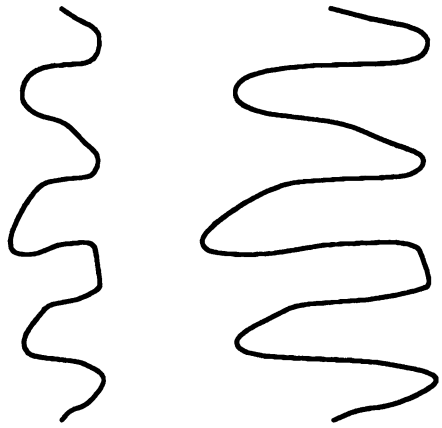
at least I thought that was what you and Alyosha and An'gele were saying about when it was looser." I was trying for a difference in amplitude here but I also made a purposeful and opposite difference in frequency which is of course a gross exaggeration of what a string on a guitar or

violin actually looks like when it is plucked--there is usually a small number of wavelengths. Danping stops drawing and says that she agrees with my picture. I ask, "Which one is vibrating more?" There would be different answers the on basis of amplitude or frequency. Danping says the thin one, the one with greater frequency, is vibrating more. Andy also says this. No one says the one with greater amplitude.

Alyosha says he thinks the thin one and also has something more to say. He points out that the fat strings appear to be made of something different from the thin strings. They are different colors and the thick ones appear to be made of metal. Shumshad shows us by drawing that the fat ones look like little springs:



Of course this doesn't really relate to thickness but to the length of the string--if these little springs were straightened out the string would actually be very long and the resulting wavelength of the sound is very long. This is why the pitch is lower. This isn't what Shumshad wants to say however. He wants to tell us that the fatter strings are harder to pluck then the skinny strings. He is relating the thickness to the tension of the string. This isn't really the result of a property of the string but is a result of the setting of the keys. His final statement is that if it is easier to pluck the string, the amplitude is larger. Danping draws Shumshad's idea.



Notice that she drew the same number of wavelengths for each string. The result of what she drew would be a change in amplitude in what we hear not a change in pitch. They aren't, though, relating this phenomenon to the sound, rather to the tension put on the strings by the keys. All these things are linked but to make any sense of it we have to separate them out, think about each separately, construct an identity for each variable.

An'gele has had her hand up for a while. I call on her and she corrects all of us about how the strings actually look when they vibrate. She points out and then draws that actually they vibrate with only the one half wavelength or multiple of this and she says that this is true for both fat and thin strings:

She adds that, "they go all the way down like that, back and forth. That's how they vibrate, then they go in this hole and out that hole, that's why it makes that living sound [*she is talking about the hole where the strings thread into the bridge not the hole in the guitar body*]. The children talk about this, most agreeing with her observations about how the strings vibrate. Suni says that means that the difference between the fat and thin strings would then be how much they vibrate--their amplitude. That isn't right but that is the way it stands at the end of this class. The greatest debate is now about An'gele's claim that the vibration goes into the guitar body at the bridge. People don't see a hole in the bridge and therefore don't agree with her. Only Sueh-yen agrees. He says that it echoes inside. I remind the children of Shumshad experiment when he covered up the hole in the guitar body and plucking the string and it sounded differently. Then Suni says that he thinks the hole and the vibrations going into the hole effects the loudness. Then he adds: "It's just like the xylophones, don't you know there was a big hole and you use that xylophone and when you tapped it, it made kind of a loud tune and when there was not that big hole and you taped it, it didn't make that loud tune, so I think the same goes with this, when you pluck it, it makes a loud tune with a big hole and if you used a little hole, it makes not such a loud tune."

That was the end of class. In this class the children continue to define the variables that characterize sound. This is done as an interplay between observation and experimental action. In this instance this is systematic because the guitar, the vehicle for the exploration, makes it systematic. Only one variable at a time can be worked on. This is a final repercussion of design--the design of the instrument, the medium through which an experiment is carried out, determines the things that can be done and seen. The design of the experiment determines the result. The act of design is an imposition of meaning. I think a final important point about this conversation is how it contains and makes continuous references to things the class has already done. There is a developing history to this unit and this community and its pursuits. I think this is another important quality of a community--a shared history.

This is the end of the first stage in this final unit in which we explore music and sounds and patterns. In this stage I wanted the children to use the tools we had developed looking at, seeing, recognizing patterns to "look at" music and sounds and things that make music and sounds. This meant observing patterns passively but then also observing patterns actively, discovering that by doing things systematically, or maybe seeing a system in things that weren't done systematically, they could observe new patterns which correlated to the patterns they had passively observed. This act of correlating lends itself to constructing explanations for phenomenon, or at any rate, apparent explanations. I say apparent because the appearance of causality constructed by the correlation can be an illusion. For example things that make music, vibrate--two observations correlated but do they have any genetic relationship to one another and, if so, what? Does the music make the vibration or the vibration the music? Once you've got that kind of relationship you've got to go outside that relationship to find variables that characterize the two constructs, in this case music and vibration, that you can fiddle with systematically in order to see how this experimenting effects the constructs. In this way causality can be established. But does any of this really explain "Why?" or does it actually just push the why question to a more fundamental level? Once a relationship is established you can accept it on one level but then you have to ask why it occurs. Music and vibration go hand in hand but that doesn't tell you why something can vibrate in the way that it does to begin with. I believe that this sort of "why" question becomes a vanishing point in our explorations. With each new discovery that apparently explains an observation, the why question is pushed a step back. I think this is important because I believe a shared pursuit is focal to the development of a community. This pursuit cannot be easily resolved. Rather it must reshape itself and in essence develop a life of its own to remain compelling.

In the class about the rubber bands we have got our initial correlation and now we are working on characterizing our constructs with variables. We are locating the variables and seeing what happens when we change those variables. The next class, about guitars, is about this even more so. Doing this is a pattern in itself. Acting systematically to alter one variable at a

time means acting within an established pattern. Doing this in conjunction with theorizing is a mental pattern of logic making, testing, altering.

What is music? What is science? The discussion begins.

May 19th

On May 19 I decided to ask the children what music is and whether or not they think there is a difference between sounds and music. I am not sure why I did this at this point but I think I had decided that we had done enough systematic exploration of the constructs, sound and vibration, and we'd done enough locating and working on variables which characterize the two. I had always planned that we should think a bit about some of the more subjective and value-laden thinking that underlies the judgments we had been making or assuming. In other words, back to the idea that thinking within patterns should involve an awareness of figure *and* ground and that periodically the choices made to articulate the figure should come back up for conscious re-evaluation. This is important because it keeps us aware of ourselves and helps us to realize the relativistic quality of our choices (Habermas, 1991; Arendt, 1977). It is also a tool used by me to work to prevent the hierarchical development of relationships between people in the class, between the people in this community (Foucault, 1980). Both are important scientific and personal values for me.

In the next three classes the children work to define three words: pattern, beat and rhythm. They do this within the context of defining the word music. I asked them to do the second. The choice of defining music through pattern, beat and rhythm is theirs. This choice of variables very much shapes the definition of music--how it is articulated from the continuum of sound. The children effectively state that music is made up of the three other words. Then they work to define those words in such a way that the words themselves become differentiated from each other and it is the relationship between constructs that defines music. Again there is a

pattern being created in the phenomenon and in the method generated to work on the phenomenon and communicate about it.

This is an example of both the development of a community and a community developing. There is a shift as we move into this part of our explorations from conversations focused upon sharing our observations and our experiments. Embedded in the way that we talked about both observation and experimentation are explanatory ideas about phenomena. This necessitated the development of certain patterns of observing, acting, talking, thinking, interacting. In the discussions of the question "what is music?" observing and acting come second to talking and thinking--as the children try to communicate what they think is important about music, they find they have to "show" us. Through the acts of telling and showing us and articulating that in an environment where people respond, the children's ideas change. Portraying what a child thinks they "know" becomes an act of rethinking. Knowing, thinking, learning become linked. This happens as a new community develops. I call this a new community because the focus--the qualities that the community forms around--has shifted and re-coalesced. I would not like to imply here that I could specify what the community was formed about before or what it becomes formed about in this final portion of our explorations of sound and music. It is different though. Possibly I could say that before we were chasing after explanations of sounds and now we are thinking about the uses of sounds. These two are linked though. I do know that the ways that the children talk about what they are thinking and how they respond to each other are different. There is a different "feel" to this community. A constant, though, is the respect that I require children to show for each other's ideas. This doesn't mean they can't disagree, they certainly do that, it's a matter of *how* they express disagreement. Again this is a fundamental to the development of the community--a valuing of each other and each others ideas as they interact in a mutually shared pursuit.

I start our discussion by asking Benjamin if all sounds are music. When he says no I ask him what is the difference and then to help this along I ask him to name a sound that's not music.

Benjamin says: "Well this is a sound--dum, dum, dum, dum and music is like when you hit it a lot of times and kind of get beat or it's like rock and roll." This starts immediate controversy.

> Suni: I have something to say about that. When you did that dum, dum, dum, dum, I think you are wrong. I think that's a music beat. So, so that is a musical sound.
>
> Emily: When we talk it's a sound.
>
> Timmy: Yeah but it's not always music [*to Suni*].

I ask Suni what he means by musical beat, what is a beat in music? He replies: "Like sometimes when people play drums they go dum, dum, dum, dum and then other people play something and that's how they make music."

I clap my hands once and ask if it's music. Everyone says not. Then I clap my hands three times and ask again. Many say yes that it is. I ask Emily what she thinks. "Well music is one thing that you, um, it's like one kind of sound that you're playing, it's just like one kind of sound . . . " I ask her what the difference between a musical sound and "the other kind" is.

> Emily: 'Cause like music, it has a whole bunch of different things . . . Like different beats and stuff, it's like, if you were a cow you would just go moooo and that's just one thing.
>
> Teacher: So lots of different kinds of sounds makes music?
>
> Emily: Um hum . . .

My interpretation of this is that a sound is musical because of it's context. This is not the answer that I was expecting particularly. I was expecting a conversation about the qualities of the sound, that musical sounds are different from other sounds because of an intrinsic quality not extrinsic. Both ways of thinking fit into what I wrote about at the beginning of this section about my thinking in the set up of this. They do this in different ways though but I think it adds up to the same thing. Anyway my response to Emily's statement was to ask: "So what if you went moo, baaa, meow, is that music?" Some children thought yes and some no. Suni says that it's just noises from animals, not a musical sound at all. I think that he's meaning what I was thinking--intrinsic quality of the sound--but he goes on to place his thinking within the contextual definition Emily had started on. "I think a sound that's not music is like when people walk across the street with their feet stomping, it always keeps going it doesn't like, um, it doesn't like repeat

in the same way, like they go like this instead of going like this and this and this, so that's why they make a different sound that's why I think it's not a musical beat." I ask him about marching, whether or not that's a regular beat and whether or not that's music. He says that it is because they "stomp at the same time." Danping joins this but she says that she thinks music is sound that has rhythm. I ask if rhythm is the same as Suni's beat. She says yes, that music is "regular."

Now Emily asks Suni: "Is this music? ... *claps hands on thigh* ..." Suni tells her it's a musical beat. Emily says that yes it's a musical beat but it's not music. "Musical beats are music!" responds Suni. Danping agrees with Emily. She slaps her hands on the floor a couple times and says that she doesn't think that is music. I asked her why not but Suni answers both me and continues his argument with Danping and Emily. He says: "Not going like that [*referring to Danping's demonstration*] you're supposed to make a beat ... *slaps hands deliberately on floor, with deliberate pauses in between which he indicates with head nods* ...." Then he adds a new phrase with which Kathy describe the rhythmic hand clapping she uses to get the class's attention. "Now if you would want a rhythm pattern like our class is doing, now that's a rhythm pattern, just going like that is music." Now this is different to me. First of all, a rhythm pattern doesn't repeat like clapping to a beat does. It doesn't repeat but it can repeat, it's like the definition of the word pattern which means a design that can be copied. It also doesn't have regular spacings between claps. It seems to be different from what Suni has just said about beat and music.

Through out these conversations on the nature of music Suni plays a key role. His definitions, though, of patterns and the components of music evolve as he talks and does things. There is a feel in his talk that he has an idea in his head of what he thinks music is and is trying to find ways of describing that. Maybe the prototype/schema language could be used here to describe what he has in his head and is trying to articulate but there is also the feeling that he is constructing the prototype as he is going from components of different things that he has experienced that he would call music or not music. Anyway his use of beat and rhythm pattern to define music is somewhat contradictory.

I ask Andy what he thinks next. He tells us that he thinks music is: "a bunch of sounds put together in a type of order." I ask him if that means it has to repeat like Suni said and he says no. Suni corrects me: "It doesn't *have* to repeat but it can also be a rhythm pattern."

> Emily: I think he means, I think Andy means that this ... *hits hand once on floor* ... that can be ...
>
> Suni: That's a rhythm pattern.
>
> Emily: Yeah.
>
> Teacher: Is it a rhythm pattern if you just do it once or does it have to repeat to be a rhythm pattern?
>
> Suni: A rhythm pattern has to do the same thing over and over again.

There is much talk going on now about this with children asking each other whether or not they think various sounds are music or rhythm patterns. An'gele says that she thinks people walking do make music. I think she is thinking that she can hear a rhythm listening to herself walk, Suni though is thinking about listening from outside, listening to others. Larkin raises her hand and says that she thinks that screaming isn't music. My daughter, Larkin was visiting this class and the next. She participated in each class as a class member. She and Andy both say that it's just a loud sound. So I ask what if someone were to scream repeatedly, would it be music then? Lark says no, so I say "Why not? It would have a beat." I am thinking suddenly about experimental music I listened to in high school in which elements of traditional music were separated from others and whole "songs" were composed and played using just one element. I am somewhat more familiar with this "playing" with the elements of art in the study of minimalist modern visual art in which an artist purposely pushed upon the constraints and demands of various components of painting or sculpture, making the subject of that art the components and the play themselves. When I studied art I was taught that the purpose of such art was to cause us to reflect on the question "What is art?" I think in the conversations to come about music, the children do something analogous--they break music into parts and then explore the meaning and interplay of those parts in the total phenomena. I think the children here are

getting at whether or not sound has to be purposeful to be music and whether or not it has to be purposefully music to be music, I think Larkin is saying the latter and Suni the former.

Lark agrees that it would have a beat and Andy adds that if you also had a guitar it would be a song. Alyosha says that sometimes screaming is music. He gives an example from opera. Teacher: "And that can be musical screaming?" Alyosha says yeah but Cory says that that is singing and Andy adds in *loud* singing rather than screaming. Again a lot of children are discussing this. Finally Suni and Benjamin start to talk about rock and roll music and screaming in that context. Benjamin says that he has heard rock stars scream and it's music. Emily asks him how he knows it's music and he says because the person was also singing and playing the guitar and he was also singing/screaming words. Also I think embedded in this was that what Benjamin heard was called music and it was on the radio and on videos on the TV. So a number of different kinds of context define this screaming as music. Finally people seem to agree that screaming could be music sometimes.

Through this conversation and those in the next few weeks the children work on what they think constitutes music. In my thinking there would be three categories of criteria that we might be playing with--intrinsic qualities of the sound (tone, pitch, etc.), relational qualities between the sound (the beat, pattern and rhythm that the children are talking about) and context (music is music because it's in a context where it is labelled music). I had thought that the children would focus on the first quality because this would have been the most connected to the discoveries that we had been making in the first part of our explorations of sound. From that we would work on the second quality because music is an assemblage of sounds. I had hoped that this would be how we would get back to talking about patterns, and what constitutes a pattern, rather than just continuing to use patterns as we had been in the part of this about sound. I had thought that discussions of context would be our vehicle for calling into question whatever definitions we constructed using intrinsic and relational qualities of music. The children though skip the first quality and instead debate at length the relational qualities of musical sounds. There is a continuous interplay with ideas about the contextual quality of music although this

does not become an overt questioning of the definitions of music until the very last class. At times various children (particularly Thomas) remind us that musical sounds have intrinsic qualities but this is not important until the children start to create their own examples of music and they use the different qualities of particular sounds as components of their patterns. But still these qualities are not used to judge the music, it is still the relationships between sounds which is the primary criteria.

Different children define the relationships between sounds differently. They struggle through conversation both to make others aware of their criteria and to define words to describe what they mean. This is complicated by the continuously interactive and social qualities of these classes. The children are trying to explain their ideas to each other as they are formulating them for themselves. Their ideas are a work in progress. In the final parts of this chapter I include a great deal of these conversations. I do this knowing full well that they are somewhat tedious to read and confusing to try to make sense of. The children are changing their minds continuously. It was very confusing to participate in as a teacher. My primary role in this was to keep conversations open rather than focussed between two or three people, to continuously invite new people into conversations. In other words I took as my responsibility keeping the community one that encompassed the whole class. To me it is amazing that a conversation like this can go on for weeks and continue to engage so many of the children. I think that speaks most powerfully to the concept of community that I am developing in this chapter.

Alyosha returns us to hitting the floor, rhythm and beat, adding in things that have come up in the discussion of screaming. He hits the floor once and says: "See this ... *hits the floor* ... is a musical beat but it doesn't have words and it's not a part of a song ...." Suni repeats his opinion that that's not a musical beat. And Emily agrees. She says that it's just a sound. Suni then echoes Emily and demonstrates his idea of a musical beat. He hits the ground a number of times with even and deliberate spacings between the noises. Thomas calls that a rhythm pattern. Then Suni says something a little new. He says that a rhythm pattern is "when you do it fast and other people do it, it is a rhythm pattern." Now Alyosha says: "That has rhythm and it sounds

like some music, it has rhythm and this is just a sound, it doesn't have any rhythm, when you just hit it."

I summarize this: "Okay you just hit it once and then the next time you did it repeatedly and then the next time did it an actual [*pattern of long and short pauses*] something that was different, can somebody play something on that?" I am referring to the xylophone. Most children say no way for some reason--I really don't know why because they showed no hesitation to interact with it before. Maybe they thought being asked to play music meant play an already existing piece of music. Anyway Emily volunteers. I give her the sticks and she plays kind of randomly different notes, with a sort of progression up in tone but ending on a down note, but with consistent timing between notes. Danping says that she thinks that is music and then she amends that to she thinks it's a song. That is an interesting differentiation that I don't ever pursue. I ask Emily why she would call that a piece of music. She replies that "it has the sound of music, of music, and it was well, it's not like this ... *hits the floor a couple times with even spacing between slaps--no change in tone* ... it has different beats to it." Suni picks up on her use of timing to call it music but not on her requirement that it have different tones. He says: "Yeah not like this ... *hits the floor with random timing* ... but like this ... *hits the floor with a rhythm pattern* ... like that." I point out to him that "you could do that on the floor, but it's different when you do it on the xylophone."

Next Suni says that what Emily played isn't a pattern. I ask him why not. This is interesting to me because throughout the rest of these classes Suni will insist that to be a pattern it has to repeat. The consistent beat doesn't make it a pattern. Again though this is at odds with his use of the phrase rhythm pattern. Suni says: "Cause she was doing it in different ways like if you wanted to, it to be a rhythm pattern you'd have to repeat the same thing." Emily responds: "But Suni just like Andy said it's different parts of music hooked together." Now that is not what I heard Andy say but it is interesting. Suni repeats that it isn't a rhythm pattern. I ask if in order to be music it has to have a rhythm pattern. Suni says "sometimes."

Suni now agrees to play a rhythm pattern on the xylophone. He plays three different notes over and over. I ask him if it was music and he says a rhythm pattern. I ask other people if they thought it was music and if Emily's was music, if only one was music or if they thought both were. Thomas says that he doesn't think Suni's was music because it doesn't sound like music. Suni replies that it's a part of music.

> Thomas: Well sure but it doesn't sound very nice.
>
> Suni: I know because you have to put different beats in it.
>
> Emily: And you have to play different notes.
>
> Suni: Except you didn't make it into a pattern.
>
> Thomas: You should play different notes if you want it to be a nice thing of music, now that could be a part for a piano because when you're on the xylophone you can't really hit the two at a time and keep them going but when you're playing piano that could be a nice part, you might go ... *sings it again.*

Suni and Thomas continue to argue this. Thomas making the point that pattern in sound isn't necessarily music. To be music it has to have some "song" in it too. I don't think he ever communicates what he means by song though.

Suni responds rather defensively that he was "just showing you a pattern that's all." I ask Thomas if he thought Emily's was music. He says that yes it was because it had different notes but "it didn't have a rhythm pattern which it really needs . . . ." Emily says that music doesn't always have to have a rhythm pattern. Thomas says that he can play a piece of music with a rhythm pattern and I tell him to go ahead. He plays two, three note series with the same descending qualities. Suni states, "You have to repeat it over and over again." Thomas agrees, "You go and repeat the pattern over and over again except it will have different notes." Now Suni adds that then you have to play different notes though. So next Thomas plays a three note pattern and then plays another three note pattern which is the same but at a different place on the scale. Then Thomas changes the pattern. Suni tells us: "That's a rhythm pattern with different beats." Thomas agrees and says that now he is going to: "make a rhythm pattern with one beat but with different sounds." This starts a new argument with Suni.

He interrupts to claim that each piece of music is one beat. I take it from this that he means each note. Thomas seems to have something of an idea, very foggy, that a beat can contain more than one note in it. Neither of them is able to communicate what they are thinking to each other. I think this is because it's vague and formative for both of them. They keep arguing about it though for quite a bit and this working on the definition of beat continues on the next day and the next few days in even more detail. I fluctuate in all this between letting them work out their own definition and trying to communicate my own. My additions come next time.

Thomas demonstrates a beat containing more than one note and Suni continues to insist that a beat corresponds to a note. Thomas tries to explain that a beat has to do with how you divide it.

> Suni: No no no no I'm asking you why are you saying that you are going to make one beat with different music pieces 'cause that would be impossible, why'd you say that?
>
> Thomas: Well what I mean was ... *plays something with three notes* ... maybe it would be like that, and you'd play all those different notes and it would fit into one beat.
>
> Suni: Well how are you going to get one beat and all those different other different pieces?
>
> Thomas: One beat and all those other pieces? Well if I cut this into one, maybe sixteenth ...
>
> Suni: No no you have to play it ...
>
> Thomas: Play it faster!
>
> Suni: But that won't make a beat, that will make lots of beats ... *Thomas plays about five notes fast* ... see?
>
> Thomas: See that is a beat divided up!

I ask Thomas finally why he did what he did. He replies that it would be boring if he hadn't. Larkin offers her definition of a beat and how many notes can be put into one beat--with a slur. Then she talks about timing and notes having different timing so that one or more notes can make up one beat just so the timing stays even. I ask Sueh-yen what he thinks since I know about his ability to play. He agrees. Neither of them is able to communicate this to the others. The children debate this quite vigorously using the xylophone to try things out.

Cory returns us to the question of whether or not music has to have patterns. He says that it does because he has observed in his brother's music book patterns. I presume that he is talking about the way written music looks, that it forms visual patterns. Suni doesn't think that means *all* music has to have patterns. Alyosha says that they *usually* have patterns.

I send them back to their pods with rubber bands. I remind them of all the things that we discovered about the rubber bands and discussed on the 30th and before. They are to play with the rubber bands and think about what they think music is. I had them write on this--what they did, whether or not it was music and why they thought so.

The meanings of variables, defining words.

May 21st

The class on May 21st starts with me asking that question about what is music. For this class I got three more xylophones, two of metal and one of wood and two glockenspiels so that each pod has their own instrument.

I set up the rest of class by having the kids review the last class for Abeni who was absent. Emily tells us that we had been talking about what sounds were and how sounds started--how sounds are made. Danping says that we talked about what is music. She says that we said that it involved beat which she explains according to Suni that you can't put too many notes in one beat. Suni says if you do that fast, it makes it into a beat. I ask if they have to have beats in music, all agree that they do. Emily says that irregular hitting isn't a beat, it has to be regular. Suni says that is a rhythm pattern. I ask Abeni if that is music, she doesn't think so but won't define it herself.

I remind the kids of what they had been doing with rubber bands and ask them whether or not they thought it was music. Timmy says sort of because it has beat and rhythm. Sueh-yen says also it had rhythm. I ask about being able to make more than one sound. Dan says that the two different sides of the rubber band played different sounds. Tity thought it wasn't music

because the rubber band just vibrates. Thomas doesn't think it's music because there's any one note, he can make more than one rhythm pattern but not different notes. Tity says that even when she did what Dan described all she got were different "sounds" not notes. Larkin says she thinks it can make music because the rubber band is similar to a violin string which vibrates to make music and so a violin needs strings to make music. Tity thinks rubber bands and violin strings are different. Suni agrees with Tity, music can have more than one sound, it doesn't have to, but it can. Danping thinks that with rubber bands, you can make rhythm and different sounds.

Back to their pods in cooperative learning groups they work on the xylophones and the glockenspiels. I tell them to experiment with them to think about what is music. Then as a group in their pod they had to decide what music is and what to show us in the whole group on the xylophones.

Differentiating rhythm, beat and finally pattern is to be the substance of all the conversations until the end of school. That and the role of those three in music. I think these are very interesting conversations. To me differentiating between these three concepts isn't and shouldn't be easy or stable. The differentiation of these words hinges on establishing conventions. In turn, establishing conventions is dialectically tied to the uses the words are put to. This is a fundamental task of a discourse community. The children in these conversations are working on the meanings of these words as they work on their concept of what music and finally language is. They are constructing the meanings of these words in the context of what they are doing and what others are doing and also within a context created by the interplay of the three words. There is an initial assumption, I think, that because these are three different words, they must have three separate and different meanings. In many ways, I am directing the conversation to bruise this assumption. I want the children to look for ways the words are related and similar as well as different and separate. By doing this I am positioning myself outside the developing discourse community and effectively altering the development of conventions. According to Foucault (1979, 1980) a fundamental quality of the process in which discourse communities are created is the creation of dominance relationships between members of the community. I don't

wish for this to happen and I work to prevent this: I keep our conversational referent external to the personal relationships developing in the class. I keep our questions unanswerable. I think this is an important point and one which keeps this classroom community focussed by science, dynamic and shifting rather than becoming established into a set pattern of thinking or interactions. My fundamental goals in doing this are not about the science as much as about shaping the interactions between people. I want people to genuinely value each other and in particular value differences between people. Keeping the science answers receding is a tool in doing this. This is not just a social goal or value for me; it is also intellectual. When voices are silenced, then those perspectives are lost. When we lose those perspectives, we also lose the potential of these to help us understand things differently. I would argue that the accumulation of different understandings adds up to a more profound understanding. Those that don't speak often do so for social reasons. The social and the intellectual converge in a negative as well as positive sense.

The first group (and only group) that presents what they have done on the xylophones is "The Cheetahs". This group is made up of Tity, Paula and Meiying. First they play a pattern (*Paula plays two notes one high and one low and alternating*). Then a rhythm (*Paula plays three notes repeatedly, two are the same and are both two bars played at the same time then a third which is lower and not in a major scale and is just a single note*). Then beat (*Paula plays the same note over and over about four times and then she pauses and repeats that same thing*).

Teacher: So the whole thing with the pause was beat?

Tity: No each note.

Teacher: Now what about music, you did patterns, rhythm and beat but what about music?

Tity: Well I think music is sound and it's something that has rhythm and beat and pattern.

Teacher: So all of those were music?

Tity: Yeah.

I ask the class what they think. I have Paula play the pattern over again and ask if others would call that a pattern. Everyone says that yes it is. Then I ask if people think it is music and again everyone answers yes. I ask Suni what he thinks. He says: "I think it's a part of music, just part of music." Dan says that he thinks it's part of music and music too. I ask Paula to play rhythm again. She does ("The Cheetahs" have written each of these out on a piece of paper using the notation carved on the xylophone bars). Suni says that he thinks "it's a rhythm, I don't think it's really rhythm, I think it's a rhythm pattern because it's repeating over and over again." I ask him if he thinks it's music and he replies: "Uh huh, part of music." Danping says that it is a kind of music. I end the class.

Defining words continued: Comparing/constructing similarities and differences.

May 26th

I start May 26th exactly where I left off the last class. I ask "The Cheetahs" to perform rhythm, beat and pattern over again and start the discussion. I ask "The Cheetahs" first, this time, what they thought was the difference between rhythm, beat and pattern. Paula says that they all sound different. So I ask how do they sound different. I ask Paula what they were thinking about when they decided what was what. This didn't get much of an answer so I tried again. I said: "Well I guess the reason why I'm asking is what you showed for rhythm could be a pattern and what you showed for pattern could be beat and I didn't know what was the difference between the three from what you showed." She adds that to her they all sound like beat except rhythm and that rhythm sounded like pattern.

The children discuss how they created the music that they played. Finally Suni adds: "A pattern repeats over and over again, rhythm doesn't have to have a pattern in it but it can, it can just be mixed things that make it sound like music." I ask him if he can show us an example of a pattern that's not a rhythm. At first he says sure but then retracts: "Well it's impossible to make a pattern without rhythm." So I ask if he can make rhythm without pattern.

> Suni: Well yeah ... *hits random notes with equal timing* ... except it doesn't repeat over and over again.

Teacher: So how is it rhythm?

Suni: It has, like, a kind of beat to it except it's not called beat.

Emily: He means like you can put rhythm, you can put anything in rhythm but it has to, it doesn't have to have pattern but then pattern, it won't be a pattern if it's not one thing, well not one thing but it has to repeat to be a pattern.

Cory: Well this isn't really a pattern ... *hits notes randomly* ... you're just going ... 'cause nothing's repeating.

Suni: 'cause that's not a rhythm pattern.

Cory: I know this is a rhythm ... *hits notes with equal spacing, all notes are different* ... you mean a pattern is [*plays two notes back and forth*] it's got to repeat, this is not a pattern [*hits random notes*].

Teacher: Now listen, there's nothing that repeats in this ... *play the scale descending* ... but it goes high, lower, lower lower, lower, lower, lower, lower, lower, lower, that's a pattern but it's not repeating.

I introduce this because I am thinking that patterns aren't just something that simply repeats or rather the question is, if repeating is the criterion, what is it that does repeat. In doing this pattern, my actions repeat, the change between notes repeats, the timing between notes repeats. Just the actual notes don't repeat. This is a background/foreground kind of argument--what is in the background and what is in the foreground? Defining those two generates the pattern.

Suni says that it's not a pattern. Emily says that it has beat. I have said that I think it is a pattern and ask how could it be a pattern. Suni says that it has to repeat, for music, it has to repeat but all patterns don't have to repeat, just musical ones. Sueh-yen also thinks that music has to repeat. Suddenly Suni seems to change his mind. "Well I never said it really has to, did I? Well it can also make patterns different ways but, um, just rhythm is mixed up things instead of just going one one one, I mean a different way ... you have to do it mixed up instead of like, you have to make it out like a musical sound." Suni subsides to think a bit. Danping says that pattern has beat in it. I ask her if that means it also has rhythm. She says no but it does at least have to have beat.

While the children are saying these sorts of things I think about patterns elsewhere. I mean, I think they are constructing these definitions just thinking about music and what they are doing with the xylophones. Whenever they say something like this I think about the things that they are doing and showing to us but I also think about visual patterns or mathematical patterns or patterns in actions and think about how the things that the children say apply. That's really the source of my counter-examples. When Danping says this about pattern having to have beat but not rhythm I am thinking about visual patterns. It seems to me that to apply her statement to visual patterns, rhythm is the repetition, beat is the substance of the pattern--the design in any one unit of the pattern. Her statement doesn't work with visual patterns at least as I've got them defined. With patterns in numbers maybe it does work. That is the source of my proposed pattern when I played a scale. Here the repetition, "timing"--the relationship between the units--is a constant, the substance isn't. In a scientific equation, say $E=MC^2$ (energy equals mass times acceleration), the relationship between the variables stays the same, the content of the variables can differ in some ways--magnitude--but what is actually being measured stays the same. E is always energy, M is always mass. So back to the number line, the relationship between the numbers stays the same, the content differs. But does it? Actually each is always a number. The magnitude changes. But that happens as a function of the relationship. Very confusing. Maybe this is a matter of where you stand to look at the pattern, what perspective you take. Especially whether or not you stand outside the pattern and look at the meanings of the variables or you assume the meanings and effectively stand inside the pattern. Then you can see the relationships but maybe not the identities. Moving between standing inside and outside the pattern--using the pattern and assessing the pattern--are primary goals of mine in our explorations in the fall and now with sound and music.

An'gele suggests that if all three were put together we would have a little song. Emily says that that is what they did in their group so I ask if they would like to show that to us next. First of all Emily tells us that her group thought that music was pattern, beat and rhythm all together. Then she says that they did this because then "it wouldn't be so boring, for a pattern

you wouldn't do ... *hits two different notes repeatedly one after another* ... it's kind of boring but with all of them, it gets more interesting." I respond: "And you think in order for it to be music it has to be interesting." Emily nods yes. Again this is really interesting to me. This is the reason I embedded this "scientific" exploration of sound in a study of music--to invite aesthetic judgements that we could talk about and examine. I think an overlay of aesthetics characterizes science. The generation of patterns is through the application of an aesthetic (i.e. Chandrasekhar, 1987). Differentiating background from foreground is through aesthetic judgement--judgements based on unarticulated values and relationships between those values. I both want us to explore using such values but also to examine them and how we are using them. Constructing music from sound, as well as deconstructing music into sound, is a part of this process. Understanding sound by defining variables--by seeing patterns--is a part of this process. When Emily says that applying a pattern, beat, rhythm makes it interesting, I think she is really saying that the interplay between pattern and the undifferentiated whole, between foreground and background makes it interesting. The over-application of pattern, so that there is no irregularity, makes it boring. Weaving the irregularities into the pattern makes it interesting.

> Emily: No it doesn't have to but it's just more fun when it's interesting, instead of just going like this [*hits a couple notes*] that's not very interesting, you're just hitting them, well the first thing we're going to do is do all of them together and I wrote down a separate of them.
>
> Teacher: Okay you're going to show us pattern, rhythm and beat together and then you're going to show us the separate parts, could ... um, Cory in a second I'm going to ask you to sit in your chair, could you please give the group your attention ... *Emily plays first a simple pattern which she repeats twice then a pattern on a descending scale then a more complex pattern which she repeats twice then an ascending scale and two simple patterns which she repeats twice* ... okay so that has pattern rhythm and beat together?
>
> Emily: [*Nods*] Okay and now we're going to separate them, this is pattern ... *plays a pattern of two notes alternating then goes down the scale and does it again then back up the scale and again* ... and then this is rhythm ... *plays two notes in a descending scale with one timing, then tree more notes ascending but with a faster timing, then some other stuff which is more complicated and ends with a descending scale with a slower timing.*
>
> Teacher: That's rhythm?
>
> Emily: Um hum and this is beat ... *plays up and down scales with little do da's in them but all with the same timing.*

Teacher: Okay I don't see how pattern, rhythm, or beat were different, how were they different?

Emily: Well pattern is like ... *plays three notes descending then a different three* ... two or three at a time, this isn't really pattern ... *plays random notes* ... it's not an even pattern it's not close to a pattern but this is pattern playing one or two or three at a time ... *plays a scale twice.*

Teacher: Okay and show me what beat is again?

Emily: Okay this is beat ... *plays a little tune with deliberate spacing between notes*

Suni says that this doesn't really sound like a beat, rather it sounds like a pattern "a little." Emily starts to argue with him. She plays a descending scale, hitting each note twice and challenges him: "You call this a pattern?!" Suni responds: "Yeah it's a pattern, beat just keeps going, it has spaces, long spaces." Tity agrees, she thinks it's a pattern too. Emily continues to play and starts to vary the timing in between notes. Suni says that it should have consistent spacings between notes.

Then Emily tells us that: "What we did, what we decided was that we would just do like three or two at a time in patterns ... *plays the xylophone* ... and then we'd just rest for a minute and then go on and do some others and go like that ... *repeats* ... and then we'd rest and we'd go again ... *does it again* .... Danping comments: "Emily when you played the first thing, I think the five notes, or whatever, in between the two notes or whatever, the time was a little bit longer than at the end because, see, when you went like, first, when you went like da do la la la and then at the end you went like do do do do do [*fast*] like that, well that didn't sound like beat to me, it sounded like a song." Emily replies: "Well that's your opinion, it's not our opinion." That's true but still I want her to be able to articulate what she is doing and the base upon which she and her group have decided to do that thing. I think though that is an interactive process--interactive with other children and interactive as the "music" is created and with the creation after it has been made--purposely creating illustrations and also discovering what they have done after they have done it.

Now Alyosha says that he thought what Emily played was a pattern, a beat is much simpler. He plays the same note over and over with no change in timing. Suni says that he

agrees but then he says that "it's a pattern except it's a beat." Alyosha responds: "It's a pattern because it goes a lot of times, but this is a beat ... *hits it once* ... that's why I think it's a beat, then it's in rhythm, well that sounds like a pattern to me."

> Emily: Well we decided that a beat doesn't always have to have repeats, you can just keep on going ... *plays different notes* ... 'cause like every part of music is a beat, music has to have a beat.
>
> Suni: Emily why did you put rhythm in it, when you know you're not supposed to mix things up.
>
> Emily: Well because we decided that a beat doesn't always have to be going like this ... *plays something* ... we decided that you could go like this and put rhythm and pattern in there ... *plays different notes repeatedly.*
>
> Suni: I know but a beat isn't supposed to go like this and this and this ...
>
> Emily: Music has to have a beat, has to have a beat first.
>
> Suni: I know but it has to hit on the same thing each time.
>
> Emily: Not to us!
>
> Suni: Well why'd you think of that?
>
> Emily: To us we think that we can just go like that ... *plays random notes with the same timing.*

They keep on debating what a beat is very much like last class. Emily seems to think it's the timing that defines a beat and Suni the note. Finally I ask Cory what he thinks a beat is. He says that he can't really say, a "beat doesn't go anywhere ...." I ask Sueh-yen. He says: "A steady beat." I ask him if he means that it has the same amount of time between and he agrees. Suni says: "A pattern is when you repeat it with different notes and sometimes you can do the same notes." I think his insistence that beat means hitting the same note is because he is trying out ways to differentiate beat from pattern. Sometimes he says that one is part of the other and sometimes he is working on how they are different and he wants to make them completely different. Finally he says: "A beat is a pattern except a beat just keeps on going going going just like Sueh-yen said, a steady beat."

Emily thinks that he is trying to differentiate between beats and rhythm patterns which she calls pattern beats in which I think she is saying that the beat is defined by the repetition of

the whole pattern. This gets confusing because Suni keeps bringing in different criterion to judge them by. This time he says that the tone can't change. I ask Andy what he thinks. He says that he sort of agrees with both Emily and Suni. "The reason why I agree with Suni is because beats do have, um, one note in them sometimes and sometimes they have different notes that's why I agree with Emily." But Suni repeats: "That's a pattern, beats are patterns too and beats just have to stay on the same bar (note) and just keep going and you can add more beats to make it music." Finally he adds: "You have to keep doing it and add other stuff to it [*I think he is talking about resolving to a tonic*] you can add."

I end class by telling them to write in their notebooks a sentence saying what they think a pattern is, a rhythm and a beat.

Defining words continued: What is a pattern in and out of a context?
Playing with context to think about meaning.

May 28th

On the 28th we start class trying to write paragraphs together that define pattern, beat and rhythm. Emily suggests this sentence "if a pattern doesn't repeat it wouldn't be a pattern." I ask Emily to explain why she said the sentence that way. She explains it by giving an example hitting on her desk. Suni doesn't agree that a pattern needs to repeat.

Danping: If a pattern doesn't repeat it's not going to be called a pattern.

Suni: Yeah but it could be something else.

Danping: Yeah but it can't be a pattern.

Emily: It wouldn't be a pattern, it would be something else, it wouldn't be a pattern.

Suni: Well what if it's called a pattern.

Emily: Well there's two kinds of bats, one bat and another bat. [*Many children are talking.*]

Suni: Well see a pattern could have been another thing.

Emily: I know but it could be two kinds of patterns.

Suni: Or one kind but it's not what the pattern . . .

At this point Emily gets up and goes and gets a dictionary and starts to look up pattern. I ask Shumshad, who has his hand up, what he has to say. He says that he sort of disagrees with Suni and sort of agrees with Emily because "sometimes a pattern doesn't have to be . . . if it didn't repeat, it couldn't be a pattern, and sometime I agree with Suni. I agree with Emily and disagree and I agree with Suni and disagree because, see, you could . . . pattern has to repeat otherwise it couldn't be a pattern and sometimes maybe not." Thomas says that he does think that patterns have to repeat; he doesn't agree with Emily but Emily tells him that she has changed her mind.

Danping: She didn't say that patterns have to repeat.

Teacher: Well she didn't really say it, she just did it.

Suni: Patterns don't have to repeat. [*Many are yelling.*]

Emily announces that in the dictionary there are "tons" of meanings for the word pattern. She reads from the dictionary. "An arrangement of forms and colors, designs, the pattern of wall paper, rugs and jewelry; a model or guide for something to be made, I use paper patterns in cutting the cloth for my coat. A fine example; model to be followed, he was a pattern of generosity. Make according to the pattern, pattern yourself after her." I reread them and after each ask whether or not that works for music. These definitions appear at first to be unpromising except that they link pattern to design, to having a purpose, and to human agency. These are important concepts for me--pattern, design, method are all connected by people purposively doing chosen activities. These activities are chosen with respect to the attainment of a goal. This is something I would like to develop with the class--thinking and talking overtly about this. To do this I increase the dwell time on the first definition.

For the first definition the children say that they think it doesn't apply to music. All are thinking about visual designs. They talk, using the word design until I ask, "Is pattern a design, are pattern and design the same thing?" Emily says that pattern has different meanings. Cory has said that wood has a pattern so I ask if that pattern repeats. Suni says that the wood is like finger prints. I ask if this repeats. Suni says "Well they're a design." An'gele says something

about people who are talking on Mars, who are from Mars, that wouldn't be a pattern because it couldn't be understood by us or recognizable as language by us. I summarize the things that the children have been saying, "You're saying that patterns have designs in them, do musical patterns have designs in them?" Now most of the children seem to think that musical patterns don't have to have designs in them. Teton says that some patterns do have to have designs. I ask him if he can suggest a pattern that doesn't have a design. No one can so I suggest 2, 4, 6, 8, 10, 12 and ask if that's a pattern (I think it's both a pattern and a design, I think they go hand in hand). Some say yes and some say no. Teton says that he thinks it is a pattern and so does Sueh-yen. "Yeah 'cause it keeps skipping two all the time." I ask him if he thinks it's also a design.

Teacher: Is that a design?

Sueh-yen: Ummmm . . .

Danping: And they're all even numbers.

Teacher: They're all even numbers? Does that make it a pattern?

Andy: Even even even even . . .

Sueh-yen: And odd odd odd odd odd . . .

Teacher: And those aren't designs or those are designs?

Andy: Those aren't!

Teacher: So Sueh-yen how about in music does music have designs?

Sueh-yen: No.

Teacher: Does music have patterns like two four six eight?

Danping: No.

But many others think that it does. Danping changes her mind. Sueh-yen adds that "they have certain kinds of patterns but not the two four six eights." He suggests that you can play a pattern like hitting two bars and taking turns between them. I do this and ask whether or not it is a pattern like two, four, six, eight. Everyone says no. I play an ascending scale skipping every other bar. People say that is like two, four, six, eight. Timmy says: "When you skip each one . . . it says out the name, like when you skipped the first one, to me it says, um, two and the

other one says four." Danping adds that "when you write a piece of music, you could use numbers." I ask her how she would do that.

She comes to the board and writes 3 5 7 then she plays those bars on the xylophone. After doing this she explains that you could do this same sequence at different places on the xylophone and the notation for describing this would involve putting "dots" above or below the numbers. If you wanted to sing something along with this you could write the words under the numbers. I suspect this is from one of those little books that come with simple keyboards that teaches kids to play songs. I remember something like this from a present Larkie got when she was four. Sueh-yen has a different suggestion he writes do re me fa so la te do. He calls this the scale and equates the words with Danping's numbers and the actual notation written on the bars of the xylophones. I ask him if it's a pattern and he says yes. I'm not sure if I am getting at or he is thinking pattern in the words or pattern in the correspondence.

I got back to the definitions in the dictionary. I read the first one again and ask whether or not it has anything to do with music but this doesn't get anywhere because Emily wants to talk about more notation for the music. She suggests that when using numbers, the numbers should correspond to the relative positions of the bars from one end. Then letters above or below the numbers could be used to refer to tones that aren't really on this particular xylophone (ones with larger ranges of notes). I ask how any of this could be a pattern though because I don't see how using numbers leads us to patterns that repeat and they have defined patterns as repeating. I ask Danping how her's repeats. Danping says with the dots. Danping, Andy and Emily debate the qualities of their different notations. They get into working this out on the xylophone. Danping seems to be quizzing Emily on whether or not she wants the numbers to just keep on going or if there is some beginning and ending. Danping's scale seems to have implicit recognition of an arbitrary beginning and Emily's doesn't.

Cory asks Emily why her scale is descending rather than ascending. Emily says that it could go either way, it's just what she likes best. The two of them start playing with the scales. They start discussing what of various patterns sounds better and then the two of them together

begin to do different incremental changes to one pattern of four notes. Cory seems to want the pattern to end on a descending note. I ask them why the final choice sounds better to them. Emily says because it's not boring. This goes on a lot longer with different kids adding in what they think of the piece or how they would alter it.

Teacher: I don't understand what any of that had to do with patterns.

Benjamin: Nothing!

Cory: It had to do with patterns.

Teacher: What?

Cory: Well it didn't have anything to do with patterns but if me and Emily kept on, the last one that we made up, that we said was good, we should have kept on, kept on doing that.

Teacher: So this is a pattern ... *play their bit again a number of times* ... that's a pattern [*yeses*] and is that a design? [*yeses and nos*] Who said yes? How is that a design?

Thomas: It's a design in music, well that wasn't just their's, somebody designed it, they couldn't have just said we'll make D D E or something like that, they had to design the music, to make it, they had to make up the notes.

Teacher: So a design is something somebody made?

Emily: They had to go let's try D C C and see how that sounds like.

Teacher: What's the difference though Thomas between your idea of design, which is something somebody makes, and a design in the wood on the table.

Thomas: Well they're designing music not a table, I mean somebody didn't really design it, but they designed the shape of it, of how it would look.

Teacher: Oh I see, so somebody had to decide how that would look and somebody had to decide how that would sound.

Thomas: They designed the wood!

Emily: They had to decide what they were going to do to make this and how they were going to make this, what they were going to do.

I summarize Thomas's definition of design as "something that someone has made so if you play a piece of music like ... *do it* ... that's a design because somebody made it." Then I ask what people think of that. Cory says that he disagrees, a design has writing. Suni doesn't think that has to be true. Different people suggest designs like the school, the color pattern that the cubbies are painted, carpets. I ask again if designs are things that people make.

Tity: Yeah!

Teacher: So if I write a book is that a design?

Suni: Yeah, you designed the book

Tity: If you designed a book . . .

Andy: If somebody else made it, if somebody else invented the book and you put the book together that would, that wouldn't be your design.

Teacher: You have to invent it too as well as put it together?

Andy: Yeah.

Danping: Yeah.

Suni: But army people they design their faces with paint!

Cory says people are designs. I ask him how and he says that "somebody made em . . . if nobody made em then there wouldn't be any of us right now." Some children respond to this by saying that god made people. Some start to disagree with this. Sueh-yen says that people are designs because they choose what to wear, how to look.

Then Emily returns to talking about designing the school. She starts to draw on the chalkboard and says: "A design is, well, if someone said, "well let's build a school," they'd have to design it . . . how they were going to build the school, they'd say, "well how are we going to build the school?" and they'd probably go like this . . . *draws a school* . . . they'd make a school building and they'd make a school and stuff instead of just going like this . . . *draws a scribble* . . . it doesn't really look like a school." So I ask her what she would think if somebody just took a whole bunch of wood and started to put it together to make a school. She says that it wouldn't be a school. Suni says that it would be a building at any rate. I ask the same question again. I am thinking that the act of designing could occur, does occur as the building is going on. I don't think you can really separate out design from building. Also what about building something and then naming it, when is the design in that? What is interesting though is how the children have linked design and pattern through the idea of purposeful action. I would define method as purposeful action that mediates between object and subject. I think this is exactly what they are

doing also. This time Suni responds to my question about just starting with wood and building until you got a school: "Just because you did that-- you designed it-- so it is a design."

> Teacher: It's being designed as I do it, is that what you are saying?
>
> Suni: Yeah but you designed it, you wanted to make it, then you made it.
>
> Emily: But if you were planning on making a school . . .
>
> Suni: That's designing, but you don't always have to plan on it, you can just think it over.
>
> Emily: But if you designed it on a piece of paper and you said this is what my school's going to look like . . .
>
> Teacher: What do you think Teton? Do you think that you have to design a school, if you're going to build a school, you have to design it on a piece of paper first or do you think you're also designing it if I just go out and start banging pieces of wood together and call it a school?
>
> Teton: I think you have to design it because, um . . .
>
> Teacher: On a piece of paper?
>
> Teton: Yeah well you could . . . just if you had lots of people and you do it and each of you had an idea and if you make your idea and if it's at the same place, it's going to be different.

Exactly my point--a design represents a plan, it enables purposeful action, it necessitates methodical, disciplined action, it gives meaning to action. Timmy adds: "They have to do that on a piece of paper because usually they have like a big piece of paper and then they design what they are going to make and then they, when they make it, they bring their paper with them and then they look at the paper so they can design it like they drawed it on the paper." I think he is talking about making sure the outcome matches the design but that's not really what I am suggesting or Teton either. Finally Andy says: "Maybe if you just start banging wood together and you didn't know what it was and you were just banging, like you didn't shape it before, and then when you were finished before you know it, you had a school made."

June 2nd

June 2nd is the last science class. I start class with a hand clap and ask if it is a pattern. All seem to say yes but then I ask if it's rhythm and they also say yes and Danping says it's rhythm but not pattern because it only happened once. To be a pattern it would have to repeat again. Suni agrees with this. So does Meiying but she does a simple repetition and someone argues this is a beat. Cory says whether or not it's a pattern depends as much on the "rests in between." There is a lot of argument about this. Alyosha and Suni say it depends on the regularity of the rests. Timmy and Thomas say if there is at least two, it's a pattern.

An'gele suggests as an example of a pattern that a person grows from a tiny baby, larger and larger and larger and then when they are very old, they start growing smaller again. This is important and we get back to it in a minute. For now though the children continue debating whether or not a beat is part of a pattern or *is* a pattern. Finally Cory says that pattern repeats and so does beat therefore beat is a pattern.

Sakti has had her hand up for a while and I call on her. She says that she disagrees with An'gele, she says that she doesn't think that as people get old they get small again. Danping and Emily both say that they do. Paula says not all of them. Cory says they shrink and giggles. Shumshad says that he doesn't think that they go as small as a baby. I ask An'gele to repeat her claim. "When you are a baby, you are maybe about this big and then you get bigger and bigger and bigger and bigger, when you get older, you sort of you loose your balance and you go like this [*hunches over*] and it looks like you are shrinking a little bit." Sakti and Emily continue to disagree. Sakti refers to her grandmother who hasn't shrunk. I ask Sakti if it would be okay if we amended An'gele's pattern to *some* people. She nods yes. Emily though still disagrees: "It can't be a pattern if you're born about this big and you get bigger bigger bigger bigger until you get old and then you just shrink a little bit ...." I remind the children of an old pattern we talked about in the fall, of the bricks in the slide. I sketch it on the board to remind everyone. Then I continue: "It went bigger bigger bigger and you called that a pattern . . . you said that was a pattern because

it went bigger bigger bigger bigger? So how come it couldn't be a pattern, as a child gets bigger bigger bigger you know that's a pattern." This is like the two, four, six progression. I ask Sakti what she thinks. She says that it takes a long time for a baby to grow. I'm not sure if she doesn't want to call this a pattern because she thinks it takes too long to see a change or if her point is that the change is continuous--there are no discrete "bits" to form the units of the pattern. Suni says that taking a long time doesn't matter; it can still be a pattern. Emily says that she still disagrees with An'gele because even if old people do grow smaller, they still don't return to the size of babies. I ask her if she thinks that a person would have to return all the way back down to a baby's size for it to be a pattern--does it have to be a complete cycle? "Yeah she'd have to go small bigger bigger bigger bigger small bigger bigger bigger bigger small bigger bigger bigger small." I ask again about the pattern in the bricks or just about a pattern that continues to progress. Cory and Tity both don't think it's a pattern. Tity: "It just goes up up up up." Suni and Danping do think it's a pattern. Danping: "Well I think it's a pattern 'cause it keeps going up though." Abeni thinks it has to go up and then go back down.

> Suni: Well, um, what Abeni . . . well when it grows up and up, it doesn't have to stop, just like a new baby doesn't stop, see just like numbers, they always grow, they grow and they don't go smaller.
>
> Emily: They go one two three four five six seven eight nine ten but if they were to grow smaller, then they would go one two three four five six seven eight nine ten ten nine eight seven six five four three two one!
>
> Teacher: Right and they don't they just keep one getting bigger and bigger, is numbers just getting bigger and bigger, is that a pattern? [*yeses and no's*]
>
> Cory: No 'cause they never get smaller and smaller.
>
> Suni: Yes they can if you count them backwards [*different kids are doing this from different starting places*].
>
> Teacher: Um, I heard what Emily said, she said it would be a pattern if you count backwards forwards backwards forwards but is it a pattern if you just start at zero and count forever? [*Nos*]
>
> Suni: [*Sonny shakes his head.*] 'Cause your just repeating it, repeating, just repeating it and that's a pattern 'cause it's repeating.
>
> Emily: Repeating what?
>
> Suni: Repeating like growing . . .

Benjamin: Numbers.

Suni: . . . they keep going and that's a pattern too [*many talking*] well that's a pattern too, numbers are patterns going backwards and forwards.

Shumshad: I agree with Suni because see they're growing and growing . . . first it grows a little, then it grows a little more and then it grows a little more and that's a pattern.

Sueh-yen: Well I think the numbers . . . when you just go zero and up and forever is a pattern because every time, when you get to one thing, there's always a zero and then one two three four five six seven eight nine and then a zero and then one two three four five six seven eight nine and then a zero and the numbers are five or six or seven.

I end this part of class. I feel that through talking about pattern in such a number of different contexts we have come to examine quite thoughtfully what we mean by the word. We have done this also by examining examples of patterns--what the word means for different sorts of pattern, musical, visual, numerical--and by seeing how we could use patterns to construct other things. Examples of the latter are when the children composed music, when they worked on musical notation, when they talked about building a school, when An'gele discussed how talk from an person from outer space, an alien's language, wouldn't be a pattern because we wouldn't be able to understand it.

I have one final place in which I would like the children and myself to think about patterns and music. I had planned that today, the last science class, we would listen to bird song. My idea in this is that bird song varies in pitch and loudness in very complex ways which are hard to describe. I want to see first of all if the children would call these patterns and then how they would articulate the components of the pattern. I don't think this is a simple task but it seems important from the way that the children up to now have been defining pattern, beat and rhythm. I want to know whether or not the children would call bird song music and what the criteria for that might be. We start by looking at some feathers and I tell a story, then we listen to bird song. The bird song is from the Peterson *Birding by Ear* (Walton and Whanson, 1989) tapes out of which I have edited the talking.

The first song I play is of the carAminal. There are both the call and the song and each is repeated three times. I ask if the children think that is music. Andy says yes. Emily says "bird

music." Other children are saying both yes and no. Thomas says that it is music because: "Well some people might think it's not, some people might think it's pattern or beat, I think it's music, it sounds good, it has beat, it has pattern and it seemed like it to me." I ask what music has that pattern and beat don't have alone. Thomas says that music doesn't have really big spaces. He uses an example from the tape: "At the beginning they have a peep peep peep that was not music that was just the beginning."

Danping says that she thinks it was music because it had a pattern. I ask her if that is all it needs and she says no, it also needs rhythm and beat. Suni says that it doesn't have to have beat: "I don't think it had to have beat, but it did have a kind of pattern, it went chewww, cheww, chew chew chew, but it went like chewww, chewww, chew chew chew chew, chewww, chewwww, chew chew chew chew when it went like that, I think that is a pattern 'cause it's repeating."

We listen to a meadowlark next. Tity says that she thought she could hear a pattern. I ask her what the pattern was and she says that she can't say. So I ask how she knows it is a pattern then. Sueh-yen says because it repeats. I stay with Tity and ask her if she needs to be able to say how it goes to be able to call it a pattern. She says that she doesn't know. Suni does think it's a pattern and he articulates the sound that he thinks repeats. Alyosha doesn't think it matters if you can describe what repeats just so it does repeat. Abeni thinks that it is just beat not music. "When they repeat that pawwk pawwk pawwwk pawwwk over and over again I think that's a beat but I don't think it's music."

Next I ask how the children think birds make their sounds. Danping says that you'd have to test them to find out. Shumshad says: "I think that's their language because we have a language, because if there was a giant and we spoke their language and it was just like the birds . . . so those would be words that they are speaking, so it might be just like our language." I ask how we make sounds. Shumshad says from our brains. I ask if it's made in your brain. "You can't talk but you know what you talk about and your brain helps you a lot." To me this is a lot like the discussion of design as purposeful action last time. Bird song or language is the result of

design. Emily, Alyosha and Timmy disagree with Shumshad. They claim that bird song comes from various parts of the mouth and throat--Alyosha, the uvula, and Timmy, the tongue.

Many start to talk about that. So I ask if you can make sound without talking. Thomas and Emily says yes and Emily adds that she knows a person who has had her tonsils taken out and she can still talk. Alyosha says you need the thing in the back of your throat and your tonsils. An'gele says that you can't *talk* without your tongue but you can make noises. This is interesting--it's not what *you* mean by your noises, it's whether or not others can interpret them that constitutes talk. Andy agrees and I ask him where the noise comes from then.

He says from your throat but he indicates in your neck. Suni says that when you talk you can feel something in your neck but he can make a click with his tongue that he can't feel in his throat. Sueh-yen says that when he talks he can feel what he says. I ask him if he means he can feel the vibration. He says yes and then he does Suni's click. Everybody starts experimenting with that now and seeing if they can feel it in their throat. Some say they can, some say not. Andy says you can't because "it doesn't have anything to do with your neck or throat it only has to do with your tongue and mouth."

I remind them that they said before that sound happens because something is hit and it vibrates so what is vibrating for us or for a bird. Cory says he can feel it vibrating when he talks in his throat. I ask how they make it vibrate, they don't hit anything. Abeni says that her voice is vibrating. Alyosha says that the thing in the back of his mouth moves, when you scream it goes up and if you aren't so loud it goes up just a little bit. Andy says that he thinks when you scream your neck vibrates. He points to his voice box but calls it his tonsils. I ask if that means it's making the noise or is it vibrating because of the noise. Andy says because it's making the noise. Suni says that "air waves push through your neck and then when it goes through this part, it makes a sound."

> Teacher: So the air waves moving though your neck vibrate and when it hits that part, it makes a sound.
>
> Suni: Uh huh.

Shumshad: See, um, I don't think we should talk about this anymore, we are talking about birds we aren't talking about humans.

Teacher: Okay do you have anything more to say about birds? How do you think birds make noise?

Shumshad: Maybe same thing.

Teacher: Like what Suni said the air moving through vibrates and . . .

Shumshad: I think when you scream in your throat, it's not loud see when you do it, it's not loud but when it moves [. . . out through your mouth . . .] I think it widens and then it makes the voice louder, that's what I think.

Teacher: And is that how birds work?

Shumshad: Um, maybe.

Teacher: Do people think that birds make noises the same way that we make noise. [*nos*]

Abeni: I don't think that birds make sound the same way that we do because birds, you can't understand their words.

Danping: Yeah I kind of agree with Abeni because maybe they're not singing, maybe they're communicating.

Emily: Okay say this was our throat, it has a whole bunch of stuff in it like the bones and stuff, then there's a little thing here that helps you talk and then this is a bird's throat and it doesn't have anything circled so it can't speak, so they have a certain thing that makes them talk but they don't talk like we do 'cause it has a different thing than we do.

Teacher: So the inside of their throat is different, is that what you are saying?

Emily: Yeah 'cause if they talk different from us, then they've got to have something different in their throat.

Conclusion.

In this last class the children argue about three possible examples of pattern and design--a child growing, numbers and bird song. In all three instances, they apply and therefore test their working definitions of pattern, beat, rhythm and design. Within the context of the child growing and numbers, they seem to be continuing their contemplation of the meanings of the word pattern. There is a sense of their weighing meaning against example and thinking critically about both. In thinking about bird song, my attempt to get them to think about pattern in this context

seems to 'cause the children to juxtapose music to language. In this instance, through being asked to think about the meaning of pattern and music in this new context, they thought about the phenomenon--the context itself, bird song--and argued that wasn't music at all but rather language. They reassessed the phenomenon, the context.

The children in the course of this unit have engaged in seeing patterns (in the xylophones, rubber bands, guitar and the sounds that they make). Seeing patterns in these contexts means reducing the whole of the phenomena into parts--seeing variables which can be correlated. Because seeing these variables was intertwined with seeing the patterns and correlating the patterns (these last two are fundamentally questions), the children became engaged in developing patterned ways of interacting with the music and sound and with each other. They developed a method--a patterned way of acting and interacting around a mutual purpose.[22] This is at the core of community: shared purposes, shared ways of acting, shared ways of talking. It also comes about through knowing each other: another aspect of acting in patterns--when Suni or Emily, for example, speaks, others know to an extent what to expect.

When asked to examine sound within the context of the question "What is music?" the children again reduced music into variables and began to argue about the meanings of those variables. Defining the meanings of those words--the variables--meant defining what they are and are not. What different words share with each other and what they don't. Finally it meant weighing the developing meanings of the variables against the phenomenon, music. To define music with solely the variables the children chose--beat, rhythm and pattern--excludes many qualities of music, tone and aesthetics for example. The children debated the usefulness of their variables to capture what they thought was important about music. Often by trying to apply just their variables they found that did not describe what they wanted. They thought about both how music is composed of their variables and also about how it is more than just those variables.

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[22]Note this is a different way of viewing the meaning of method in science from that commonly cited in philosophical works about the nature of science, i.e. Rorty (1991) *Objectivity, Relativism and Truth: Philosophical Papers*, "methodical: ... to have criteria for success laid down in advance." In a social sense I am agreeing with this definition however: to successfully communicate with each other the criteria for interaction must often be laid down in advance.

Through these discussions the children worked on both the development of a language as well as "ways" of talking--acceptable ways to present and debate their ideas. Aspects of this process parallel those of a discourse community. Unlike a discourse community, however, I saw my role as teacher to be one of preventing the development of conventions and hierarchical relationships of power between the children. I try to keep the conversations of the community from reaching closure by keeping the referent point of discussion external to the relationships between the children--the referent point was what does our discussion tell us about the phenomena, not just what use can we put our knowledge to. In this way the community remained dynamic--it's purposes, questions, methods evolving. In effect the community formed through the medium of our exploration of science. The science was not an end point to the community but rather the opposite: the science was a tool in the formation of the community. This of course was not my intent. My intent was that the children acquire "habits of action for coping with reality" (Rorty, 1991). This, though, can be regarded as at the core of a community[23] and expressions of, conversations about, this activity, its result.[24] The development of patterns of acting--of method--is a manifestation of and a tool in the construction of community.

In the course of their conversations about music, the children came to discuss the meaning of the word pattern and also design in both senses, as noun and as verb. I felt the children reflected on the meaning of the word "method," although this was never explicit, in a number of contexts. The discussion of method--purposeful action--grew out of the discussion of design which in turn grew from the discussion of pattern. The three are linked.

Finally in the context of a discussion of the growth of children, numbers and bird song, the children used their ideas of the variables of music and patterns to assess whether or not those three things were patterns or music or designs. In doing this, they again thought anew about the definitions of those words and about the classification, the nature of the phenomena, itself.

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[23] For example see Marx (1983) Theses on Feuerbach.

[24] "Dewey...*any* philosophical system is going to be an attempt to express the ideals of *some* community's way of life" (Rorty, 1991).

CHAPTER 4

KNOWING

The focus in this chapter is, in a sense, on me--the things that I do in the class and why I do them. That is not to say that the previous chapters were not also about that. I think that in the stories that have preceded this, I wished to communicate that my role was both proactive and reactive. I chose the science that we were exploring in class and I responded to the children's ways of shaping that science. This rarely, though, meant a fundamental alteration of my original choices. In this chapter, I have to choose between the science and maintaining the classroom discourse. There are many fundamental choices that I have made, moral, emotional and aesthetic, about how I manipulate the children into interacting with each other as well as with the science. I hold those values more important than engaging the children in the science. In many instances in this chapter, I recast the science so that I can maintain my values about the discourse.

In the other chapters I make the argument that the classroom community is shaped both by the ways that I encourage the children to interact with each other (respect for each other and each other's ideas) and by what I feel is a genuine engagement the children have with the science. I have up to now emphasized the latter--that it is the sense of shared purpose that enables the construction of ways of interacting. This is not entirely true, the community of the classroom is dynamic, its purposes and focuses shift and reshape themselves as our explorations evolve. The constant is the way the children interact with each other. Because I require the children to act in a certain way, the focus of the community can change without the community dissolving. The children value each other and so they value expressions of new ideas which become new

purposes as more and more children participate in exploring them. (Remember these ideas are expressed primarily as questions and assertions--this enables exploration and discovery, method and purpose.) In the classes in this chapter there is a greater tension in this choice for me between the science and the discourse. Often in order to maintain my ideals about the discourse, I reshape the science radically so that we can respect each other's ideas. In order to maintain the sense of a community with a shared purpose, I abandon the science that I want to be doing (exploring simple machines) and allow the children to shape a new topic (the solar system). Finally when I want to stay with one particular topic in the science and not allow the children to reshape it, I invite conflict in the class, either by introducing discrepant theories myself or by allowing children to argue ideas out. It is a measure of the strength of the children's valuing of each other that this conflict does not disrupt the community. I do this rather than explicitly telling the children science. I do not do that because it seems a violation of my ideas and goals about the development of a community in the class. On the other hand, I am uncomfortable with the role of manipulating the children into acquiring knowledge that I have already pinpointed. This seems a violation of my ideals about respecting and valuing the children. It makes me feel like I am not a member of the community with the children. I think this is at a fundamental level the source of my discomfort with these classes.

A description of the unit on the solar system.

In this chapter I write about a unit I taught in third grade on the solar system. This unit developed because of the line of inquiry that the children and I evolved during an exploration of simple machines. We went from machines to the solar system because of an experiment that we had done from the children's science textbook using inclined planes. In this experiment there was a lot of confusion about why the weights of objects being pulled up inclined planes of different slopes would differ. From this we started talking about gravity--what is gravity, where does it come from, what are its effects. From gravity we moved to the Moon and planets, thinking about

gravity as we talked about the motions of the planets intertwined with talking about the planets themselves because that was what the children wanted to do.

If I think about *content*, this unit had four stages. The first was its beginning, while we were working with simple machines. That was when we started talking about gravity. In the second stage we started to talk about the bodies of the solar system but this was so we could understand gravity better and could then get back to machines. In the third stage I realized we weren't getting back to machines and let the children take over choosing the direction of the class's explorations of the solar system. I would call this part of the unit "developing a shared body of knowledge and language and ways of talking about the solar system." It enables the final stage: the children's conversations and sharings about the planets in the third stage make the conversations about the workings of the solar system possible. In these conversations the children return to talking about gravity.

Talking about *content*, which is what actually happened in these classes, obscures the emotional and intellectual groping that shaped this content. Writing about this unit is writing about curriculum construction. This construction was by me and by the children. As we construct the curriculum I articulate my beliefs and values--through this process I give shape to what was ill defined, amorphous, part of a continuum. The first and most important statement that can be made about these beliefs is that this construction/articulation occurs *during* teaching (Heidegger, 1962; Schwab, 1976). The beliefs articulated are done so reactively--in reaction to the things that happened in class--as well as pro-actively--in order to shape the things that will happen. They are defined by context. What is done in class is not an *illustration* of pre-existing values. What is done in class is those values. I am saying this strongly on purpose. Let me give an example to explain why.

To say a teacher respects children has no meaning without giving substance to that respect; without illustrating how the teacher acts on that respect and the children are able to act within that respect. Giving substance to an amorphous statement like "I respect children" involves instantaneous choices and actions made emotionally as well as intellectually and which

appear rational and intellectually defensible retrospectively because they leave historical artifacts--the content described in the previous paragraph. Values and beliefs such as respect for children are *known* things though, but this knowing often isn't articulated until suddenly their embodiment appears before me.[25] I am not saying that this knowing is without intellectual qualities--it has those but it also has intimately intertwined emotional and even sensual/aesthetic qualities.

This is about "knowing" certain things--a "knowing" that enables acting. Not "knowing" because the things known can be "articulated"--stated--but rather because those things develop an articulation as they are given substance through what is done in class. The values and beliefs that I think are being articulated concern how people should interact with each other within the context of science. The science is shaped by this as much as the interactions are. In order to enable each child to participate in the inquiry, this unit is about inquiry itself--asking questions (which is by articulating what you know as well as don't know) and working on answers (which is through feeling and judging as well as thinking). The subject of the inquiry is the solar system. That's the vehicle. This is not a unit about learning facts about a particular area of science although it does contain some of that. It's about thinking in science which is something created by people and therefore has people in it. And science, which is a living, growing thing (to me anyway), has people interacting. This interaction, between people and between people and things, is how it grows. I am not saying that the way the science is portrayed or the way I want the children to interact reflects either science or scientists as I have experienced them. I hold the value that *all* should participate first and I rethink and reshape the science to make this possible. I do this by looking for ways and places that other ways of thinking and knowing--emotional, religious, aesthetic--intersect with the science.

The particular conversations that I have picked to talk about are places where the children and I illustrate various ways of knowing, thinking and interacting, all of which are both intellectual and otherwise, scientific and otherwise. The conversation between me and Timmy

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[25]I am awakened to this self knowledge (Habermas, 1991).

and Jin about gravity and gravity boots is about the relationships between theorizing, questioning and the phenomena. It's about how different explanations work depending on your purpose. It's also about the relationship between knowing, thinking and taking chances. The conversation between Ricardo and Yong Sun about whether or not the Moon and Sun will crash into each other is about the same thing and also about people trying to understand each other rather than just asserting their own ideas. The conversation between Daniel and Yong Sun about the word satellite is about meaning and understanding of words in context and in isolation: Can fundamental meanings be defined?[26] The conversation about the orbits of the planets about the Sun between Jin and Joey is about portraying what you know, knowing with certainty but still having this "knowing" being questioned and changed. They both portray their knowing as "certain" because they are attempting to communicate their ideas to one another. But because they are attempting to communicate, which also means to hear and understand what another is saying, each child's "certainty" is infused with inherent yet unstated uncertainty. Because they are talking to one another, a statement of knowing becomes a statement of not-knowing (Heidegger, 1962; Wittgenstein, 1969; Habermas, 1991).

The reason these conversations portray science in this manner is because *I*, the teacher in this class, choose to portray science this way. I actively shape this class to conform to values and beliefs I already have about science, about children and about how I think people should interact. I also shape these classes as those values and beliefs take on substance through the concrete realities of what is actually happening, the questions and observations we have about the science, the ideas and qualities the children articulate, the emotional as well as intellectual ways they interact with each other and with me.

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[26]Can meaning be divorced from use and context (Wittgenstein, 1968)?

What do you measure when you weigh something? Finding fundamental questions.

February 27th

I started this "unit" in third grade[27] on machines at the end of January. Up until the class before the following class we had just been exploring the terrain of simple machines and definitions of the word machine. In the class before this story starts we did an experiment in the book about inclined planes.

On February 27 I started class with a return to a discussion we were having previously about an experiment that they had done in their science textbooks in which a weight attached to a spring scale is pulled up a short inclined plane and a long inclined plane. The height each plane is raised to is kept constant as is the object weight being pulled but because the length of the board varies, the steepness of the slope changes. This means that the effective weight being pulled changes--the shallower slope gives the lowest weight, the greatest weight is from pulling straight up. This change in apparent weight is a measure of the work being done to lift the weight--more work for more weight or, conversely, the efficiency of the machine at helping decrease the work that you are doing. Of course all of this neglects frictional pull on the thing being dragged.

This experiment is, I think, pretty confusing because of the use of the two different boards--it's not obvious that what you have done when you change boards is change the slope--rather children say that they've changed the length that they drag the weight along. Also embedded in making sense of this experiment is understanding what you are actually measuring when you measure the weight of something--where that weight comes from. Weight (of something moving at the same relative speed to its surroundings) is derived from the interaction of the object's mass and gravity and gravity is also a function of mass. So the object itself has its own gravitational field too. Gravity is a measure of an attractive interaction between two bodies

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[27]See Appendix I for a description of the school and classroom setting in which this unit occurs. See Appendix II for a discussion of children's pseudonyms.

determined by mass if the bodies are stationary with respect to each other. At least that's the way that I think about it (I think about the relationships F=MA and $F=G(M_1M_2/r^2)$ in which F is force, M is mass, A is acceleration, G is the gravitational constant and r is the distance separating the two bodies, and think about the way those fit together in pictures I construct in my head. I do think about how space around a body is warped by a gravitational field and how objects with less mass fall down the contour lines of that warped field as analogous to a glass of milk spilling in my bed--these three images/things fundamentally shape the science for the next month.

It occurs to me here that I should say something about my background in thinking about the science that is about to come up in this story. As a child I was absolutely fascinated by astronomy. I read anything I could get my hands on in this subject. Primarily the sort of "popular" science books written by Isaac Azimov or George Gamow. I think in this I had a lot in common with some of the little boys in this class, particularly Yong Sun. In college I continued to take a number of classes in astronomy. My very favorite class in college was in astrophysics. Astrophysics was the place were classical physics finally started to make sense to me I think primarily because in that class there was an assumed understanding of differential equations and because of the kinds of understandings mechanics were used to construct. For example, it never made sense to me to think of acceleration as velocity divided by time but it does make sense to me to think of it as the *change* of velocity over time. Then constant acceleration becomes a special case. And this made sense to me because I could think about it in terms of orbits of planets or more accurately I could deconstruct what I knew about the orbitals of planets and come up with equations from mechanics and suddenly I could see how they worked. I really liked this feeling.

When I went on to teach, as well as teaching in my field, in crystallography and optics, I taught a course on Earth Science which was a "service course." It was a full-year course, extremely highly enrolled and it was the major way our department funded itself so everybody taught it. It was roughly divided into a half-year of geology and a half-year of atmospheric science and astronomy. I always taught the atmospheres and astronomy half.

Anyway at the end of the last, third-grade class I had asked which experiment was easiest and most people said that pulling straight up was easiest because experimentally it was the simplest. We started with a recap of that. Although most children thought that pulling the weights straight up was easiest, Selamawit thought the short board was easier because the distance pulled was shortest and Yong Sun thought the long board was easiest because it required the least amount of work. He knew this because the numbers for this experiment were the smallest. The trick here is what the numbers mean. I ask Hamal this. He replied: "It means whatever you weigh, the number, it means that's how much it weighs."

I ask John and Daniel what they think. All agree with Hamal that the number signifies the weight of the object lifted so I ask: "Do you actually think, I mean those numbers though are different, when you did it on the long board you got a different number from the short board and when you lifted it, do you actually think it changed how much it weighed?" This to me is the key question to seeing how they are making sense of the experiment and also leading them on to try to work on making sense of what they have done. It's my confrontation of what I suspect is a place where they have *stopped* having it make sense. Where they are either being passive or trusting or are invoking magic. The children answer my questions with both yeses and nos. Yong Sun yells out "Always weighs the same!" I choose though to call on Joey to comment on this rather than recognizing Yong Sun and then quiz Joey to push the class on this. So I chose to ask Joey to speak for two reasons: I am checking out Joey who I would like to bring out in class more and who I think knows a lot. I also don't want Yong Sun to talk yet--Yong Sun is recognized as knowing a lot and I want to hear more of what everyone is thinking before I focus the argument. That is how I use Yong Sun: to focus or redirect an argument. To excuse my not recognizing Yong Sun, I remind the class about the hands up rule. (This is a convenience, this rule, that I use as a controller in many ways involving social stuff and content and personal relationships with the different children. It's a rarity that I cite it for Yong Sun.) Then I call on Joey. He says that it always weighs the same but I push: "So why are the numbers different?"

Joey: Because when you have to pull them up different heights, 'cause when you lift it, it goes all the way down [*the pointer on the spring scale*], as much as it weighs, but if you pull it up something, it won't say as much as it weighs.

Teacher: So if you pull it up different heights it weighs more or less?

Joey: Um . . . less.

Teacher: But it actually doesn't weigh more or less it stays the same weight ?

Joey: Um hum . . .

Teacher: Why does it seem to weigh different?

Joey: Because you're not pulling it up the same thing every time.

Teacher: Oh so it has something to do with what you're pulling it up . . .

Joey: Yeah.

Teacher: What do you think Kristin?

Kristin: I disagree. I think it's different, 'cause I can prove it . . .

Kristin points to the numbers that her group has recorded on the chart. For one experiment they are very different; her group measured 150 grams and when she did it alone she measured 250 grams. I had watched this group do the experiments quite closely because Kristin presents a social problem in the class and in particular in her group--Kristin wants to be "in charge" and her group won't let her. Anyway they got very different numbers because they measured differently. This is obviously a valid issue in scientific experimentation. I let Kristin explain what the group had done and then I asked for comments. Ricardo responds that he knows that the object keeps the same weight and the apparent weight change in this case is "a mistake." I table this (we return to it at various times later because it is important: knowing whether or not to think about or reject an unexpected or out-of-the-orAminary answer is really important in experimental science) and redirect the conversation back to comparing the numbers *between* experiments.

Teacher: So the difference . . . when you weighed it on the long board it weighed 70 grams and on the short board it weighed 110 grams and when you lifted it straight up it weighed 160 grams and that was just because you made mistakes?

Ricardo: Uh no, 'cause like with the first time we got three ounces but it was really supposed to be 2 and a half ounces.

Teacher: *That* was a mistake. But what about the difference between on the long board you got three ounces and on the short board, I can't see, you got four ounces and lifting you got five and a half or six ounces. What about the differences between the different experiments?

Ricardo: Oh 'cause one takes the most force and one takes the middle and one takes the least force. So . . .

Teacher: So the numbers aren't just weight, they are also a measure of the force? Do the numbers have something to do with the force?

Ricardo: Yeah.

Now suddenly we have here introduced an *IMPORTANT* word but whenever this happens I know that it's also a magic word and suddenly I get all stressed out trying to keep the conversation centered on examining *that* word in *this* context. It's like when Bullwinkle pulls a rabbit out of his hat and it's a lion. In some senses he's pulled off the trick but it's starting to go completely out of control. I feel like this conversation which is flowing and has it's own rhythm and which I am shaping by following, suddenly I have to stop the waves, hold it in one place. But not really because we would work on what the word "force" means as it is applied by the children--the class would still moving and evolving. So there is this *tension* . . . And in some senses "force" is a truly magic word. What does it signify anyway? It is a word we invoke to silence questions. A rabbit in a hat that makes relationships between other real data, measurements, observations work. Forces aren't *things* we can talk about directly. We can only talk around them.

Rather then going with the flow and letting Ricardo keep on talking, I call on Joey for comments. Joey is of course in a different place: "Um it can't change its weight because it's not a thing that's living" which is a wonderful statement that normally I would draw out, but no we've *got* to talk about force now. I recapitulate the question/answer dialogue. "What do you think about what Ricardo said about why the numbers are changing?" But I get no real response. I try Mwajuma. She responds that the object pulled did weigh differently on the two boards but not because it really was a different weight but because " . . . you pull it more [on the short board] and [on the long board] you don't pull it so much." The key phrases in this statement are around

pulling the object and around differences in magnitude of pulling That *is* a definition of force but rather than relating this to the change in slope of the two boards, Mwajuma connects it to the length of the boards and again Hamal restates this: "When you pull it on the long board you pull it longer and when you pull it on the short board, um, you pull it um, in not that much time and when you lift it, all you do is lift it up."

I stop the conversation at that point and have them redo the experiment just using the long board and dragging the weights up a slope constructed with different numbers of books (6, 3, 0--pull along the flat board) and also lift them straight up. Between this experiment and the class having a conversation about the results a week passed. This happened because Sylvia Rundquist, the classroom teacher, wanted to have the children read in their textbooks about simple machines and also she took one class period with them to talk about wheels. In the middle of this class on wheels I started to think about how hinges are so similar to wheels that I didn't understand how they were different. After class I tried to tell Sylvia about this and said that I thought the difference was around the perspective you took on what was moving relative to what was stationary. After talking about this for a while I went home and had this insight about how both wheels and hinges were reducible to inclined planes. That's why they seemed so similar to me. Then I started thinking about the other simple machines as reducible to inclined planes. This was getting me very excited because all those vector diagrams I used to just memorize were starting to seem like they might make sense. I had always thought of each of the simple machines as unconnected before this. This seemed to me what I *really* wanted to do with the kids in class--explore this idea.

So finally in class we come back to talking about this second inclined plane experiment a full week later on March 10th. I start by reviewing the problem with the children and then having them take a couple minutes to discuss their results in their groups and then start the conversation. Dembe is the first to present her group's numbers: "We got one hundred grams and 3 and 1/2 ounces, oh, we got 110 grams or 4 ounces with six books and 3 books we got 80 and we noticed that each time we used less books we got less ounces or grams and so it doesn't

weigh as much ... Lifting it weighed more because you have to pick it up and lifting it you used energy and the weights are very heavy ... because when you're using a board you can just lift it up on the board and you can lay it on there instead of having to pick it up yourself." Ricardo, though, continues to argue that it's easier to pick the weights straight up. "I think lifting is still easier 'cause all you have to do is wrap a spring scale round the things, put it on and then lift it."

Timmy clearly disagrees and starts a discussion with Ricardo. I remind them again about the hands up rule--this happens a lot in this class and is a measure of the level of animation of the discussion going on--and then call on Kristin. She says that she agrees with Ricardo, that it's easiest just to lift the object rather than drag it up any of the inclined planes. But when I ask her for her reasons she is back to talking about the experimental conditions not the actual results of the experiment itself. So again I ask: "But how come if it's easiest it weighs the most?" Kristin starts to answer but Dembe cuts her off: "It uses more energy!" [Another magic word!]

Teacher: It uses more energy to lift it?

Dembe: Yeah because like for example on the board you can just slide it instead of having to lift it.

Timmy: Yeah but ...

Teacher: Hands up ... Timmy?

Timmy: Yeah but you have to get all the stuff ready with that after you've done the rest you just pick it up ... now you don't have to lay anything down you just do it!

Dembe: She's not talking about that she's talking about how come it weighs more when you lift it.

Timmy: Because because you're just pointing it down you're just pointing it down, that's all you're doing.

Timmy gets very excited when he talks in science class. He also gets all tongue tied with his ideas. He does a lot of thinking out loud--he seems to come to class with quite a good store of outside knowledge on the various topics that we talk about but not to have thought about them in the ways that I like to try to encourage in the class where connections between ideas and between ideas and observations are important. I put quite a lot of pressure on him in many

classes to work to reconstruct his knowledge and understandings to enlarge their applicability and the connections between the things that he knows. I do this for two reasons primarily. He does do his thinking out loud so that other kids can participate in it and he does this quite happily. He seems to enjoy it when I push and pull on him and his thinking and to enjoy it when the other children join in. I don't mean to imply that he is playing a game with the discourse and the content in the class because that would be far from the truth. He is very passionate about his ideas but he seems to enjoy the stimulus of the class's discussions and challenges. I feel that my relationship with him is quite special. We like each other a lot. One thing that is interesting though is that while I really value his chance taking and mistake making in the class, Sylvia listening to the conversations in the class and labels his ideas "misconceptions," I respond to her that I think that those are things that are constructed in the class through the discourse that Timmy and I engage in in the class. I think this is interesting because it illustrates the subtlety of what it means to participate in the loops of logic the children are articulating. I am detailing this right now because of Timmy's big role in the next few classes.

I should also probably say some things about Yong Sun because in this particular class he says some very surprising (to me anyway) things. Yong Sun does a great deal of reading and talking about science outside of class. He and a number of other little Korean boys apparently (this is what he has told me) get together after school and read books on science. He seems to know a lot about chemistry--atoms and that kind of stuff, planets and astronomy but with big holes. For example he seemed to know about stellar evolution but not what the Sun was made up of or how it generated heat and light. Those concepts are rather intimately tied. I normally count on using him in class discussions to feed in bits of scientific information when I need them to goose a conversation along. In this class he plays a role much more similar to Timmy's usual role--he takes a stance which is only partially okay and I generate a discussion which challenges it. He however responds in ways very different from Timmy. He is clearly accustomed to being "right" in science.

Teacher: Because *what*,Timmy? I didn't understand that.

Timmy: You're just bringing it down, like bringing the spring down. It's not sideways [*he indicates movement along the board with his hands*], it's not like this, it's just going straight down . . . [*He is talking about the spring in the spring scale and the pointer also; a part of the scale which indicates the weight. This is the first hint of a connection to the concept of gravity. I had planned class discussion to include this.*]

Teacher: So then you could just pull it up the board, if it weighs less you can pull it easier . . .

Timmy: No gravity pulls it down and it will weigh more.

Teacher: Yong Sun?

Yong Sun: I think Timothy's confused 'cause gravity doesn't pull it down, the weights pull it down.

Jin: *Plus* gravity!

Teacher: What did you say Yong Sun, say that again?

Yong Sun: Gravity does not pull it down, the weights pull it down.

Timmy: Yeah but plus it, plus gravity does, and those aren't weights . . . [*They're washers in plastic bags.*]

Yong Sun: Gravity makes you fall or something like that. Gravity, it doesn't pull things down . . . [*Children start yelling: "Yes it does, yes it does."*] *Look!* Is gravity pulling this down? [*pen in hand*]

Timmy yells out: "You're holding it!" and others chime in: "Yeah! Yeah!" Dembe and Timmy make the connection back to the experiment and claim that it's the scale that's holding the weight and gravity is pulling it down against the scale. Everyone continues to yell at Yong Sun until Jin says: "If there isn't any gravity then if you drop it, it will just go in the air." Everyone agrees but Yong Sun: "We're not talking about gravity, we're talking about how much it *weighs*." Jin counters: "But if there's no gravity when you lift it . . . then it will weigh less!" Yong Sun at this point starts to get offended. So I interrupt and ask: "So why does it weigh anything? Why does it . . . what are you measuring when you weigh it?"

Yong Sun: You're measuring how much it weighs and how much force it uses.

Teacher: How much force it uses to do what?

Yong Sun: Like if you pull something that's heavy then it just will use more energy and that's using more force.

Of course what Yong Sun just said is a description of gravity, he just isn't connecting his "force" with the force of gravity. I suspect this happens because of the way books talk of gravity as if it were another property of an object, as if it were a "thing." I could have chosen at this point to work with Yong Sun to make that connection, instead I chose to return to Timmy. I did this because both children are saying correct things and both of them need to connect what they are saying together. I need to keep them engaged with each other and also work to have their ideas converge. It is important for me that members of the class work together on making sense of this topic. This means using children who have interesting things to say to stimulate others. In this process holes in their thinking are often exposed and the "working together" becomes increasingly genuine.[28] I ask Timmy what he thinks now and he responds that he still thinks that gravity has something to do with it, that " . . . gravity is helping it to stay on the floor, it's not just the weight that is on it." Then the class starts talking about how if there were no gravity the desk would float. I turn this to a discussion of whether or not this would mean that it would have no weight. This is an important concept--to differentiate between weight and mass. I think the root of the confusion in this part of the conversation is that the children are unwilling to say that something that exists, that is and remains an object, has no weight because they have not learned to differentiate weight from mass.

> Timmy: Yeah, no I'm not saying that it wouldn't weigh anything I'm just saying that gravity's helping it to stay on the ground, it's when it's hanging down, it's heading toward that way so . . . just like when you drop something, like when you drop it, the gravity's pulling it down, you don't feel it pull it down but it's pulling it down, if there were no gravity when I dropped it, it would stay right up.

Now Alice makes an interesting comment. She says that: " . . . you know how Dembe is standing up? That's gravity that's helping her stand up." This seems to me to be similar to the observations about how a person can hold an object up despite the force of gravity, that there is a balance between the things that we can do--moving, standing, picking things up--the force of

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[28]It also makes paramount my role in anticipating who might be able to make those sorts of contributions as well as in knowing when to invite those contributions. How I do this I would describe as a process of "nibbling" as well as developing a depth of knowledge about each child. The two are linked though.

gravity and properties of ourselves, the ways that we are constructed. This gets picked up and amplified when Dembe and then Amina start talking about gravity as a tug-of-war and will again be returned to (by Alice) in a subsequent class in which she asks "how can birds fly?" I ask: "How is gravity helping her stand up, I thought gravity would pull her down?"

> Alice: Well I mean help her stay on the ground because if she wasn't on the ground then she would be floating up in the air somewhere.
>
> Amina: I have a comment for Yong Sun, Dembe and Jin ... Jin and Timothy. I agree with them and I have something ... I agree with them because if I jumped up, I would be up in space, I would be up and floating, I would be, well actually, your cup would be floating the book would be floating, everything would be floating and we would be like doing our studies up there and Kristin would be drawing....
>
> Timmy: She'd be drawing upside down!
>
> Amina: And there'd be no way for us to stay on the ground we'd have to have something hold us like a rope or something.
>
> Teacher: So are you saying that if there were no gravity that things wouldn't weigh anything?
>
> Amina: They would just be floating up in the air.
>
> Ricardo: They'd be floating...
>
> Amina: I don't understand what you're meaning, Yong Sun, I mean if you if I just hold a book, you're holding the book, you're *holding* it, but if I don't, if you just drop it ... your book, it just ...
>
> Yong Sun: Wait a minute, wait a minute, are you saying that without gravity this doesn't weigh anything?

Timmy says that yes this is true in space, things don't weight anything. There is no gravity and they weigh nothing. He read this in Florida at the Kennedy Space Center. Others though think they will still weigh something, it just might be less.

I summarize: "Okay it seems to me Yong Sun is saying that if there was no gravity, things would still weigh something? Is that right Yong Sun? And other people are saying that if there were no gravity things wouldn't weigh anything like Dembe's building. Is that true are people saying that?" The children yell both yeses and nos. I call on Dembe who has very patiently had her hand up through all the yelling. Dembe states that she agrees with Timothy and Yong Sun. Kristin turns in surprise and asks her why.

Dembe: Because gravity is part of this because you know when we're lifting this it [*the weights on the spring scale*], it's pulling it down and also because if you're holding it, the gravity won't be pulling it down that much because it's still going up but gravity is still pulling it. It's like um, tug-of-war? When you're pulling it and the gravity is pulling it . . .

Teacher: You're using force against it?

Dembe: Yeah!

Amina: You can't do that, you can't have a tug-of-war with gravity.

Teacher: Why do you say that?

Amina: Well if there's a rope and there's one side, well there's just one person against gravity . . . the person would win . . . so that you can make things go down, you can make things go up, like hold it, that makes it go up I mean but if you let go, it will fall but gravity just lets things go down, it doesn't let things float, all it does is make things go down, all it does is let things go down and it can't move the rope unless you throw it up in the air.

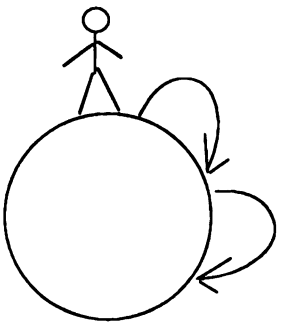
Teacher: So are you saying that if you hold something up in your hands gravity is no longer working?

Yong Sun: Yeah it's working.

Teacher: Dembe, why did you say tug-of-war?

Dembe replies: "Because tug-of-war is like you're, if you have a rope and one person is pulling it, okay, for example, one person is pulling on my right hand and the other person is pulling my left hand and of course Kristin would win because gravity is pulling it down but she's pulling it up and she's a lot stronger than me . . . " At this point Dembe and I have to stifle some interruptions. I remind everyone that they need to put their hands up to talk and then finally Dembe continues: "I mean that, I'm not even done Timothy, I mean that like gravity if you're pulling . . . okay for example you have Joey's shoe and then somebody is pulling it but gravity is pulling it down and you're pulling it up and you would win of course." Suddenly I felt that I had had enough--I think the idea of gravity as a piece of a tug-of-war is extremely important but there are too many other things going on. I also don't like it when the children just seem to be arguing rather than arguing ideas. Other children are not a part of this. I want the whole of the class focused before we continue with a central idea to the concept of gravity. When Timmy started to respond ("Then why'd you just say . . . ") I stop him ("Hands up!!") and change the subject:

"Kristin are you ready? [*Kristin has been drawing a picture on the board that she wants to use to present an idea to the class.*] Can you show us what you drew?



Kristin: Well see on the Moon here, a man can walk and he can jump up and down but on the Moon there's no gravity so if he went to the bottom of the Moon and just stood there he wouldn't fall because there he could just . . . he would not fall because there is no gravity and gravity makes you fall.

Timmy: No, gravity makes you stand!

Teacher: Hand up Timothy . . .

Kristin: Okay Timothy! Okay here here's some chalk, okay, now this is the Moon but it goes back onto the Earth and it's got gravity now watch . . .

Jin: It's still on the Earth.

Kristin: It makes things fall, gravity makes things fall.

Kristin has been a delicate problem in science class since we started the unit on machines. She has reached the "social" level that I sometimes see in third graders where all discussions take on personal overtones. I am uncomfortable with this facet of children. I am very aware of children's abilities to exclude and wound each other. I am not very good at handling it. In the first part of the machine discussions Kristin turned out to be very knowledgeable--more so than Timmy or Yong Sun. This was I think due to her spending weekends working with her father in a garage rebuilding cars. She also seemed to possess a better intuitive grasp of how machines worked than the others. I spent a lot of time in those classes reaffirming her knowledge and encouraging her to share it with us in class. I made sure that she had enough room to speak whole thoughts without interruption and then often I would organize ensuing discussion so that people were talking in response to what Kristin had just explained to us. I made sure that the

(apparent) antagonisms between Kristin and some of the little boys like Jin and Timmy were suppressed. I wanted Kristin to have a chance to exercise a knowledgeable voice in my science class--often this was difficult because Timmy, Jin or Yong Sun would just *assume* that they knew more. Things are different in these classes on gravity and the planets. The children argue until I stop the class and have them write in their notebooks what they think gravity is.

At this point I felt like there was a huge amount of stuff out on the table, all of which we needed to deal with in order to make sense of the experiment. There were so many ideas in the air because each child was in a different place, coming from a different perspective or source of knowledge and experience. I wanted to center the argument on gravity and to do this I took it back to the abstract--to a definition. I chose to do this because I wanted a common point to end class on. I wanted to have *everyone* cognizant this was what we were talking about. I needed time to think about the children's different examples of gravity and think of an example of my own that would catch something "common" to each of their's. In this way they could think through their own ideas within this one, common idea and I would have children thinking convergently as well as divergently. So I felt I needed to think through their ideas and their abstract definitions in conjunction to do this. I also think this is a valid approach to science--as a conjunction of abstract ideas and concrete, personal, experience-based sense-making. I started the next class (on March 12th) with this.

In many ways the nature of the explorations in this unit are different from those described in the previous chapters. We started out unfocussed--our explorations were about simple machines. This was similar to the work with sound and music. This, however, became focussed as we tried to make sense of how a machine worked. This is very different from my usual teaching--there is a particular goal here which I am maintaining. I am shaping and manipulating the conversation in service of this goal--first to understand the machine and then to understand gravity. For this reason the conversations the children participate in are qualitatively different. Rather than sharing ideas which listeners try to understand and only secondarily critique, the children have been engaging in argument with each other in which they are making

claims and attempting to convince others of their validity. I am fostering this, in the subsequent classes I even introduce conflicts in logic to further this process. It is, though, problematic to me--this sort of argument is a part of the activities of a discourse community in the sense of Foucault and I am uncomfortable with the sorts of inter-personal relationships constructed in such a community. For example, Kristin or Amina--I will not allow them to be silenced by more conventional scientific thinkers. I believe in the validity of their ways of thinking and in their right to both speak and be heard respectfully. It is stressful for me to be playing these multiple and conflicting roles--of scientific expert (in shaping the conversation so that it stays focussed on first machines and then gravity), of being *so* controlling of the class, of being respectful of others ideas, beliefs, feelings, desires.

What is gravity? Our goals and objectives evolve

I start the next class by asking the kids to open their notebooks to the page where they had written about gravity. "Would somebody like to read what they wrote about gravity? Karen?" Karen reads: "Gravity is a force that tends to pull something . . . [*I start to write her definition on the board*] . . . Gravity is a force that intends to pull something down that has gotten off the surface." Next I add Ricardo's: "Oh, something that keeps you down." Then Alice's: ". . . it's a force, it's something that holds things down." I finish writing and read the three definitions emphasizing the verbs: "*Holds* things down . . . *keeps* things down, *pulls* things down . . . . Anybody have anything different than that? Amina?" Amina responds not with a definition but that she disagrees with Kristin's argument from last time. I stop her for the time being because I want more definitions. In particular I am looking for one that connects the idea of gravity to the Earth. I have decided that today we are going to play more with the difference of weight and weightlessness and environments where this occurs. So I ask Jin if he has anything different from what is on the board. He adds: "Gravity makes you stick to something." And Mwajuma asks him to explain.

Jin: . . . if we jump up it still makes us come down!

Teacher: Why's that..you just said it makes you go down, I don't understand how that's "stick to something . . . "

Jin: I mean it makes you stick to the ground.

Timmy: I know what he means.

Teacher: Mwajuma?

Mwajuma: You don't really stick to the ground . . .

Jin: I know, it's like it's stick to it.

Ricardo: Then it would *stay* on the ground!

Jin: That's what I mean. I found it in the glossary . . .

We go to their textbooks. This almost immediately becomes different kids looking up different things. We had started this pattern of textbook use when we were exploring plants. One of the things I did when we first started to use the science books was to teach them how to use the index because I regard the textbooks primarily as references. Anyway I find that letting kids chase after things in their texts using the index is a useful initiator of bracketed wanderings. I found this very useful in discussions--different people would find different things and then we would share and discuss them all with a common referent.

Finally I call the class together to listen to Jin read the definition of gravity given in the book: "The force of one object pulling on another object, gravity pulls things toward the Earth." (Wrong, I think, gravity is the pull. The measure of gravity is how much the object is being pulled, the degree of pull.) I start asking different children what they thought that definition meant. I start with Amina.

Amina: Um, that means that, well I don't understand the first part, the force of one object pulling on another object . . . um, um, *OH* one object is pulling on another object, this is an object [*she holds up a pen*], so if I jump off with the pen gravity pulls both things down at one time.

Teacher: Is the pen pulling on anything?

Amina: No. The pen can't be pulling on anything 'cause it's not living.

Teacher: When you jump up in the air with the pen in your hand what's pulling on you?

Amina: Gravity, gravity it's not like something, it's white like air, you can't see it, it's like clear.

Teacher: But the definition says that gravity is a force, from one object pulling on another? The force of one object pulling on another object . . . oh if gravity is pulling you down it must be pulling *you*, something is pulling you . . .

Amina: I'm jumping and then gravity is pulling me down, like this. I can't fly like a bird, but I don't know why gravity can't pull a b . . . well gravity can't pull down a bird because it has wings.

We're going too fast; again there seems to be just too many ideas out and in particular the children are using the idea of gravity to explain different phenomena rather then focusing on talking about what gravity is--I still want more talk about that. I move back a step: "Where is gravity coming from?" Timmy answers: "Gravity is coming from down in the Earth." I repeat his answer and he adds that gravity can also be on all the different sides of the Earth. So I ask him if the Earth is also pulling on him. He replies: "No, gravity's from the middle of the Earth." I ask him if this means gravity's pulling on him and he agrees.

Jin: I think gravity pulls birds down cause, well 'cause when they're flying and they're trying to pull it down and then they're still flying and it makes them more tired and it makes them have to go down.

Teacher: They're working pretty hard to stay in the air, is that what you're saying and then they get really tired and they have to come down?

Jin: Um hum, yeah 'cause if there wasn't gravity then they could fly like for over an hour in the air with out stopping.

Sook Chin and John both think gravity comes from the Earth. Kristin wants to return to Jin's statement about birds. "I have a comment for Jin, um, Jin if there was no gravity wouldn't people, flowers, things be flying up in the air?"

Jin: Uh uh, not trucks!

Kristin: Uh huh!

Jin: No because it's like, people going to the Moon then there's no gravity but they're wearing very heavy boots so they won't fly 'cause it's very heavy.

Kristin: They can't wear very heavy boots 'cause then they couldn't walk.

Jin: They could 'cause there's no gravity.

Kristin: Then I'm saying they could fly!

Jin: If they don't wear heavy boots they can!

Kristin: So you're ... they can't walk!

They start to argue seriously so I interfere: "I don't understand, what's the point of what you're arguing about?" Kristin responds (with Jin breaking in repeatedly): "Well I think that anything could fly up in the air if there was no gravity ... [*Jin interrupts.*] ... and um, but Jin said, "but not a truck" because um, because it's too heavy because um, the gravity ... [*Jin interrupts again. I ask, thinking about the talk of birds, if she means fly or float. She answers float.*] ... and um, the people on the Moon they wear boots that just make them, they don't quite fly but they jump up really high but they do come down." Jin really doesn't like this. He says again: "No they wear really heavy boots that make them stay on the ground if they don't wear those boots like um, I think if you're on the Moon then I think things weigh six times less, I'm not sure but it was much less so, so if like, if you have, if we were running right now and we were on the Moon then we would be floating because our shoes are not heavy enough!"

Teacher: Is there gravity on the Moon?

Jin: No.

Teacher: There's no gravity on the Moon? But you do have a weight on the Moon?

Jin: Yeah 'cause if you have boots or like heavy boots like six pounds or something really heavy, well not six pounds but like really heavy, then, then you'll stay on the ground and but you can still hop really high you can still jump really far and high the boots just make you stay on the ground.

Kristin: How?

Teacher: How do they make you stay on the ground if there's no gravity?

Jin: 'cause they're heavy.

Teacher: But if there's no gravity what difference does it make how heavy they are? If there's no gravity doesn't everything just float?

Jin: No.

Timmy: No!

Teacher: Gravity's the thing that makes things stick together ...

Yong Sun: But there's a ...

Jin: Then if there's no gravity on the Moon, then the things on the Moon would go up ...

Teacher: So why would heavy boots make any difference?

Jin: They'd make you stay on the ground.

Teacher: But there's no weight, I mean there's no gravity, they're not going to help.

Jin: Some boots make you stay on the ground ...

Teacher: But you said there's no gravity.

Jin: I know that's why they made gravity boots!

Teacher: You mean the boots have their own gravity?

Timmy: Yeah they give it out, that's what I just told him, they're gravity boots!

Jin: That's what I'm trying to say.

Timmy continues, his enthusiasm mounting: "The gravity boots can make you stick on the ground where there's no gravity, That's why they have them but they have to jump or else it's too hard just to walk in the gravity boots but if they jump they can't float away the gravity will bring them back down but they'll jump!" The children in the room are *very* interested. The room is full of huge round eyes. I can hear wheels turning. *Now* I ask Yong Sun what he's thinking. Yong Sun, though, is also thinking real hard: "I don't know if they actually can, if they can jump real high, higher than we can ... then how can they stick to the ground?" Timmy, Jin and Amina start arguing about how high they could jump on the Moon. I stop this with a summary--I want us to talk about what *I* think are the main points rather than the repercussions of this theory. "So Jin and Timmy are saying that on the Moon there's no gravity so people would float away except they wear these gravity boots that make them stick to the moon's surface and then they can jump up in the air and then they come back down and it's all ... they come back down because they're wearing gravity boots. Is that correct, is that what you're saying?" Timmy says yes. Joey, who I think of as a conservative, careful thinker (that's why I call on him here) also agrees with the theory. He does so though by applying it elsewhere; to images he has of men in space ships who *don't* seem to have control over themselves like astronauts on the Moon do. Timmy adds: "They have something that they put on each thing that they take up, they make

their own gravity." A major argument starts about this and about the Moon. The class talks especially about things they see in pictures in the book. Finally I stop the talking and call on John.

> John: If there was gravity on the Moon they would stay on the Moon, and if you jumped you wouldn't start flying around or floating you would jump and then you wouldn't do that and Kristin's saying that there's gravity on that [. . . *remember her picture . . .]* then you would fall off but I don't think so, if you fall off there's nothing to go on to, you'd just sit there.
>
> Teacher: So are you agreeing with Timmy and Jin that because they wear their boots they go back down? [*John nods.*]

I ask another question which I hope will turn the conversation back from examining the effects of Timmy and Jin's idea to looking at more foundational assumptions. "Can I ask a question? Why does the Earth have gravity?" Daniel answers: "Maybe it was made that way." Then Karen: "Cause people need to live on it, 'cause that's where people live and where all the air is, so they can breath, I don't know why the air is except the gravity is where all the people are and the air and if there wasn't any gravity everything wouldn't be, it wouldn't be organized, it would be hard to do things." This is a common sort of response to this kind of why question. A sort of inverted logic or causality that makes me think a lot about Habermas and Arendt and the nature of moral claims. It's also horrifyingly realistic scientifically. For example scientific evidence and arguments for differences between men and women, the superiority of the white race, mating behavior of birds . . . I respond: "Well, maybe if the Earth didn't have any gravity we wouldn't be here."

> Alice: True we'd be up there maybe . . .
>
> Teacher: Floating around . . . Ricardo what do you think, why do you think the Earth has gravity?
>
> Ricardo: The people need gravity to because um, what if they need . . .
>
> Teacher: No that's not the question. It's not if people need gravity. It's why does the Earth have gravity?
>
> Ricardo: Because so the people can live on it and then they can walk . . .
>
> Teacher: If people didn't live on it would the Earth still have gravity? [*People nod their heads and murmur yes.*] Why does the Earth have gravity?

Ricardo: I don't know.

Alice: Well I think the Earth has gravity well I have two reasons, I'm sure about the second one. The first one is because . . . maybe it was made that way. And my second reason is, I'm not sure this is right but, ah, space doesn't have any gravity . . .

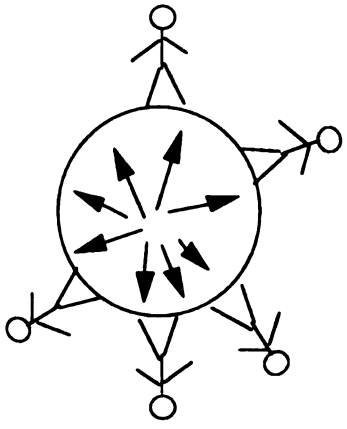
Teacher: Space doesn't have any gravity?

Alice: I don't think so.

Teacher: You don't think so. Why do you think space doesn't have any gravity?

Alice and then Amina, though, just repeat that there is no gravity because things float there--they have no weight. I think that for me the difficulty I find in shaping this sort of discussion is in the sort of cyclicity of the children's logic in the statement that the Earth has gravity because it was made that way. It does have the gravity that it has because it was made the way it was. It was also made the way it was because of gravity. You have to step outside this cycle to make sense of it or for that matter to think differently.

Sook Chin has been drawing a picture to show us since I asked the question about where gravity comes from. Finally he is ready to present his picture. He is only recently becoming competent in English so he talks a little English then goes to Korean and Yong Sun translates. Notice, on his diagram, the direction of the arrows. The way he has chosen to draw his arrows has important repercussions for the rest of the month. Arrows indicating the direction of the force of attraction would go the other way.



Yong Sun: He thinks there's gravity everywhere so um, [it's from] under the Earth, there's gravity but we can't feel it.

Teacher: So everywhere on the Earth there's gravity even if you're on top of the Earth or on the bottom of the Earth there's always gravity so you ... that's why people on the bottom of the Earth don't fall off.

Sook Chin: Yeah and they don't feel that [*he gestures to indicate upside down*] ...

Teacher: They don't think they're on the bottom of the Earth.

Sook Chin: Yeah, they can't, but I think they can't fall because outer space is very large.

I decide at this point to tell the children about gravity and then see what sense they can make of it rather then seeing if they can "discover" it. I do this because I think that the kids (and I think this is borne out again in the next class) are postulating theories which are more-or-less spontaneous bright ideas (or insights if you'd rather). They are based on almost nothing. Many are constructed on the spot. I think the gravity boots is an example of this. Jin was saying they held the astronaut down because they were heavy. My pointing out or him recognizing that this was inconsistent with his claim that the Moon had no gravity led to the claim that the boots *made* gravity. The children who liked the idea were busy trying to apply it to other things to see if it would work there. This is in line with the manner Kuhn (1970), for example, describes the testing and assessing process scientists put new theories through. In the same line I suggest a theory and invite them to see whether or not their data make sense analyzed within it. My theory, I know, has the advantage of greater simplicity and consistency. It has greater explanatory power, it can be extended beyond the immediate phenomenon. I rarely do this--tell the children a scientifically more correct answer. I choose to do it in this instance in a particular manner. I am careful to portray what I say as another theory because I don't wish to make an authoritative statement which would stop the sort of weighing and assessing Kuhn describes. I wish to keep my idea with the pre-existing norms of our classroom conversations in which people share ideas and then they are discussed and weighed. I want them to think about my theory in the same way as they have gravity boots--weighing its usefulness in explaining what they know about phenomena. I do this because I respect both that form of the scientific process and I respect the children--their theories (gravity boots, like any other scientific theory is discarded only when it proves not useful) and their ability to think critically and creatively. I

don't actively disprove their theory, rather I give another theory that's more powerful for them to try out. I feel I have to be extra careful in doing this (and in describing it here) because I do feel the children may attach more weight to my statements, when I make the, but I wish in this instance to minimize this.

> Teacher: Listen to me, let me tell you an idea, the reason why the Earth has gravity is because it's a great big thing . . .
>
> Kristin: Bigger then the Moon?
>
> Teacher: [*nods*] . . . the bigger the thing is the more gravity it has, everything has gravity, everything has gravity like you said at the beginning Amina . . .
>
> Timmy: Except . . .
>
> Teacher: Wait! Everything has gravity but how much gravity it has is because how big it is. [*This makes me very uncomfortable using "big" rather than "mass" but I didn't want to introduce a new word at that moment.*] So the Earth has gravity and it has a lot of gravity, the Moon has gravity but the Moon is smaller then the Earth so it doesn't have as much . . .
>
> Jin: One quarter . . .
>
> Teacher: It doesn't have as much gravity as the Earth.
>
> Timmy: So it's not easier to get around?
>
> Teacher: So it's easier to jump in the air. I have gravity but I don't have nearly as much gravity as the Earth but if I was in outer space where there is no gravity, there's no gravity in outer space because there's nothing there, but if I'm in outer space, I have gravity and if Amina was to bring a pen up there and let go of it, just let go of it so that it is floating, it would be attracted to me, it would be pulled to me because I have gravity. [*Many children start murmuring to each other.*]
>
> Timmy: Dr Osborne I have a question.

I repeat my theory before I let the children talk. Ricardo says that both the Sun and the planet Jupiter must have a lot of gravity then. I agree with him and emphasize that it is because they are so large.

> Jin: I think it's interesting that if you were in outer space and if someone gives you a, maybe if someone would hold a pen and it will stick to you.
>
> Teacher: You think that's interesting? Okay Timmy?
>
> Timmy: Um, I have a question. Does that mean if something's bigger than you, you would be attracted to it?
>
> Teacher: Uh huh.

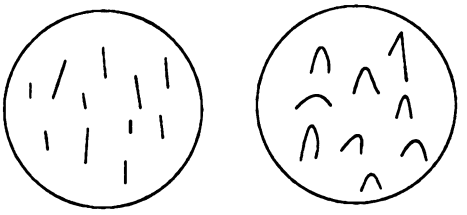
Timmy: Oh then I say the same as Jin.

John adds his own interesting idea: "What's interesting is if a space ship were to fly too close to the Sun it can't get away 'cause the gravity of the Sun is pulling it towards." But Amina disagrees with the new theory. She draws a picture and then states: "The Moon has nothing on it because it has no gravity right?" I tell her that no that's not right or at least that's not what *I* had said. I emphasized the I. I reiterate that according to my theory the Moon has gravity because of its size. But Amina insists that it doesn't have gravity--at first because the book says it's in space and that has no gravity and then because: "Well I think I'm sort of revising because I thought if you think it's the Moon, the Moon could have gravity because I thought if this is the Earth there's lots of people, 'cause there's lots of living things on it, that's why it has gravity. But the Moon it has *nothing* on it." On that note I end the class.

Constructing and testing scientific theories and the development of a community: Out into the solar system.

We start the next class, on the 17th, in the same spot we left off. Kristin disagrees with my theory. "I don't think the Moon has gravity because it says it in our own science book." Amina also still disagrees and goes to the board to redraw her pictures. It is very important that these two were the particular children who started the conversation in this class through disagreeing with my theory of gravity. These are the two children I am most focussed on in my worries about discourse. They alter the shape of the ensuing conversation so that it feels more like those portrayed in the chapters on the first and second combination class. They tell us their ideas and we listen to them and work with them and through this process become critical.

I ask Kristin to find in the book what she is thinking about. Meanwhile Amina explains her picture. "Now this part, just pretend it's flat, um, the Moon has no gravity, some people think it does but it doesn't. These lines are the people [on earth] and the Moon, it has nothing but bumps on it and that's why the Moon has no gravity."



Teacher: So in order to have gravity you have to have living things is that what you are saying?

Amina: Yeah um, I don't think I should say this, but whatever one you believe in, god, well god, um, he thought that there should be, well, I don't know but maybe this, but maybe it's just because the Moon doesn't have to have gravity because there's nothing, why should it have gravity because there's nothing on it that *should* have gravity.

Teacher: Oh so the Earth *needs* to have gravity *because* there are living things?

This is very true, would the concept of gravity exist without us needing it? Mightn't there be another way to visualize the whole relationship that doesn't require pulling out or defining a concept like gravity? This is on a continuum with Karen's explanation of why there is gravity (because we are here and we need it). Amina's linking this to her concept of god and what god's plans are is also a part of this sort of teleological argument; arguments which hinge on a higher authority or a greater purpose--stated or unstated. In traditional science the higher authority is the rule "This must make sense!" It doesn't have to be that way either or it can make sense in multiple, often conflicting ways. Both Amina's and my conceptions of gravity arise because of different qualities of the abstractions we make about what we sense in the external world. Concepts such as gravity or god arise because our articulations of reality are partial and incomplete. God and gravity are different because our abstractions are different. Amina's way makes sense to her as does mine to me but how we can *use* that sense making is very different. That's how I like to think I approach this sort of argument in class--asking children questions so they can try out their arguments in different places and contexts, with different data. That's also the approach I think you can see the children adopting. When Amina talks about god as an explanation no one challenges her right to talk about this. They listen to how she is using it then present their ideas. In a much later class (where we were discussing theories of the origin and end of the solar system) Amina asked me privately whether or not she could tell about her

religious beliefs. I asked her to think before she did it whether or not she would be comfortable with kids challenging and discussing her ideas as problematic. She chose not to share.

A funny thing about Amina and my interactions is that I don't feel the same sort of moral dilemma in encouraging her to question and think in this way as I did in other classes with different students such as Farzoneh (a child from Iran that I had in first grade in the year before this--I talk more about this in the next chapter). I suspected at the time of this series of classes that they were from the same sort of conservative Moslem background though. This is actually not true but it is what I was thinking and acting on at the time of this conversation. Maybe this is because Amina's age and the age of the other children give me opportunities to talk with them *about* the discourse and what we are doing in class that I didn't get to do in first grade. About Amina though--she acts extremely feminine and very silly but is very perceptive about the discourse of the class. She writes to me in her lab notebook commenting on the kinds of questions that I ask and why I phrase them the way that I do. She is the only child who does this.

Amina: Uh huh gravity, um, people would be floating . . .

Jin: Yeah we couldn't breath!

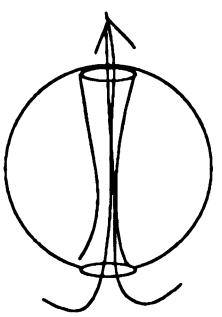
Teacher: Hand up! Um, but how does the Earth make its gravity?

Amina: Well it comes, I'll draw a picture right here . . .

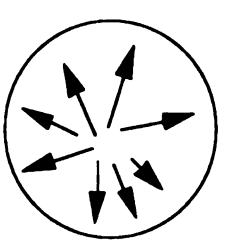
Dembe also wants to draw a picture at this point. While the two girls draw, Ricardo has a comment: "I think without, without gravity the sharks wouldn't be able to live because without gravity, the ocean would fall into space." This is a classic Ricardo sort of comment to me: right on target but warped by his own strange head space. I never know what to expect from Ricardo except that it will be perceptive. Many children make comments like these in all my classes. I have included many of them in these transcripts. They are said too loud to be side comments but they never become central to our classroom talk or if they do it is at a very later date. I feel these comments are important because they indicate something about the atmosphere of the class--they are usually said in a humorous way and connect to the topic at hand in a peripheral or even eccentric manner but indicate (at least to me) the child is connecting to the topic. I usually smile

at the speaker or laugh a bit but don't respond directly to the comment. In this instance, I respond, not about Ricardo's statement about sharks but just to Ricardo in general: "So do you think the Earth has gravity because there are living things and therefore the Moon doesn't have any gravity?" Ricardo says that he thinks the Moon needs to have at least a bit of gravity. When pressed he can't say why though.

Amina explains her new picture. She tells us that gravity comes from the center of the Earth and out the north pole.



Then she changes her mind: "Well wait a minute that wouldn't make sense because I don't think I agree with my picture 'cause that would mean down here I don't know what it would be down here but it might not have no gravity." She decides to draw another picture. I suspect she is confusing magnetic field drawings into her sense making about gravity. We never return to this though so I don't know. Now Dembe shows us her picture.



Dembe: I think that the Moon does have a little gravity.

Teacher: What's your picture of?

Dembe: Um the Earth and the Moon, and I think that the Moon does have a little gravity because if the Moon didn't have gravity, well it should have gravity because it's a little smaller than the Earth, and it should have gravity and like you said, well, like the Earth is

big, but the Sun would have more gravity 'cause it's bigger than the Earth and the Moon and, um, I think that since it's still a size and it's kind of big too and so it has gravity and also the Earth because it's big.

Teacher: 'Cause of the size.

Dembe: Um hum.

Teacher: Okay Ricardo?

Ricardo: I think the Moon does have a little gravity. If there wasn't any gravity on the Moon it was, um, if the astronauts,even with heavy boots, they won't be able to touch the ground.

Amina: Remember . . .

Teacher: Yes Amina?

Amina: Remember when Timothy said they have gravity boots . . .

Timothy: Well I disagree with myself now because when I heard what Dr Osborne said and I agreed with her.

Amina: Dr Osborne what did you say?

Teacher: I said that the Moon had gravity but it had less gravity than the Earth and the amount of gravity that it has is dependent upon . . .

Amina: Oh I think that it doesn't . . . doesn't have any, the [moon] doesn't need it because it doesn't have anything on it except bumps, it doesn't have things, it doesn't have space creatures.

Joey also thinks the Moon has gravity. When I ask him what gravity is he replies: "Something that helps you stay on the ground." Yong Sun adds on to this an extension of the theory from something he has read: "Well I was kind of thinking that some stars are bigger than the Sun and um, if you're out in space, if something was really big, then it would pull you to it, it would pull you to it." I get back to Amina and ask her what she's doing. She is musing over her drawing of the Earth with people and the Moon without. "I know the mountains should have gravity I mean they're bumps." Dembe reminds her: "You said the Earth doesn't have bumps . . . ." and Joey adds in: "Or doesn't need bumps." Amina: "No, No No No what I meant over here was all there is on the Moon is bumps, bumps is not living things!" Dembe: "But when you were over there you said that the Earth does not have bumps and I think it does." To which Amina answers: "Well yes the Earth does have bumps like the rocks like in the roads um, I'm gonna

revise." I think this is an example of Dembe and Joey trying to think inside Amina's theorizing. But their approach to attempting this is critical. I don't think their statements should be interpreted as counter-arguments. Rather they were trying to think along with Amina and these were problems they saw in the theory through this process. This is much more similar to the workings of the community in the conversations in the last chapter about sound and music.

> Finally Dembe says: "I think the Moon has to have gravity." I ask her "Why?"
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> Dembe: Because if it doesn't have gravity, how can you go to the Moon. Like the space rockets and stuff when they're going to the Moon, do they just glide right ...
>
> Amina: Dembe, Dembe! I think you're getting a little carried away, see their space suits, they *have* in their space suits to carry gravity, there's this little plug goes in, there's air and there's gravity.
>
> Timmy: No it's just oxygen.
>
> Kristin: No it's for oxygen.
>
> Amina: Oh then I think it's the boots that helps them.
>
> Timothy: It's those boots you saw how they have gravity on the Moon, you saw how they jump, it's because they, the gravity's not real big so the gravity's not real strong, so you float up but then you come down because the gravity pulls you down but then you float back up because the gravity isn't very big ... I made a mistake because now I don't think there is and I don't and all they do is they have oxygen packs on them and that's all.

The children have seen these things in pictures and books and in movies or television and they believe there has to be reasons for their observations so they try on theories, to see if they work for a bit, then keep them or cast them aside. A testing process. Note: this is very different from the way science is normally taught but very much what goes on in research. Amina does this for herself. She adds on addendums to her theory, tries it out for its explanatory power and coherence then throws it out. Like epicycles in pre-Copernican astronomy.

> Amina: Air and gravity are opposites.
>
> Teacher: Air and gravity are opposites?
>
> Amina: Uh huh. [*Many children start asking her to clarify.*] Not opposites, well they're not opposites actually, but they're sort of the same, they're not really the same but ...
>
> Timmy: Opposites means different.
>
> Kristin: Like yes and no are opposites.

Amina: Yeah but I think they're sort of the same, gravity and air.

Teacher: You said that last time you said that, air and gravity were the same because you can't see either one.

Amina: Yeah it's true . . .

Ricardo: Um, ummm . . .

Amina: . . . 'cause they're like the same like, Dembe may I erase this? It's clear and it helps people . . . air helps them breathe and gravity helps them stay on the ground.

Teacher: Is air like something that you can hold in your hand? Am I holding air in my hand? [*All respond yes.*] Okay, can you hold gravity in your hand? [*Amina says yes all the others say no.*]

Amina and Yong Sun argue about whether or not you can feel gravity. Amina seems to be claiming that you can feel gravity because you can feel the effects of gravity. I'm inclined to look at it this way also although she is also saying that gravity is located just on the floor--we feel gravity because we are held to the floor. I don't agree with that part.. So I ask the children: "Let me say something about a way you can feel gravity, if you pick something up, you pick it up and it weighs a lot is that feeling gravity?" Now everybody agrees with me (while they didn't with Amina). So I ask why they think that is feeling gravity.

John: It has weight and it, um, pushes down on your hand.

Joey: Um, I disagree with her [*Amina*] because if gravity is just on the floor because right now I'm not touching it [*the floor*], if it's just on the floor I felt it all over.

Amina: That's not what I mean . . . [*Lots of arguments start.*]

Teacher: Wait wait wait stop hold it I'm not totally sure I even heard what Joey said, Joey you said gravity's all over, it's not just on the floor so you wouldn't just feel it on the floor you'd feel any old place?

Joey: Yeah or I'd just be floating up right now.

Teacher: Okay any comments to what Joey just said? John?

John: Um I agree with him 'cause if it was just on the floor then you'd be half floating and half on the ground right now and if you'd want to stay on the ground you'd have lie down on your back or something or your stomach.

Jin: I agree that gravity's all over 'cause then you'll be sticking, you'll be like . . . your one arm will be going like that and your other arm will be going like that and . . .

Ricardo: Then your head may rip off!

Teacher: That might be true if wait a minute, your saying that might be true if gravity were all over, not just on the ground, are you saying gravity's just on the ground or gravity's all over?

Jin: It's only on the ground 'cause if it were over there then it will stick.

Dembe: If, if I agree with Joey because gravity is all over, if you um, if gravity wasn't all over your hair would be going like this and everything.

In the last ten minutes of class, Kristin reads a page in her textbook on experiments in outer space while Timmy struggles for words with Dembe to describe how space is nothing. Ricardo says that space is different from the Moon--the Moon is in outer space. Joey joins the word struggle to describe space [words- like air, night, nothing]. Karen takes us back to Amina's drawing and points out it makes no sense for the south pole, also where would the gravity go at the north pole? Kristin talks about the ozone layer, that it would hold gravity in and spread it around the Earth. Yong Sun thinks this is a mistake and I define ozone as part of the atmosphere. I ask if she means that the atmosphere, the air keeps the gravity in. She replies: "Nothing can get out except rockets and I think the rockets have a special thing that makes them able to get in and out of the Earth because the ozone keeps everything from getting out of the Earth, helps the gravity to work." Yong Sun says this is a mistake and draws the Earth with the atmosphere around and explains the greenhouse effect and says it has nothing to do with gravity. Finally I ask them to write in notebooks where do they think gravity comes from? At the last minute two children (Timmy, Daniel) want to bring something in to share next time--I invite this and this becomes very important in shaping the subsequent classes.

In this last class the children construct consistent theories. I give them new "stuff" to do this--theories, phenomena-- which 'cause the children to revise old theories to accommodate the new ideas or to throw their theories out, Amina is attempting to do this revision--she is unwilling to release her own theory. Others are testing the new theory through its self consistency and by its ability to explain phenomena they are familiar with or by extending to the unknown (example: Yong Sun). Again these are all examples of the workings of a discourse community. Describing the workings of a scientific community upon the publication of a new

theory, Kuhn (1990) argues that the scientists weigh the theory against the phenomena and accept or reject it on the basis of whether it explains more and whether the new theory is generative. According to the ideas of Foucault (1980), this process is mediated by the abilities of the members of the community to communicate with each other--there must be shared language and shared understanding of that language. The later is developed by the use the language is being put to. This comes about in a scientific community by the process Kuhn describes.

Gravity and the solar system continued. I realize we have changed direction.

We start March 19th with a short review of what has been going on about gravity for Alice (who missed the last class). I thought for sure this was going to be a short process and we would return to the inclined plane experiment today. The real class starts when I ask Alice what she thinks of our discussions.

> Alice: I agree with Dembe [*Dembe has just defined gravity as something that keeps you on the ground and as proportional to the size of planets*] and I have a question for her, if gravity keeps things down and it helps you stay down, well why aren't you laying on the ground, because it's pulling you down?
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> Dembe: I mean like gravity holds you, I mean, like on the bottom of your leg, you see when you jump, it pushes you back down on your legs . . .
>
> Jin: It pulls you . . .
>
> Dembe: It pulls you on your legs!
>
> Teacher: But why aren't you lying in the ground ? That doesn't make sense . . .
>
> Dembe: Well because that, you're up, your feet are on the ground and that's why gravity comes from the ground.
>
> Teacher: What do you think about that Alice?
>
> Alice: I don't really understand.

I see this as a chance to revisit Alice's and other's questions about birds and find a place to explore how we "feel" gravity--work against it, the tug-of-wat idea. I say: "Remember we were talking a couple days ago about how birds can fly? I mean how *can* birds fly if there is gravity, Kristin?" Kristin responds that birds have no bones. Everyone disagrees. I say: "Well if

they do or don't what difference would that make? I mean shouldn't gravity work on someone without bones?" Kristin tries again: "Birds don't have weight." This is again shouted down. Everyone is debating my question. I stop the conversations and call on Yong Sun. "They don't look like they have any weight but they do have weight and they use their own force to keep them up."

Teacher: How do they do that?

Yong Sun: By pushing the air to the floor and lifting them up.

Teacher: By flapping their wings? [*Yong Sun nods.*]

We start talking about how they are able to flap their wings. Yong Sun says because they have a skeleton. I ask the class "Is it just the skeleton or something else that helps them?" Timmy says they have muscles and Jin says feathers. I push it further: "Okay let me ask this, if birds know there is gravity and birds do have weight but they can fly because they have wings and they have muscles and they have skeletons and they have feathers so *we* have weight but we aren't lying flat on the floor, why are we not lying flat on the floor? There is gravity and we do have weight but we aren't lying flat on the floor." John says: "Bones, if we didn't have bones we'd be flat on the floor."

Alice: Well I agree with John and because there's not enough gravity to pull us down on the ground.

Jin: Yeah there is!

Teacher: There's not enough gravity? What's that Jin?

Jin: Yes there is because if you don't have bones then you'll fall down.

I ask: "Can you think of any animals that don't have bones?" My reasons for asking this are because I want them to think that they have to work to stand up and that their bodies are constructed to facilitate this. Animals without bones are supported by the ground, water or exoskeletons. I want them to see that the morphology of living things is related to the things that they can do--a functional morphology argument. The danger of functional morphology arguments is that they are often discovered to be the inverted forms of logic and causality that I talked about when Karen suggested that the Earth had gravity because people needed it.

From Ricardo we hear about worms and where they live. Karen talks about snails and slugs. We talk a bit about snakes and remember that they do have skeletons. I suggest jellyfish and Ricardo adds shrimp. At last Amina says: "I have a comment for Kristin and Dembe and also for you Dr Osborne, not only your bones hold you up but also your muscles and your force." Everyone seems to agree this time so I summarize: "Sometimes your muscles don't work and you fall on your back but you don't lie on your back because you can't get up like because what Alice was saying about gravity, if there's gravity why doesn't it just hold you flat on the ground? I think the reason why it doesn't just hold you flat on the ground is because, as you guys have just answered, because you have muscles and you have bones and you use this force that keeps you up, that allows you to stay up. Does that make sense to you Alice?" Alice says that it does.

Then I return to the Moon: "Well what would happen to us if we were on the Moon, is there gravity on the Moon?" All but Kristin and Amina agree that there is. We talk some more about how people move on the Moon and in outer space. Timmy looks the Moon up in an encyclopedia he has brought in to show us. It talks about the calendar, the phases of the Moon and craters. Sook Chin defines these by drawing a picture. I talk about my research on lunar rocks and soils.

The children effectively planned out next time and probably a number of days after with the things they want to share about the planets. I was still not happy with what they are saying about gravity. I really wanted them to understand weight as the manifestation of a dynamic tension between two bodies. I wanted to get back to the machines. I didn't want to do more on gravity or the solar system. I didn't like the feeling of manipulating them into knowledge that I'd already got. On the other hand they really wanted to do this. The only children I really didn't think were very interested were Mwajuma and Selamawit. I felt that I must do this though because they clearly wanted to and I wanted to respect how they shaped the science we were doing.

This was the last class in which I thought our primary purpose was exploring gravity to get to weight to get back to machines. After this class I let us explore the solar system (and

gravity) for themselves although in my head I still kept the idea of relating things back to what I thought were underlying concepts in making sense of the machines. In other words, in my head the organizing theme of the children's explorations of the solar system was an exploration of gravity--its meaning and effects.

I let the children lead the way on a superficial level by letting them control (introduce) the materials we would discuss. I made no attempt to ask why particular children chose to share the things that they did. I think there was an interplay of children bringing things they had that they thought were pertinent to a discussion going on (I think this because often we didn't get to a child's offering for days and when we did, the child would say things like, "Oh let's not read this now, we aren't talking about it anymore"), were points that they would like to make to support their views of an argument, were very interesting to them. How what the children brought in played out in class was something I manufactured though.

Connecting gravity to motion: Connecting to each others ideas.

So we started in on Monday, March 23rd with me recapping the children's plan from the last class. I had asked Sylvia if I could teach on Monday that week (normally I don't) because I had thought that one long class and then the shorter classes that I normally taught on Tuesday, Wednesday, and Thursday in which they shared things that they had brought from home would end their interest in planets. The Monday class is an hour and a half. My other classes are 40 minutes. First I poll the room for who brought stuff in, then for who else planned to, then of the children who had got stuff, what they had. This is how I arranged the conversation. I also explicitly said we were going to end talking about planets on Thursday.

I start with Timmy who has information in his encyclopedia to share. Before we get to his choices though I ask him to look up gravity. Then he asks me to read the selection. The paragraph I read defines gravity through Newton's law which states that any two objects are

pulled towards each other with a force that has to do with the amount of their mass and the distance between them. The closer they are together the more they are attracted to each other. I define mass for the children as having to do with size as I was telling them before. Then the encyclopedia talks about how in order to escape the Earth's gravity an object has to be moving very fast, at an "escape velocity." So this is where I suddenly get the idea that exploring the revolution of one body around another would be a way to start thinking about gravity as a dynamic interaction between two bodies; another version of Dembe's tug-of-war. I bring this up later in class.

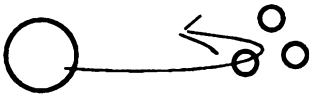
Timmy asks for questions or comments. This is how I have established that children lead discussions in my classes. A child who wishes to share something--a book or a drawing for example--presents it to the class, explaining why they thought it was important. Then they take questions from the class. Children who ask questions must raise their hands and be recognized by the speaker. To an extent, the speaker controls who talks and for how long. The speaker also responds to the questioner. When the topic seems particularly fruitful or becomes important as the question/response progresses, I often step in and interfere with what is talked about and who does the talking. I also step in to make sure certain people who I suspect have something important to add get air time and I also step in with these people to increase the time spent on their ideas. In other words, I don't rely on the speaker to know what is important scientifically. I feel it is my role to keep these sessions focused on the science and I break the norms of this type of conversation to do this. Timmy calls on Amina first. Amina asks about another experiment that the class did on static electricity. In this experiment, they rubbed balloons on their hair and tried to stick the balloons together, or not, depending if the other balloon was also rubbed. Timmy and Amina argue about whether discussing this is applicable to a discussion of gravitational attraction. Timmy thinks she is arguing that gravity and electricity are the same thing.

It's pretty obvious I feel that Amina is pointing out the similarity in the descriptions of the attraction between two bodies due to gravity and that caused by electricity, not saying that

these are the same thing. I think this is very perceptive. The equations that describe this are of the same form. The difference though (and it's a fundamental one) is that while gravity can only attract, electricity can both attract and repel. I want to know if the children see this similarity also and see the difference so I continue polling the room. No one seems confused by the two as different and Alice does point out that most fundamental difference between the two. This is a nice short exploration of similarities and differences that adds to the understanding of both concepts I think. A similar sort of discussion will happen between Yong Sun and Daniel about definitions of the word satellite in the next class. These two conversations are different in substance although the form is similar--here we are exploring the differences and similarities in a phenomenon. Around the word "satellite" we are discussing the meaning of a word, a human-made construct. It is important to think of Wittgenstein's ideas about meaning and language in these contexts and ask if and how words have meanings outside the use they are put to, the contexts they are found in. How we construct meaning and that meaning is shaped by the social context in which it is formed.

Next Timmy has me read from his book on planets. His encyclopedia defines planets as bodies moving around a star each in its own orbit. It lists the planets in our solar system and I show the children the picture the book has of the planets, labelled, in orbits around the Sun. I ask the children what they have in their textbooks. Karen starts us by talking about a picture of the orbitals of the planets about the Sun. I ask Karen why she thinks the Sun is in the middle. She answers: "Because all the planets have to move around it, like planet Earth, then one half isn't warm while the other half's cold." This is very true. The only planet that only presents one side to the Sun is Uranus, a gaseous planet, that can convect and even out the temperature differential. But Karen's answer really explains why planets rotate not revolve around the Sun. So I ask her why they have to go around the Sun, why can't they just sit? This question returns us to the idea that planetary motion represents a dynamic tension between gravitational attraction and centripetal force. My reason for pushing on this as a means to try to develop an understanding of gravity with the children relates to my own understanding of gravity. Remembering the

equation which describes gravitational attraction: $F=G(M_1M_2/r^2)$ in which F is force, M is mass, A is acceleration, G is the gravitational constant and r is the distance separating the two bodies, there is a force of attraction between any two bodies. They must work to stay apart. We work to stand upright on the Earth but because we do it constantly we aren't aware of it. The fact that the planets revolve around the Sun is a manifestation of their gravitational attraction towards the Sun. It is hard to understand gravity as a force if you can't recognize the work (the motion) being done to counteract it. She replies: "Cause they'd burn up in the same spot." Dembe adds: "Well I think it's in the middle because [? they can't share the same orbit then they'd] share the heat." Then I interrupt and draw this picture:



I also want to know why the children think planets can't share orbitals.

> Dembe: That wouldn't be a good idea because, 'cause if they were too close to each other you would just have to jump to get to one and another thing, the Sun would only be on the one side and it needs to get on the other side because then on that side there would be something and on the other side there would be nothing and it needs to be around.
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> Teacher: Karen didn't you have your hand up?
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> Karen: Um hum, if it were to stay in one spot and the Sun is in one spot, um, the people that was on the half that was cold they would get kind of tired of having it freezing all the time, and the people where it's warm they'd get real hot . . .
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> Ricardo: Not if you live in Florida or California, you're used to it.
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> Yong Sun: All the planets have to do is spin around instead of go around it.
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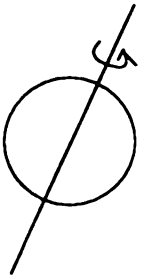
> Teacher: Oh okay let me see if I can draw, so like here's the planet here and so it would be just spinning around like that?



Yong Sun: Yeah then everybody could get Sun.

Teacher: But it still would just be sitting here, it wouldn't be um, going around the Sun. It would just sit right here and spin around by itself?

Yong Sun: Yeah but the bad thing would be um, then astronomers, I mean then people wouldn't know how long a year would be 'cause every time the year spins around the Sun one time is a year.

A debate starts up about what is a day and what is a year, about the difference between rotation and revolution. We spend a lot of time trying to demonstrate different people's ideas of how you could get a day through revolution and whether or not that kind of thinking makes sense using globes and people walking around each other. Timmy takes the globe and revolves it around the Sun once and says that's what makes a day. Yong Sun, though, says that is a year.

Alice: I think I know how it gets dark and light and um, the days because when the world turns around, like Timmy was doing, see, when it turns around then on the other side of the Earth, the Sun is on that side so if you are on the opposite side of that, then it would be dark over there.

John: The Earth doesn't go around the Sun every day . . .

Timmy: *It has to*!!

Teacher: Timmy . . . let John finish.

John: It takes the Earth a year to make one revolution around the Sun.

Teacher: So when it goes around the Sun like this line, the white lines that are in your book . . . those are the revolutions around the Sun and it takes a year for that to happen?

Both John and Yong Sun agree but other people are still all tangled up and Timmy keeps arguing back and forth. So we do more demonstrations with globes. Finally I summarize again and Timmy agrees to the logic behind a day and then *he* asks my initial question. He asks why if it is spinning does it have to travel around the Sun also.

Teacher: Okay good question, why does it go around me, why doesn't it just spin? And the reason why different people are saying it just spins I think, like Karen said if it didn't spin and I think Dembe said this also, if it didn't spin then the Sun would always hit the same place and then it would burn up, is that what you guys said? Or it would get very very hot.

Karen: I still think it goes around [the sun] and at the same time, it, it's turning and then it's also going around [the sun].

Teacher: You think so? Why though?

Ricardo: Why would it do both?

Karen: I think it does because if it was turning in one place then it would be hot and then it would be cold and then it would be hot and then cold, I've changed my mind, in one day then it would be hot then cold, so I think it just goes round the Sun.

Teacher: You think it just goes around the Sun, it doesn't spin too?

Karen: You see while it's going around the Sun, it's heading this way and it goes, the Sun is pointing this way and then it's like that.

Teacher: So are you saying that it goes around the Sun once a day, every day it goes all the way around the Sun?

So now Karen has argued herself back the other way. We demonstrate Karen's theory with the globes and Karen revises. Timmy says: "I think that I agree with Jin but I'm just not sure, I don't know if either one is right, I'm not sure I'm not saying Jin is right and I'm wrong or I'm right and his is wrong, I'm not sure . . . "

We debate this some more. I am letting this talk go on for so long because of two things. I think this talk recapitulates a long debate in the history of science and is a good place to try working on making sense by theorizing with "data" that we "know" for sure. We know there is a year and a day. Where do they come from, what causes them? Second we can't make sense of gravity using these concepts without making sense of the concepts first. The Earth must revolve around the Sun or fall into the Sun. The Earth's orbit is the result of the gravitational attraction between the two and the Earth's tangential velocity away from the Sun. That's why I started us in on this in the first place.

Kristin suggests we look at a picture she doesn't understand in the book. This is a drawing of the Earth going around the Sun and the Moon around the Earth. I name them.

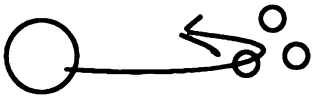
Kristin: I always thought the Moon was bigger than the Sun.

Yong Sun: The Moon is always smaller than the planet.

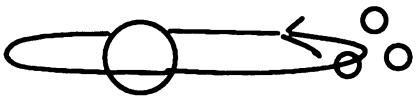
Teacher: Who said the Moon is always smaller than the planet? Why is that? I happen to agree with you but why is that?

Jin: I don't know but um, in a book I have that has all the planets and the moons, none of the moons were bigger than the planets.

We'll come back to this on the 30th. Again this is a place to make sense of gravity as dynamic but right now we go back to revolution and rotation. We go back to my picture on the board.



People are questioning it. Jin and Amina found my drawing the arrow indicating revolution only half way confusing so I complete the diagram.



But Amina has more. She goes back to Dembe's comment about being able to jump between planets. She doesn't like that idea. She is talking to Dembe:

> Amina: The part where you said that um, you're not allowed to touch the Sun, you're not allowed to be that close to the Sun and Dr Osborne said something about the planets, and you have to jump, and Dembe said if the planets are real close together you have to jump . . .
>
> Teacher: And you [*Dembe*] argued that that couldn't possibly be because they'd be way too close together and also because . . .
>
> Dembe: Well maybe if they turn around and they, if there was a planet right here and another here and it's turning around, it might bump possibly.
>
> Amina: I disagree because, if the Moon or if this was, well, if this was here and another planet was here, you couldn't jump, if you did you'd probably be floating between, just because they're close together doesn't mean you could jump from each one.
>
> Dembe: I said you *probably* could.
>
> Amina: But you, but you can't . . . well those two big ones right there um, they're close, but if you put the one on the right, if it was close, well the one on the left, if you were on that one, the one on the left and if you were going to jump off to get to the next planet you'd be, you wouldn't get to the next planet because they're really not close together.
>
> Teacher: Why do you say that?
>
> Amina: Um, that's just there, um, a picture, it's really the planets are not close together, they're far apart.

Amina often brings this sort of thing up. It's like she wants to reaffirm and make sure everyone agrees that diagrams illustrate ideas not reality and what we see can be misleading therefore we have to remember the way things *are*. Again I think this is important in science and how we represent scientific ideas. When the discussion about this ends I take us back to my original question which is the one in which I hope to expose gravity some more.

> Teacher: Now I have a question I've heard lots of good arguments why this should spin around and around so it doesn't get too hot and burn up and so we can have days, I don't understand why it has to revolve around the Sun though, why couldn't it *just* spin round and round and round in one place, wouldn't that keep it from getting too hot on one side or too cold on one side, wouldn't that be enough? Why does it have to go all the way around the Sun and come back every year? What do you think Jin?
>
> Jin: I wouldn't know how long a year is.
>
> Teacher: Oh so it needs to go all the way around the Sun just to tell *us* how long a year is? Is that right, the Earth circles the Sun just to tell you, Jin, how long a year is. Why does it need to do that, why does it need to tell us how long the year is?
>
> Alice: Well, I think I have a reason and I have a comment for Jin. What my reason is maybe so it can tell you that a year is and there's another way something could tell you a year is, well you could tell by the months you could count how many months there have been and see if that's the number of months and that would be a whole year.
>
> Teacher: Okay it's almost recess time and before you go out could you please write about this question "Why does the Earth go round the Sun and doesn't fall in, if there's gravity and the Sun is this great big huge thing, the Sun is a great big huge thing and the Earth is a little tiny thing and if there is gravity, why doesn't the Earth become attracted to the Sun and go crashing right into the Sun and burn up.

I revised the question to be somewhat more startling and also to give something of a lead in the direction I want. I start the next class, on the 24th, with this question. Yong Sun tells us he wrote: "It doesn't because if it did it would get out of its orbiting system." I write this up on the board and repeat it. This is a key statement if we are going to work on orbiting as a resolution between competing forces (gravity and centripetal force). Then I ask Kristin what she wrote. Kristin reads: "Because there is a force field that keeps gravity inside the Earth and that's why there's no gravity in space, 'cause if the Earth lets out gravity then there would be gravity in space." I write it on the board and question her. This is why it's essential to think of gravity as a warping of space rather than a "thing." If you think of space as "nothing" how can things interact across it?

Teacher: Now why does that stop it from going crashing into the Sun?

Kristin: 'Cause if there was gravity it would go straight to the Sun.

Ricardo: If there was gravity out in space then *boom*!

Kristin: Right.

Teacher: Ricardo what did you write?

Ricardo: I thought that gravity keeps the Earth from the Sun.

Teacher: Gravity keeps the Earth from the Sun?

Ricardo: I mean gravity keeps the Earth back so it doesn't go crashing into the Sun.

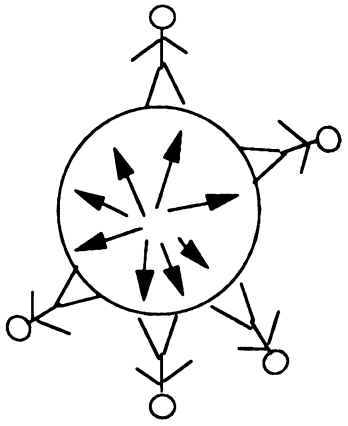
Teacher: The earth's gravity or who's gravity?

Ricardo: The Earth's.

Yong Sun: The Sun's.

Teacher: Ah so the Sun and the Earth have gravity and the Earth's gravity keeps it from crashing into the Sun ... but the way I understood gravity was that it was something that pulls things together how does it keep it back?

To understand Ricardo's statement think of this diagram of Sook Chin's:



He either means the side of the Earth away from the Sun is pulling away from the Sun or the side of the Earth away from the Sun is pulling the other side of the Earth towards it or (invert the arrows in the picture) the Earth is pulling in on itself and this is strong enough to counteract the Sun's attraction.

Ricardo: Um because gravity pulls, pulls real hard.

Yong Sun: But the Sun has more gravity . . . and the other side of it the Earth would push it this way but the Sun goes here.

Teacher: What do you think Ricardo?

Ricardo: I still think that it keeps it from . . . 'cause the Sun is far away from the Earth and if it's real far away the Sun's gravity would hardly reach the Earth.

Teacher: And what about the other thing that Yong Sun said about gravity on the other side of the Earth, did you say gravity on the other side of the Earth would push it, is that what you said?

Yong Sun: Um, hum . . .

Teacher: What do you think about that Ricardo?

Ricardo: Only one, I think only one part of the Earth would pull it.

Yong Sun: Well you think that on one side, the side, where the Sun is facing, it pulls it ,it pulls um, into the Sun but on the other side it's pulling around.

Ricardo: That's not what I mean.

Yong Sun: Then I didn't understand it.

Ricardo: Well what I mean is that 'cause gravity in the middle of the Earth is pulling and pushing from . . . from the Sun so then we won't go into the Sun. [*The third of my suggestions above..*]

Teacher: What do you think Yong Sun?

Yong Sun: You haven't answered my question yet, what about the other side's gravity.

Ricardo: Well it's the gravity goes from the middle of the Earth and one part of the gravity stays where it was and, um, then the other side goes on the pulls from the other side.

Yong Sun: Well, I think like the Sun is here and then the Earth is here and this side of the Earth is pushing this way and the other side is pushing this way.

Ricardo: One side is pulling and one side is pushing away from the Sun.

Yong Sun: So you mean one side pushes and one side pulls and it just stays here.

Teacher: Does that convince you Yong Sun? What about what you said about the Sun being a lot bigger and having a lot more gravity than the Earth?

Yong Sun: Well I can take what Ricardo says.

Teacher: You can take what Ricardo says? You think that it convinces you?

Yong Sun: Well actually a little.

Teacher: Actually a little?

Yong Sun: But he does have a good point though.

Teacher: I think he does too. Dembe?

I really liked these arguments and the reasoning of both are correct. The only resolution that I can think of would be to put numbers to it. This is the kind of thinking I like to leave hanging. I was really pleased with the form and content of this conversation. Dembe, though, introduces something new to consider--there are planets, Mercury and Venus--between us and the Sun. She also makes the point that the Earth and Sun are far apart. She recapitulates Ricardo's and Yong Sun's argument about the Earth staying in its orbit. Dembe makes a drawing of her interpretation of Ricardo's theory:

I ask her about this using the children's definition of gravity as an attractive force: "Well gravity works so that it's pulling towards another thing, one thing towards another thing, why can it pull that way." Dembe cites magic: "Let me revise about that I want to say that, I, you see the ozone on the Sun?" I tell her the Sun has no ozone so she revises to the Earth's ozone. I think this is interesting how the children have latched on to ozone as the universal explanation. She seems to want to say the ozone keeps the Earth together. Yong Sun tells her ozone has nothing to do with gravity. Dembe starts to amend her theory--this is similar to Amina, a couple of classes back--and drifts off in her talk so I call on Kristin who again has a problem with a picture in the book and a too literal interpretation.

> Kristin: On one of the pages it looks like we are really close to the Sun, right here, here's the Sun and here's the Earth.

Dembe: It looks quite close but it's really far . . .

Amina: Well it's like up there the Sun looks real close and the Moon looks real close, like one time I was outside and the Moon it was so so really close and I jumped for it and tried to get it . . . and I saw the bumps and everything . . .

Jin: It's impossible to jump all the way to the Moon.

Amina: I know but it looked that way, really, really close like I could reach it.

Kristin: Well I have something else to say, in another picture in this book on page 230 where it shows the rotation, the orbits of the Earth and the Moon, um, I think that it only takes twenty four hours for the Moon to go around the Sun too.

Teacher: Why do you think that? For the Moon to go around the Sun or for the Moon to go around the Earth?

Kristin: Well I might be wrong but for the Moon to go around the Sun.

Dembe, Jin, Ricardo, Amina all interrupt to point out she is misinterpreting the picture. It shows the Earth orbiting the Sun and the Moon orbiting the Earth. I ask them to let Kristin finish what she is saying because buried in this is what Karen was talking about with Mercury and Venus, orbits within orbits and also the true statement that the Moon does take the same amount of time to go around the Sun as the Earth. Kristin states: "I see that the Moon is going around the Earth and if the Earth is going around the Sun then the Moon has to go around the Sun too." I ask: "You guys who were complaining understand what she is saying?" and ask if the people who wanted to argue with her now understand what she is saying. Finally I repeat Jin's statement for everybody. We will come back to this.

We look up facts about the distances of the planets from the Sun for a while in their textbook and the encyclopedia. After a while I ask again about crashing together. Jin and Joey say "Because the Earth's orbit keeps the Earth in its place the Earth can't go any other place." Yong Sun agrees and I end the class with: "For next time write about how did the Earth get into an orbit where it goes around the Sun, how did that ever happen?"

What Jin, Joey and Yong Sun are saying is really no different from what we started out class with but I feel like we've given it a lot more meaning in this discussion. I phrased my final question the way I did because I think it pushes on the idea we've been working on all along about orbits being the result of a dynamic between gravitational attraction and tangential

velocity. I'm searching for something that causes us to think about orbits in terms of these two components. I wish I had tried asking about orbiting space craft, why they didn't crash to Earth now because of course in the question I did ask I'm asking the children to construct a false argument--the Earth-Sun system was always in orbit, always in motion.

The next two classes are not transcribed. They were further explorations of the things children brought in about the Moon and other bodies of the solar system. The question of orbits was really tabled until the next Monday, March 30th when it returned. Obviously we didn't end talking about planets at the end of the week like I had planned. On Wednesday the 25th I thought things were petering out but then on the 26th they got going again when people started talking about the evolution of the solar system and a couple kids shared books with pictures of Jupiter's and Saturn's moons from the flybys.

Defining words, making statements of knowing: The development of uncertainty.

On the 30th two really interesting things happen. The first is a discussion in which the children define the word satellite. They have done this type of discussion a number of times in this unit, about the meaning of the words orbit and astronaut for instance. This conversation about satellite is quite long and shows a nice interplay of defining a word by what it is, what it represents through its intersection of meaning with other words and also comparatively, by how it's different from other concepts. So defining through difference and through similarity. This sort of conversation like the one between Ricardo and Yong Sun could only happen I feel, between children who want to understand what the other is thinking not just push their own ideas. This sort of connected thinking which leads to critical thinking is quite different from the creative tension which is the result of a Foucault-style discourse community. These conversations are based on a respect for each other rather than a desire to dominate.

The second thing that happens is an interesting return to questions about planetary orbits. The two children talking in this conversation, Jin and Joey, are arguing from positions of

certainty--they both argue that they "know" what they are claiming about the manner that planets orbit about each other. When I say "certainty" I mean as defined intellectually in the Wittgenstein sense--the children *think* they know and believe they can defend their ideas logically but also emotionally or tacitly in a more Heidegger-like manner. Each child *feels* that orbitals must work a certain way. This feeling is not seated in the intellect but in a more spiritual place or emotional place, like Amina citing god. The Heidegger and Wittgenstein forms of certainty are brought into play with each other because the children are making claims in their attempts to communicate to each other. Because each child has to try to truly understand the other's argument in order to argue against it, certainty is recast as uncertainty. This is an important quality of my community. It is an illustration of how I try to use conflict to strengthen the community, strengthen the need people with different ideas and opinions feel for each other. Because certainty can be recast as uncertainty, the children can value their differences. This is a community based upon differences between people rather than on likeness.

We start the class with me reading something of Amina's on the Moon. In this book the Moon is called a satellite. I ask the class if they understand the word.

Daniel: I don't get it ...

Teacher: What? The word satellite? It says the Moon is a satellite that revolves around the Earth.

Daniel: What I don't get is, how does a satellite revolve, usually satellites take pictures.

Yong Sun and other children start searching in their science books. Daniel looks in his book on the Moon for a picture to illustrate his idea of what a satellite is then he shows us a picture of Skylab. Yong Sun finds what he wants in the book and reads it: "We will soon send a satellite into space and it will help us look at stars and identify things that have moved, so that's one kind of satellite, one that takes pictures like Daniel said but the Moon is a different kind of satellite, and the Earth is a satellite too."

Daniel: Why would the Moon be a satellite if it didn't do much ...

Teacher: Yong Sun how can all three of those be satellites, what is a satellite?

Yong Sun: Well it's just like one word can mean different things.

Daniel: What special work does the Moon do?

Yong Sun: Well it sort of does the same thing, it kind of goes around a planet.

Daniel: Yeah but how can . . .

Teacher: Wait can I just ask something? Are you saying that it's a satellite because it goes around a planet?

Yong Sun: Yeah like the Earth goes around the Sun . . . . I'm not really sure why they call the things with cameras a satellite.

Daniel: How could, um, if the Moon is similar to the, um, to a regular satellite, how could it take pictures?

Yong Sun: It doesn't take pictures.

Daniel: Then why did you say it's similar to the um . . .

Yong Sun: I didn't say that *everything* is the same!

Teacher: What do you think, if you used Yong Sun's definition that it goes around something else, why would the thing that takes pictures be a satellite?

Daniel: That's what I don't get, why would that be a special kind of word, 'cause the Earth and the Moon do the something . . .

Teacher: Go around something.

Daniel: . . . And usually a special word is where you do things differently.

I ask what is special about the one type of satellite from the other type. Joey says that he thinks the Earth is different from the other planets because it is the only satellite that can support life. Jin disagrees with this. He says that he heard on the news that while there may not be life on other planets *now* there might be in the future. Everyone finds this argument very interesting. After some discussion, I ask, if Joey's comments helped Daniel think how the Moon, Skylab and Earth could all be satellites and still be different. When Joey repeats his statement, slightly doctored to pacify Jin, Dembe starts in:

Dembe: In the newspaper, it said that some aliens they were buried under the Empire State Building.

Teacher: What does that have to do with this?

Dembe: Well I think that there are some things living on other planets right now.

I included this last interchange between Dembe and myself because I think it is an especially vivid illustration of how this whole unit was a play off of the things/knowledge children brought in from elsewhere. And like with Dinosaur Stories (next chapter), their information is mixed in quality. Science fiction plays off being scientifically plausible. It is also an example of another side comment such as I wrote of earlier concerning Ricardo's statement about what would happen to sharks if there were no gravity. In this instance the whole class ooo's and ah's and we just leave it. I finish my part in teaching this unit, however, after one more week and a student teacher continues. I suggest to him that he take this topic and work with the children to construct science fiction stories--experimenting with teaching science in this manner. So this is an example where a side comment is left for the moment but returns as a more central topic. Another example of that process are the initial comments about birds flying by Amina which then become central a few days later.

I summarize the discussion between Yong Sun and Daniel and Joey and then throw in a little demo of my own. At the end of my summary I have Ricardo run around Joey to demonstrate a satellite. Joey is by far the smallest child in the class.

Hamal: Ricardo's a satellite.

Timmy: That's wrong, that's wrong, that's wrong! Ricardo's bigger than Joey!

Teacher: What difference does that make?

Timmy: It means that if he's bigger, it can't go around, it means that Joey's got to go around him . . .

Jin, Ricardo, Dembe all don't think it matters. Actually, of course two bodies orbit around a fulcrum point (barycenter). Fortunately, I didn't think to try to get them to connect this to levers or we would still be at this. Timmy repeats: "It's just like the Sun, the Earth goes around the Sun, the Moon goes around the Earth . . . " I ask why that is, why does the smaller go around the larger. Timmy says because it's bigger. Sook Chin adds the Sun has more gravity and that's because it's bigger. Timmy says that this "is like a pattern." I think he's saying that something large can go around something small if it has an orbit.

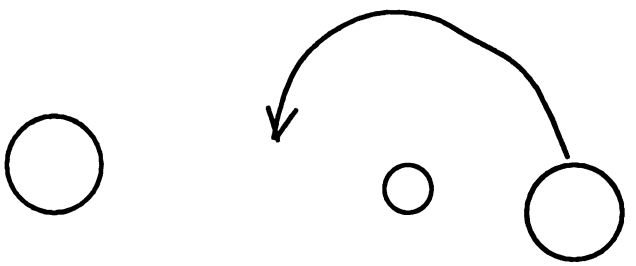
Ricardo "kind of agrees and kind of disagrees" with Timmy. Timmy repeats his argument but says he "just doesn't know" what he thinks of Sook Chin's explanation. Next Dembe, who agrees with Timmy now, adds her logic.

> Dembe: I think it's big and if it's big it really weighs too much and it can't really go around.
>
> Teacher: That seems to be a lot like what Sook Chin said but, anyway I'm sorry go ahead . . .
>
> Dembe: And then I disagree with Ricardo but I agree with Timothy, I think that small things have to go around big things because big things can't go around small things, for one thing the Sun, I think it weighs too much.
>
> Timmy: If the Sun went around the Earth, it probably could burn us.
>
> Dembe: Yeah because it would get too close and stuff.

Then there is a short animated discussion of the ways we would all die if this were to be true. But back to making sense of Timmy's assertion . . .

> Teacher: I don't understand that, that doesn't make any sense to me, I mean if the Sun goes around the Earth or the Earth goes around the Sun, it still seems to me that they'd still be far enough apart so that we wouldn't burn up.
>
> Timmy: No because if the Sun, the Sun went around the . . . see the Earth goes around the Sun and it can go in its orbit, and it goes around but if the Sun went around the Earth then the gravity from the Earth . . . I just don't think it would work, if it went the other way the Sun would get, I don't know how to say it, I know it would be just burning up but I don't know how to explain it.
>
> Alice: I disagree that it might burn you because when the Earth goes around the Sun then that's just like the Sun going around the Earth because that's just like the Earth moving around the Sun, that's turning like the Earth usually does so it wouldn't burn us and if the Sun goes around the Earth it would be like the same thing.
>
> Timmy: There's just got to be something wrong or it wouldn't matter.
>
> Teacher: So Alice why do you think the Earth goes around the Sun?
>
> Alice: Um I'm not sure I just know that it doesn't matter which way it goes, if the Sun goes around the Earth or the Earth goes around the Sun.
>
> Yong Sun: I disagree with Timothy that we'd all burn up . . . 'cause the Earth has an orbit and if the Sun went around the Earth, the Sun would have an orbit too.
>
> Timmy: Yeah but the Sun doesn't have an orbit that's why, and also they've gotten something wrong otherwise it wouldn't matter which way it would go so I revise what I said and say now that something's got to be wrong or else the Sun would go around the Moon or something, something's got to be wrong or I don't know . . .

I remind him of Sook Chin's explanation and that seems to pacify him for a moment. But then a whole new argument starts. Joey returns us to the point of orbits of planets within other orbits. Because of this, larger planets *do* go around smaller planets. "I disagree with Timmy that the Moon can't go around the Sun because in our science book Mars and Mercury are smaller than Saturn and it still goes around them, it's in a different orbit . . . " Jin gets very excited about this. He disagrees: "No, if this was Mars and it had a different orbit and Saturn was going around it then Saturn would be like this . . . " and draws a picture.



Joey says again: "It's in a different orbit here's Saturn and here's Mars right there [points]." Jin still disagrees and keeps interrupting Joey as he tries to explain. So I draw a picture which is like the one in the book of the planet's orbits around the Sun. I ask Joey if this is what he means. "So here's Mercury, it's going around the Sun but in order to go around the Sun, Venus has to go around Mercury and the Sun, is that what you're saying?" Jin, though, continued to argue for his interpretation of Joey's words. "Yeah but he's saying this is Mars and then it has its orbit and then here's Saturn's orbit and then here's Saturn. I think that's what he's saying."

> Joey: Here's Saturn and in order to go around the Sun it has to go around both of them just to go around the Sun.
>
> Teacher: Well I think that is true if this is what you're saying in my picture not in that picture?
>
> Joey: Yeah that's what I'm saying.
>
> Teacher: So it's going around the Sun as well as going around something smaller than it.
>
> Joey: Um hum . . .
>
> Jin: Well if it's going around it then it has an orbit by it, you know.

Jin gets more insistent in his disagreement and Joey gets more vehement in his explanation of *his* argument. "NO, if I'm, ah, a planet and then someone else is I'll still be going around it and the other person's just in a different orbit, or a different place!"

Jin: If it goes round the planet it has to go like this . . . [*He gestures with his arms that the planet would circle around the other planet as well as around the Sun.*]

Joey: No it doesn't, I can walk around you but far away.

Jin: I know but you're still going around me.

Joey: I know so it's still going around those other planets

Jin: But the other planet has to go around it like that . . . closer to it.

Joey: No it doesn't, I'm far, very far away and you're the different planet, I go around you and it's not, it's not, and you say you're not going around me I'll still be going around just from farther away.

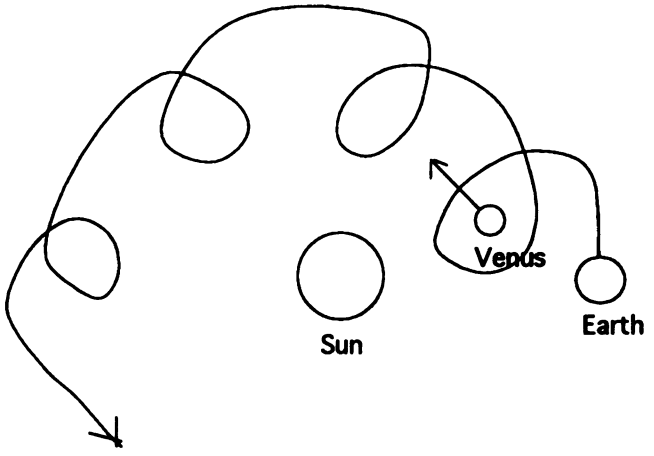
Jin: No 'cause if I were moving that way and you were moving this way you'd be going like that . . .

Joey: No because if you were the planet and I was Jupiter no not that one, Mercury and then you'd be moving too the same way but I could still be going around you.

Jin: I know but but you're saying that going around like this going around the planet.

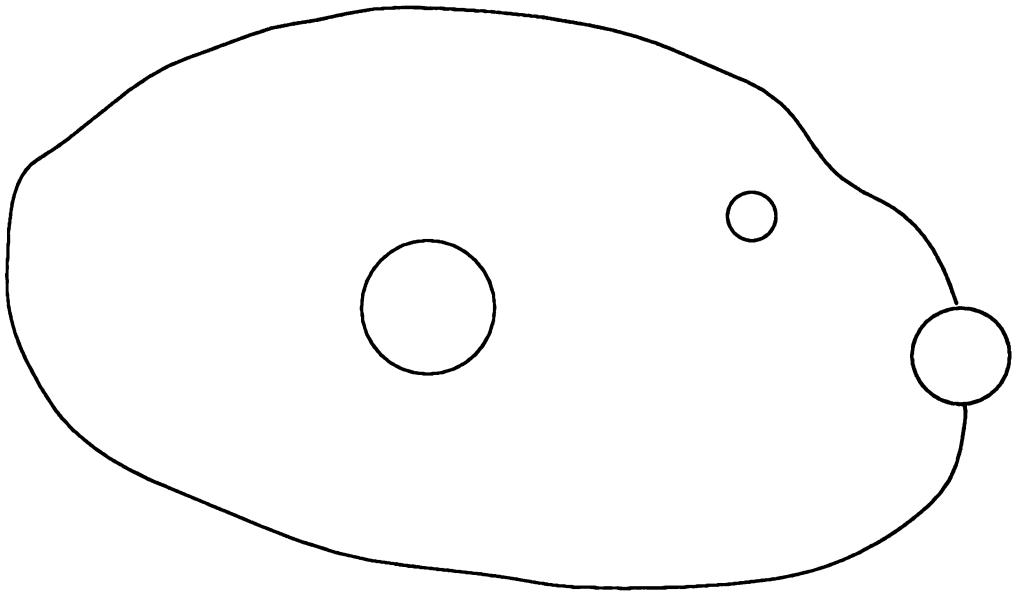
Joey: No I'm saying it can still go around a bigger thing just in a different orbit.

Jin: I know but like this is still a different orbit, you're saying it goes around the Sun and the planet so it would go like this like that.

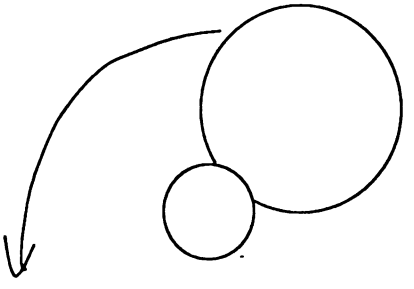


Joey: No 'cause if it's going around Venus or Mercury it would go around both of them or Venus wouldn't even go around the Sun.

Jin: But you said um, that it goes around the planet and the Sun so it has to go like this? Or like that or something like that . . .



Now this one is true, but exaggerated and Jin has now modified his theory to accommodate Joey's but they continue to argue until I have Joey, Ricardo and Jin demonstrate Joey's model. I summarize and everyone agrees with Joey. But then it starts up again when Dembe draws this picture to explain why a large thing can't go around a small thing.



Jin says again that if something large were to go directly around the Earth it would crush the Earth, Joey is adamant, I stop the argument and ask them to all write in their notebooks what they think of what Joey, Jin and Timmy are arguing about, then I polled and almost everyone said that little could go around big, Alice said she's still thinking about it, Sook Chin has converted, Dembe isn't sure.

In these classes with the third grade as in those in the first and second combination, the shape of conversations and the qualities of the community are intertwined with each other and with the science. The difference is in *my* purposes, *my* role in the two contexts. In the latter class my role is primarily reactive on a superficial level--around the science. My role is proactive--I try to instantiate values that I hold around how children should treat each other. The children and I negotiate the science that is talked about because I hold these values about the way people should interact--there is a dependency between the discourse which springs from these values and the science we are doing. This is also true in the third grade except my proactive role extends to the science content. I am quite active trying to shape and center the science. The discourse in some senses follows this. Because I wish to stay with particular ideas and get to particular places in our thinking about those ideas, the discourse patterns have changed. I encourage and stimulate conflict. This feels at odds with my ideals and values about how I think people should respect and value each other. Because I will not give up these ideals, I reshape the science to allow them.

The community in these two classes is, I think, characterized by children entering imaginatively, intellectually, empathetically into one another's conceptions of the world. This is done in order to understand each other. This thinking becomes critical. This is common to both classes. The entry point to this is different. In the first and second grade the progression of the community is as simple as described above--listening and hearing each other, then thinking critically. In the third grade from the start the critical and connected modes of thinking inter-finger. This is a reflection of what I am doing, the choices I make. I work in these classes to keep ideas problematic, to generate conflict. I do a balancing act between this and my more fundamental values about how people should treat each other. The ways the children express themselves and interact reflect this. A critical quality of this is how I use conflict in the class to increase the children's need for each other. The children express different ideas and logic in their ways of thinking. Rather than divide the class into factions, differences strengthen the need each

child feels for another. By hearing an opinion that is different from your own but is respected, it can cause you to question yourself and modify your thinking. This process is valuable when it is around something engaging, important. Again this cycles back around to the tension I feel in taking a proactive role shaping the science. To keep conflict a strengthening quality of the community, I must keep the focus of the conflict of the children's own choice. There is no resolution in this. It is a tension.

CHAPTER 5

TEACHING: KNOWING AND LEARNING

In this chapter I argue that a teacher's practice reflects both articulated and unarticulated knowledge. Praxis proceeds from the personal epistemological standpoints of the teacher. This knowledge is constructed from the teacher's prior experiences and therefore is only partially applicable to particular situations in the classroom. The immediate circumstances in which teaching occurs present different and unique qualities from those in which knowledge and values were created. The classroom environment is also an interactive one. The teacher is, therefore, continuously confronted with the inadequacy of her knowledge. The circumstances and children's activities tell her that she needs to do things differently. In this situation, the act of teaching as an assertion of knowing becomes a recognition of not-knowing. Teaching becomes an occasion for learning about subject matter, children, self. I offer two examples of teaching in a first grade classroom to give this argument substance.[29] One focuses on an example from my teaching in which parallels between scientific theorizing and story telling are drawn and capitalized upon. The second story is about, the teacher I have collaborated with in first and second grade, Kathy Valentine's teaching of a social studies unit in which the words "fact" and "opinion" are examined while reading biographies of the life of Martin Luther King Jr. This became especially problematic because this instruction occurred during the recent Gulf War when issues of tolerance and prejudice took on more than philosophical meanings.

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[29]The teaching described in this chapter occur in first grade in the year previous to that described in the rest of this thesis. For a full description of the school, classroom and children please see Appendix I and II.

Like Jin and Joey in the last chapter, when acting, talking, teaching in my classes I expose the things that I think I know. Again like Jin and Joey , I am exposing this knowledge in a context changing, in flux, one defined as social. Through this process I am recasting those known things as unknown, as questions. The acts of teaching are acts of making assertions but these assertions quickly become conjectures subject to revision and change. They become opportunities for learning. When teaching I am often surprised when I realize the things that I am teaching, am learning, that I *know*. And I have noticed that other teachers are too. When we teach, we act on assumptions founded in knowledge: knowledge about children, curriculum, teaching. This knowledge is an assumption--unarticulated, unacknowledged--because it has become translated into a value, something we have decided is *of* value and no longer think we have to defend. This knowledge has passed from the intellect and has become beliefs and emotions which are unquestioned, felt to be true. But when we are teaching, things happen to make us aware of those assumptions; to make us think about and question them and the values on which they are based. This questioning and subsequent learning occurs because of the social, interactive qualities of the classroom.

The teacher as well as the children are members of a community. A community contains people who share some goals, purposes,values, ways of acting and communicating, but not others. The basis of a community is similarity on one or more dimensions--without similarity a community would not exist, could not function. The driving force, however, the life force behind a community is difference--we need each other because we are different from each other. When we act in a community, we act on an assumption of similarity but often those actions expose our differences. This exposure motivates change, in ourselves as we learn from this and in the community as its members evolve. This process is fundamental to my classroom. I try to detail it from the teacher's perspective in this chapter.

In this chapter I argue that the knowledge base of teachers is both the foundation upon which they are able to teach and also a vehicle through which they are able to learn because through teaching they come to question that knowledge. Teachers know many things and they

base their teaching upon this knowledge. Translating knowledge into teaching involves making choices which are based upon the teacher's values and beliefs. Teaching is inherently interactive and social. Because students don't share either the knowledge, the experiences upon which this knowledge is formed, or the teacher's values when she translates what she knows into curriculum, the teacher is continuously reassessing, reforming her knowledge and values. The specifics of the context in which she is using her knowledge challenge that knowledge.

There is an increasing body of work in which researchers and practitioners write about the ways in which teacher's personal and professional selves evolve.[30] In other writings, teachers tell us how the domains of knowledge they bring to teaching are broadened through their teaching.[31] Much can be said about the sources of these "ways of knowing." In general both personal and professional values and belief systems derive from a variety of sources but especially from lived experience.[32] These personal experiences and the memberships in socio-cultural groups which create them, define a person's epistemologic standpoints from which their beliefs, values, actions are derived. These epistemologies are created and maintained emotionally as well as intellectually.[33]

I am arguing in this chapter that through teaching we are forced to articulate and act upon our values and beliefs in a context different from the ones in which they were formed. In doing this our values and beliefs are altered because of this new context--which includes interaction with students--and through the act of articulation and the self-awareness this entails.

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[30] For example, Michael Connelly and Jean Clandinin (1990) Stories of experience and narrative inquiry. Mark Johnson (1989) Embodied knowledge. Vivian Paley (1979)*White Teacher*. Shirley Brice Heath (1983)*Ways with Words: Language, Life, and Work in Communities and Classrooms*. 1983.

[31] Examples are: Deborah Loewenberg Ball (1990) *Halves Pieces and Twoths: Constructing Representational Contexts in Teaching Fractions*. Timothy J. Lensmire (1992) *Intention, Risk, and Writing in a Third Grade Writing Workshop,*.

[32] Sandra M. Harding (1991) *Whose Science? Whose Knowledge? Thinking from Women's Lives;* Mary Field Belenky, Blythe McVicker Clinchy, Nancy Rule Goldberger, Jill Mattuck Tarule (1986) *Women's Ways of Knowing: The Development of Self, Voice, and Mind;* John Dewey (1902/56) *The Child and the Curriculum.*

[33] Two references which I have found particularly helpful to me in formulating these ideas are: Jurgen Habermas (1991) *Moral Consciousness and Communicative Action.* Hannah Arendt (1978) *The Life of the Mind*.

I write about two elementary school teachers, myself and a woman that I work with, Kathy Valentine, who know a lot about certain things. I know a lot about science and about how to teach science--I have had my Ph.D. in geology for ten years and have been teaching science to children and young adults since 1978. Kathy knows a lot about teaching small children--she has been an elementary school teacher for 13 years--and about literacy and social studies instruction. I will argue, in this chapter, that as we teach these "things" that we know so well to children, we both purposely and inadvertently expose to ourselves things that we don't know. This is a function of both *how* we are teaching--with "social constructivist" means and ideals-- and *what* we are teaching. Both process and content become problematic through teaching. When we expose these areas where we don't "know" the right things in the right way, that exposure occurs simultaneous with learning. This makes it hard to articulate what is "learned" because it doesn't really occur isolated from previous knowledge or from the context in which learning occurs.[34] But what does happen is that new *meanings* of our choices and values become apparent to us.[35]

I will present two stories of teaching, one by Kathy Valentine and one by me to illustrate my argument. The first story focuses on my teaching a unit about scientific theory-making--fact and opinion in science--by having children research and write stories about dinosaurs. This raised questions for me about process and about literacy instruction. In the second, Kathy is teaching a unit on Martin Luther King combined with a part of the social studies curriculum in which the meanings of statements are assessed as "facts or opinions." This teaching occurred during the recent war in Iraq. This context and the context provided by the children in the classroom infused the substance of the unit with intensely felt meanings which became quite problematic as ideas were shared. In all cases, the teacher's knowledge of "how to teach" enabled learning about the children, the subject matter, and our own purposes in making certain curricular and pedagogical choices.

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[34] Donald Schon (1990) "The Theory of Inquiry: Dewey's Legacy to Education".
[35] Joseph J. Schwab (1976) "Education and the state: Learning community".

First story: Dinosaur stories--Substance or process, choosing instructional goals.

I decided to teach about dinosaurs and prehistoric life in this first-grade classroom because the district science objectives required it. This requirement was rather simplistic: It asked that at this grade level children be introduced to ideas of geologic time scale and the fossil record and be exposed to dinosaur names. I was interested in enabling the children to think critically and creatively in science and about science. This was really the sub-text or maybe the "real" curriculum for this unit: thinking about where scientific knowledge comes from, how it is constructed, how clues and partial knowledge can be put together to create something with the sometimes misleading appearance of coherence and completeness. Using dinosaurs for this is particularly powerful, I think, because a lot of material about dinosaurs available for children is of varying quality and scientific orientation.[36]

I decided to teach this unit on dinosaurs using the parallels between story writing and scientific theorizing, story reading and interpretation, and the reading and interpretation of the material on dinosaurs found in trade books. If children were to engage in constructing stories about the lives of dinosaurs using the partial evidence--re-constructed morphology, environment, associations--of scientists they would be participating in realistic scientific activities. The children, in sharing their stories with each other, would subject their thinking to the critical inquiry of myself and their peers. I envisioned the vehicle for this unit to be similar to units Kathy had done on story parts and the interpretive reading of stories and descriptions I had read of writing workshops.[37] I had hoped to be able to use these structures to frame our critical assessments of the children's scientific thinking.

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[36] I beleive that people in general make sense of the world and their lives through the use of stories and of story telling. An example of a teacher making similar use of story telling in the classroom to make sense of children is Vivian Paley (1990) *The Boy Who W ould Be a Helicopter*. I am also extending this idea to help my understanding how children think about subject matter and I am using story telling as a tool to challenge these understandings--I also teach the subject matter through story telling.

[37] Donald H. Graves (1983)*Writing: Teachers and Children at Work*; L.M. Calkins (1986) *The Art of Teaching Writing*; Arthur N. Applebee (1986) "Problems in process approaches: Toward a

I started the dinosaur unit with talk about the things that the children knew or thought they knew about dinosaurs and the sources of that knowledge. I wanted to see the range in the sophistication of their knowledge. Then we talked about whether or not that knowledge was fact or theory or fiction and how those start to blend together when talking about something like dinosaurs. I particularly used the words "fact," "theory," and "fiction" with the children because of their importance to my goals in this unit and to connect this unit to other teaching that Kathy had been doing all year in language arts and social studies.[38] I wished to know what the children understood about how ideas about dinosaurs--how they lived, what they did, how they looked--were constructed. I also wanted to open up the discussion to include fictionalized, fantasy dinosaur stories because, to me, this is on a continuum with the scientific theorizing. And I wanted people to start thinking about the criteria they should be using to judge dinosaur material. This became a discussion of the movie *The Land Before Time.*[39]

I asked the class what kinds of things they had found out about dinosaurs in *The Land Before Time.* Maria Theresa said that she learned that some dinosaurs were egg eaters. Bulli told us that there are big dinosaurs that eat little dinosaurs. Claire added, "It was a tyrannosaurus rex!" I responded that *The Land Before Time* was a story that someone has written just like *Charlie and the Chocolate Factory*[40] (the children were reading this in class during story time). I said both are stories and both have authors. Kyong Min, though, disagreed, "Its not real . . . " So I asked her how she knew that *Charlie and the Chocolate Factory* wasn't real. She responded by listing things in the story that are components of the fantasy. The children debated whether things that were considered plausible had to be real also. Then they talked about why they thought some things were plausible and some things weren't. Other children wanted to continue talking about this and I also thought it was important in this context. Part of Roald Dahl's power is, I think,

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reconceptualization of process instruction"; J. Willensky (1990)*The New Literacy: Redefining Reading and Writing in Schools.*

[38] An example of Kathy's teaching in which these words are used is the next story in this chapter concerning Kathy's teaching of the life of Martin Luther King Jr.

[39] Steven Spielberg, George Lucas, Kathleen Kennedy, Frank Marshall (1988) *The Land Before Time.*

[40] Roald Dahl (1964) *Charlie and the Chocolate Factory.*

that his fantasy is stretched truth, caricatured reality. Things that people and especially children really do contemplate. That is also, I think, the power of children's dinosaur stories and these sorts of conversations about what we believe and why and were what I wanted this unit to be about.

I returned the conversation to *The Land Before Time* and what was real or stretched truths or fantasy in that. The children said things like, "dinosaurs are real . . . they did lay eggs . . . eat meat . . . take care of their babies." Each time they said these things I challenged their statements; "How do you know that though?" and the children responded with statements about their beliefs, magic, the evidence presented in the story, or constructed by the children from other experiences.

I summarized the children's discussion about what was real or not, what might be real, and why the children thought that. Then I set up the construction of our own stories by reviewing the unit they had done in language arts on story parts--setting, characters, problem, resolution--using these to both construct a story and interpret stories. We went from this to the preliminary construction of a story about the dinosaurs depicted in the mural, *The Age of Reptiles*.[41] This involved more critical thinking and surfaced more of their ideas about dinosaurs. I asked the children to start talking about what they thought they saw going on in the picture and gradually helped them to weave a story out of that. I would also periodically interject "why" questions into this. For example, when they said a particular dinosaur was doing something, I would ask them why they thought that and, then, why they thought that the artist felt able to depict the animal in that way--reconstructing their logic and then the artist's logic.

The next thing we did in class was from a handout from a "Ranger Rick" publication on dinosaurs[42] which depicts nine pictures of different dinosaurs and settings like a volcano and a mesa that they could cut out and rearrange into different orders to make stories. After the children constructed their stories, I asked each child to present it to the rest of the class. This was done by children arranging larger versions of the pictures on the board at the front of the room

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[41] R.F. Zallinger, *The Age of Reptiles*.

[42] Judy Brans ed. (1989) *Ranger Rick's NatureScope: Digging into Dinosaurs*.

and then telling their story using the pictures as props. Then they took questions from the floor. The questioners usually asked the child to clarify some point or give more details or defend the sequence in such a way that the result was an enlargement of the story and the story's logic. This was in essence a rewrite. On a subsequent day, I read back a number of the stories and the child each time revised again and again interactively with the class.

Farzoneh started us off. First she arranged her sequence of pictures on the board, then she began to present her story. I wish to give a full text of her story presentation because it shows how, as an interactive social event, the presentation becomes a constructed act of story writing. The questions and additions the class contributes in this piece of dialogue are extremely important components in the science and in the process of writing. My focus, though, was the science.

> Farzoneh: First tyrannosaurus comes and then they see it, but they have to run away, then he sees it. This guy sees it and then the thunderstorm comes and then the mother comes and she sees the babies are hatching. The babies look at the sky because of the thunderstorm. They have to run away but they can't so they try another way but they can't swim and then the volcano erupts.
>
> Teacher: And that's the end, the volcano erupts? Okay, let me see if I can say it. The tyrannosaurus rex [*points*] and the herd of hadrosaurs see tyrannosaurus rex and they try to run away and then the pteranodon sees tyrannosaurus rex, then there is a thunderstorm and the mother triceratops is in the thunderstorm and she sees that her babies are hatching and she wants to get them away from the thunderstorm but they can't go by the rocky cliffs, the rocky cliff is in the way and they can't swim so they can't get across the water hole and there's a volcano too . . . Very nice story, I liked that story [*we clap*]. Everybody, Farzoneh is still up there and she will answer your questions. I personally would like to ask first of all who are the characters in the story?

I ask some questions using the story parts that Kathy has introduced to the children, as tools to help develop critical reading skills. I wish to model a form of critical questioning which would lead to elaborating and rethinking the stories. I am interested in developing the children's thinking around the content of their writing rather than the mechanics of writing. My interest is not so much in the literary value of their stories but in the scientific. Then other children started asking questions. These questions, though, were usually about why Farzoneh had made the narrative choices that she had made intertwined with discussions of alternative choices and the variations in reasoning that might lie behind those choices.

For example, Tatyana asked Farzoneh why she had put the picture of the tyrannosaurus where she had and this led to a discussion between the two girls, Chen, Cory, and Claire about the predatory habits of tyrannosaurus and whether or not the mother triceratops would be with her young and if so whether or not she would be helping them and how. I push this along by asking: "Would the mother triceratops take care of her babies or do the eggs just hatch and the babies are all by themselves? How do you know that the mother triceratops is going to take care of her babies?" Farzoneh replies: "'Cause she doesn't want them to die . . . ."

> Teacher: She doesn't want them to die? But some animals lay their eggs for their babies and then the babies are born and they're not there, the mothers and fathers aren't there. Birds have their eggs and the babies hatch and the mothers take care of the babies but snakes don't. Snakes lay their eggs and their mothers and fathers go away and when the babies hatch the babies are all by themselves . . .
>
> Chen: Alligators do.
>
> Teacher: Alligators . . . do they leave their babies all alone or do they take care of them?
>
> Chen: They don't take care of them.
>
> Teacher: They don't take care of them? You're saying that the mother triceratops was there when her babies hatched. Do you know if that's true? [*Farzoneh makes a face.*] You think that might be true? Is that a guess, a theory? [*yeses*]
>
> Kyong Min: How do you know the mother dinosaurs take care of their babies? How did the dinosaur know that the babies would be born?

Kyong Min and Farzoneh talk for a short bit about why Farzoneh thought the mother was taking care of the babies but Tatyana wants to know more about the manner of the interactions between the mother and young, "How come you need to put the mother's swim with the babies. How come she swims, why did you put it right there? Why did you put the babies over there and not over there?"

> Farzoneh: Because I thought when she was, she saw the thunderstorm she was running and she saw her babies hatch.
>
> Teacher: Oh, I see so she was running and then she saw the babies hatch. She didn't run over to see if the babies hatched? Oh.

Farzoneh, in essence, reconstructs her story as she talks about her choices, her reasoning, the science with the rest of the class. This continues in the next class which I open by reading a

transcribed version of Farzoneh's story. But Farzoneh has decided she wishes to tell it herself a different way.

> Teacher: This is Farzoneh's story. There was a tyrannosaurus coming. And a herd of hadrosaurs saw it and ran away. A pteranodon saw it and flew away. Then a lightning storm came and scared the tyrannosaurus away. A mother triceratops was scared by the lightening. As she tried to run away, she saw her eggs were hatching. She and her babies tried to run away but they couldn't climb over the rocky cliffs and they couldn't swim across the water hole, so first the babies died in the volcanic eruption and then the mother died. And that's the end. Farzoneh has revised some of her story and she wants to tell you her new version of the story. She's kept the pictures the same but she's rewritten the story. She's revised it.
>
> Farzoneh: First he comes to eat those but they look at him because he's coming to eat the babies.
>
> Teacher: Oh the pteranodon is coming to eat the babies?
>
> Farzoneh: So the stor [?] comes and then he has to run away but he ate the babies so she can't find them, she went, she wouldn't go and find her babies but she didn't care so she went here, but she couldn't go over the rocky cliffs so she went here, but she couldn't swim and then she, the volcano came and then ... but they still didn't die, only the babies did because he ate them.
>
> Teacher: 'Cause the pteranodon ate them?
>
> Farzoneh: And this because she went close ...
>
> Teacher: So now the story is the tyrannosaurus ....There was a tyrannosaurus and the hadrosaurus saw him and ran away, and pteranodon came and the pteranodon tried to eat the baby triceratops and the mother, is that the mother or the father triceratops now. *[Farzoneh answers: "Mother."]* The mother triceratops came looking for the baby triceratops and couldn't find them and she looked and she looked and she looked in the rocky cliffs but she couldn't really get over them because they were rocky cliffs and she couldn't find them and she looked by the water hole but she couldn't go any further looking because the water hole was in the way and then the volcano came and what happened with the volcano?
>
> Farzoneh: The babies died because of him [*the pteranodon*] and the mother died because, um, she was close to the volcano.
>
> Teacher: Ah, so the babies are dead because the pteranodon ate them and the mother triceratops died in the volcano. Do you want to answer some questions? [*many children murmur "sad ending"*] Those are comments do you want to take comments too Farzoneh or just questions?
>
> Farzoneh: Comments and questions.
>
> Cory: That's a sad ending, that's my comment.

The children again start questioning Farzoneh's narrative and debating the reasoning behind it. Bulli asks: "Um, why did the, wait a second, I think the pteranodon, um, oh why did

he eat the babies?" And I ask: "Is the question Bulli, is the question why did the pteranodon eat the babies or why did Farzoneh think that pteranodons would eat babies?" Bulli wants to know the second but Ok Ran the first. "I think it really was hungry!" Farzoneh explains. Once again I return the conversation to the debate about whether or not the children know or can theorize that mother dinosaurs look after their young, "How would you know that that might be true. I think the last time that I asked that question and Chen remembered about alligators, the mothers have their babies hatch out of eggs and the mothers aren't there to take care of their babies. Why wouldn't a triceratops be just like a mother alligator?"

> Kyong Min: They were different.
>
> Maria Theresa: They're not alligators.
>
> Ok Ran: The mother alligator stays with the babies, when the babies hatch. I saw it on a book, that the mother stays, the mother stays with the eggs, the eggs hatch and then the mother is there!
>
> Teacher: Claire can you think of any reason to think that mother triceratops take care of their babies?
>
> Claire: I'm not so sure because a bunch of people said yeah and there aren't any people who have seen dinosaurs so we will never know and I wouldn't be so sure about that.

I asked the children what sort of things we could do to be able to say what mother dinosaurs do with their young. Paula suggested that we look in books. Bulli and Chen said a dictionary. Ok Ran suggested asking their moms or dads. Claire thought we could go to a museum. I settle on looking in books: "Well you know we have all these books over here and maybe you guys could be looking to see if there is any evidence for that. That's all that we could do in this room I think."

My role in the story telling was to question foundational assumptions in the science and the children picked up on this and started doing it for each other also. This was, for example, asking them how they *knew* the mommy dinosaurs looked after their young, how they *knew* that certain dinosaurs ate certain things or behaved in certain ways or lived in certain places. This was to generate discussion on the content of their story telling rather than to critique the stories by literary criteria. That's not to say that the two--the content and the form--weren't linked or the

development of the two weren't linked because I think that they were. For example Farzoneh wrote her story so that it opens with a problem, which is based upon a number of embedded assumptions about the nature of dinosaurs, where they live, what they do, and her resolutions are also based upon assumptions. The way that she moves the story by adding problem after problem continues this and plays upon this.

At the end of this phase of story telling, I listed questions on a poster and said that maybe we needed to try to find out about them and then we looked at books on dinosaurs and modern analogues. This was within cooperative learning groups at this point with one question per group but one book per child. Each child would use a book and then share what they had learned with others in their group and finally we had a large group discussion.

The question about how dinosaurs care for their young or even whether or not they do seemed from the start to be the most compelling to the children. It is also the one about which I could present a number of different current theories and also pull in modern analogues to dinosaurs such as birds and alligators so that's the one I concentrated on. We had a very interesting discussion about the logic behind the various theories about whether or not dinosaurs and different dinosaurs in different ways took care of their babies. As counter-examples to their theorizing, I used modern animals. We started doing more research on that topic and then I asked a colleague who had documented a family of hawks to come in to the class and give a slide presentation about how hawks bring up their babies. The result was that some members of the class continued doing research on dinosaurs and others started to research birds and all continued to write and share their stories. But this final process was conceived of and used by me to motivate research and thinking which resulted in new writings, not explicit rewriting and perfecting of one piece of work. In other words we focused *out* from our writings rather than *in* on the writings themselves.

This was not really what I had expected that we would be doing. I purposely modelled the initial framing of the curriculum of this unit after descriptions I had read of writing workshops. I found that because I had certain goals in mind about the substance of the children's

writing that I had to lay aside the workshop's writing-sharing-editing-rewriting cycle. I stopped pursuing the literacy aspect because I perceived the goals of the two, literacy and science instruction, to be in some senses antithetical. For example, envisioning stories as "complete thoughts" which I understood to be one of the writing workshop goals rather than as vehicles for articulating questions. This was a disquieting choice for me to make; I felt that in doing this I was forfeiting the literacy instruction I had planned.

Although I had planned purposely that the instructional goals of the unit were to be the creative and critical qualities of scientific thinking, I had never really critically examined those values in myself. Through this teaching I came to do this and to see those values as potentially problematic. The child, Farzoneh, whose story is the springboard for much of this unit is from a traditional, conservative culture in which knowledge is widely regarded as received not created and in which a woman's place is to live within that knowledge not to challenge it. Many of the other children in the class come from similar cultures. All of these children would be returning to these cultures. In many ways I have a thought-out political purpose in teaching children to be critical and creative thinkers but I have done most of this thinking in the abstract, divorced from particular interactions with particular children. How defensible are these choices really? How would I feel, as a parent, if my daughter's teachers based their instruction at a fundamental level on values radically different from my own?

When I teach science to children a major belief that I bring to the curriculum is that science is a place where children are involved in *active* learning. There is no place for passivity in science, no place for uncritical knowledge. This is an important issue for me as a scientist, for a person who knows what it means to act as a scientist, but also as a woman, as a person interested in teaching girls and minorities science. But is my urging little girls who appear to be passive in school to be active learners in a social context really effective? Is it okay for me to be urging this on children whose success might be more dependent on knowing certain things certain ways rather than being critical, creative thinkers?

Second story: Martin Luther King Jr--
The personal and the political in the social constructivist classroom.

This is a story about how a teacher's pedagogical actions are infused with moral and ethical choices and about how a teacher can become aware of those *as choices* through her teaching. To introduce this, I will tell some short anecdotes about my own and other's experiences of schooling as political.

I went to junior high and high school during the second half of the 1960s and early part of the 1970s. I lived in a conservative corner of northwestern Connecticut, in a farming town peopled primarily by second-generation Swedes, and a minority of English and Scottish colonial descendents. My social studies and history teachers came from New York or Boston. Many were politically active outside the community and frustrated by the political inactivity of the community.

The common joke among my peers, when we talk about American History education in high school, is that classes never get beyond the Civil War. My personal experience was that we never did anything *but* the Civil War. We would start with Jacksonian Democracy and end with Reconstruction. In five out of six years we read *Civil Disobedience* in classes. Why was this? I would argue that this choice of curriculum relates to the political purposes of my teachers. Purposes that maybe they didn't wish to state or even defend to the community but still purposes rooted in values and moral judgements that they were willing to act on in this covert sort of way.

My mother did all of her schooling in the 1930s in Brooklyn, New York. The majority of her teachers were first- and second-generation German-Jewish immigrants. Many of these teachers were politically active, in the community, their union, nationally, internationally, around economic and social issues. They were union activists, they housed refugees. These teachers brought these concerns to their teaching but rarely overtly, explicitly. Usually the political, moral content of their teaching was submerged within other parts of the curriculum--what children read in reading or civics and how it was discussed, what children wrote about in composition or worked problems on in math. Not explicit but *there.*

I have a friend, schooled in economics and left-wing politics who taught business education to colored children in South Africa. The formal curriculum concerned simple mathematics, balancing check books, keeping a ledger. What he really taught was in *how* he taught these things and in particular in the conversations which went on in class about this curriculum. The curriculum was in the pedagogy as much as in the subject-matter content.

In these three examples, teachers were acting as political, moral agents. They were moved to do so by the intensity of feelings they had about particular issues focussed and activated by circumstances of the times in which they were teaching. These same "times" also made these moral, political choices around how curriculum was depicted more apparent and potentially more problematic. My teachers and my mother's were often called upon to defend their teaching by parents who did not agree with the teacher's beliefs. My friend, teaching in South Africa, counted on his students and their parents keeping the things going on in his class secret.

During the week in January, 1991, when Martin Luther King Jr. Day was celebrated, Kathy read biographies of Dr. King to the children. Then the children composed together a pattern book about King's life in which each sentence began with the phrase: "My dream for a better world is . . . ." This unit was combined with a unit from the social studies curriculum in which the meanings of the words "fact" and "opinion" were examined both in the contexts of the books being read and the book written by the children.

Kathy's understandings of literacy teaching and teaching students whose primary language isn't English has led her to emphasize the structure of sentences and stories as a means to enable both interpretation and communication. Her pedagogy invites interaction with the children, as a group and as individuals. Kathy continued this while reading about Martin Luther King Jr. combined with working on the meanings of the words, "fact" and "opinion." This combination allowed Kathy to attempt something very political in this class--to portray her own moral beliefs about racism but softened by intertwining that portrayal with the social studies curriculum. Her beliefs and those of the authors of the books were portrayed as personal

opinion. Kathy's relativistic portrayal of her moral views concerning racism was maintained through her choice of process in which she expresses her beliefs about the development of voice in the children. The children have ideas that differ from Kathy's and the publicness of this sharing and debate was heightened by circumstances: the Gulf War. This created dilemmas--the substance of this unit was problematic to some parents of children in the class, particularly within the context of the Gulf War. There are children in the room and in the school from Iran, Palestine, Israel, Saudi Arabia and Kuwait. These children brought their own and their families beliefs about racism as experienced in their cultures. The perceptions of many of these families were that the Gulf War, Sadam Hussein's attacks on Israel, the Israeli treatment of Palestinians were all racist. Their desires concerning the resolution of this racism may or may not be the same as that sought by Martin Luther King Jr. in the United States in the 1960s or by Kathy in this class. Other parents agreed with Kathy's values and political purpose and wished to make these ideas more explicit. They objected to allowing the children to voice different views. Still other parents thought discussion of these ideas shouldn't be part of public schooling at all. In this teaching neither process nor substance are the "private property of the teacher."[43] Rather the curriculum is "a medium evoking the critical reflection" of the teacher. This happens because the act of teaching is a public and social one.

The examination of the structural components of language--the use of the words "fact" and "opinion"--in a moral context deviates from the purely syntactical way this unit is normally taught. For example, the handouts which come with the text for this social studies unit involve classification of a series of statements on 18th century British pirates. These sentences can be classified as fact or opinion through a syntactic analysis, without any factual knowledge of pirates. By combining this unit with a controversial subject matter in a classroom in which discussion of meanings is invited ("What does the word "segregation" mean anyway?"), the child is asked to examine the contextual meaning of ideas in the books and as felt in their own lives

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[43] Mary Field Belenky, Blythe McVicker Clinchy, Nancy Rule Goldberger, Jill Mattuck Tarule, *Women's Ways of Knowing: The Development of Self, Voice, and Mind*, page 219.

and experiences. The meaning of segregation and prejudice is different and multiple for a Palestinian child, a girl from Bangladesh, a child from Iran with relatives in Kuwait, a white middle-class American boy, a girl from inner-city Detroit--all of whom were in this classroom. It is different yet again from the lived experiences of the teacher. These personal contexts for meaning are also different from the context induced through a sympathetic (empathetic) consideration of the life of Martin Luther King. All of these personal contexts and derived beliefs are invited by the process of this teaching. Because this teaching was done through people sharing different ideas and beliefs, these ideas and beliefs went from the tacit, felt, emotional state to the intellectual and articulated.[44]

This is different from what individual parents want--to avoid moral issues entirely or to preach particular viewpoints. This is the American dilemma of the role of school in moral education--should moral values be explicitly taught in schools or is this education the private prerogative of individual families? The teacher is caught in the middle because her teaching directly reflects her own moral choices and ethical code. In this instance, Kathy's beliefs about racism and her beliefs about the rights of children to say the things that they believe are both exposed. Because this is done publicly during the Gulf War when sensitivities were particularly acute about many issues, Kathy had to articulate her foundational values. This act of articulation of previously assumed, tacit values requires that they be re-rationalized, the logic behind them reconstructed within the concrete particulars of that moment. It means the development of a critical consciousness about those values.

Discussion.

A teacher's foundational knowledge, the knowledge upon which she makes assumptions in order to be able to teach, can be thought of as a "standpoint"--the "place" in which her professional being is grounded. This place reflects her experiences and identities: it is from these experiences and identities that her standpoints are constructed.

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[44] Habermas (1991) *Moral Consciousness and Communicative Action.*

Sandra Harding, in *Who's Science, Who's Knowledge*, writes about feminist standpoint theory as an epistemology which arises from an articulation of an individual's membership within historically and socially constructed communities. For example, a person who would call herself an African-American, working-class woman, would also recognize *that* naming is a manifestation of certain systems of values, beliefs, ways of thinking and believing derived from memberships in these groups. These memberships are multiple and the values, goals and means each entail are often in conflict. Values derived from being working class can be at odds with those derived from being a woman. The values are formed, however, from the "lived" experience of the person through her membership in these groups and the interrelationships among her experiences of these groups. This situates the experience of the individual--experience has meaning and significance because it is socially constructed with and by a subset of certain "kinds" of people. Then Harding goes on to argue that because this ontology is personally and experientially derived, epistemology is also--ways of knowing are derived from ways of being. This becomes translated into doing particular things in particular ways. It becomes manifested through methods of acting.[45]

Harding and Dorothy Smith in *The Everyday World as Problematic* discuss how articulating a personal lens can become a foundation for asking questions which drive research. I am suggesting in this chapter that an articulation of this lens acts, for the individual, as a vehicle in developing a critical consciousness of personal beliefs and values; the pursuit of questions developed in this process feeds back to a reexamination of the lenses and the values derived from them. This is a background/foreground argument like the ones I have used in previous chapters to talk about how conversation on one scientific topic can shift to be about a different topic, to explain how the focus of a community is dynamic and changing. In the community of the classroom we as teachers act upon beliefs and knowledge but this acting can cause us to articulate these in a new community, one which is different from the communities in which the beliefs and knowledge were formed. This causes us to rethink both the values, the knowledge and their

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[45] Dorothy E. Smith (1990) *The Everyday World as Problematic.*

source. This process is a vehicle for learning about ourselves and about those people or things causing us to do this thinking.

Harding doesn't explicitly write about a "standpoint" position as evolving and changing because, I think, she writes primarily of a standpoint as a "possession" of an individual rather than as a dynamic construction created through the continuing interplay of the individual with the group. Smith hints at this because she is discussing the interactions of sociologist(s) and the individual(s) they study representing different standpoint positions. This is not unlike my descriptions of the interactions of teachers and students. I would argue that any articulation of a "standpoint" acts to alter that stand, particularly if a person occupies multiple and potentially conflicting standpoints. Both the act of articulation--how something comes to be articulated is implicitly critical--and reflection on that articulation because of the new context in which it occurs act to alter a "stand."

Both of these things are illustrated in my stories. I think this is because the articulations that I am writing about are occurring during and through praxis, not divorced from praxis. They are what Dewey or Schon[46] call "reflection-in-action": they are articulations constructed within a context framed by the individuals involved but also by a purpose. Teaching is purposeful action. This articulation--what is done in a class, the curriculum--derives meaning from a retrospective understanding of historical context and a forward-looking recognition of the purpose, the needs it addresses. This purpose, the goals of teaching, directly reflect the teacher's initial standpoint and are both maintained and altered because of interactions between people and between people and subject matter in the class. The needs of the future rewrite the past.[47] For example, a teacher draws on her knowledge within the domains of the discipline, the learner, and the milieu in order to act but enabling action is not the goal in itself. Rather, the goal is in the results of that action. A teacher may know certain things about a child and she may know that she wants that child to

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[46] John Dewey (1933) *How We Think: A Restatement of the Relation of Reflective Thinking to the Educative Process;* Donald Schon (1983) *The Reflective Practitioner: How Professionals Think in Action.*

[47] For example, Marx (1983) Theses on Feuerbach; Buck- Morss (1990) *The Dialectics of Seeing: Walter Benjamin and the Arcades Project.*

learn to read. She may draw on her knowledge of reading, teaching, and the child to formulate actions which enable this goal. This goal of learning to read has, through this procedure, taken on concrete yet changing particulars from the evolving knowledge the teacher is using to formulate it within the context created by the child. These new concrete meanings act, in turn, to rewrite the past, or at least the interpretation the teacher puts upon her past.

Habermas argues that communication fulfils three purposes: to make statements about actions, to make statements about the quality of those actions, to make statements about how we feel about those actions. These statements are in fact claims made by the person speaking; claims about what is true, the speaker's beliefs, and about a person's feelings. A hearer evaluates these claims and judges them. This hearer can also be the person making the claims. Habermas, in his later writings, argues that the articulation of beliefs in a new context causes them to be altered. This alteration can be congruent with the original beliefs--they can be merely enlarged or constricted in application--or they can be challenged and more fundamentally altered.

A teacher in portraying a subject matter in a particular way or in choosing to teach in a particular manner is also making claims, implicit or explicit, about the subject matter and about what is "proper" behavior.[48] All of this is done within a context constructed by the interactions of people, ideas, and things. This is not a passive context. Some things a teacher does work, others don't, most work in part. It is also true that for these claims there is an audience of children that judges these claims and will express these judgements, given the opportunity, again either explicitly or implicitly.

Thought of in this way the "pedagogical knowledge"[49] of a teacher becomes another example of a standpoint. A teacher's knowledge of students, learning, milieu, subject matter, and how to teach that subject matter are constructed from abstract moral and ethical values and more concrete experiences of teaching and subject matter both as it is encountered in school and in the world outside of school. A teacher's ways of knowing, as Schon points out, are "knowledge in

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[48] Michael Apple (1979) *Ideology and Curriculum.* Linda MacNeil (1988) *Contradictions of Control: School Structure and School Knowledge.*

[49] Lee S. Shulman (1986) Those who understand: Knowledge growth in teaching.

action."[50] Therefore, they are most constructively thought of as dynamic ways of knowing; ways of knowing that are both specifiable--a teacher knows certain things in certain ways--and continuously altered and evolving, unspecifiable. It is teacher knowledge which is created in the act of teaching, when the different "things" that a teacher knows are integrated in the choices that define an action. Those "things" that the teacher knows are transformed through that integration--the sum is not a pure addition of parts, the "things" interact with each other and interact within the context of the act; that knowledge is transformed through implementation. An act doesn't stand in isolation, it follows other acts and actions succeed it.[51]

The actions of a teacher are also interactions with students. This interaction becomes a vehicle for teachers to define their own knowledge, recognize what they know, and what they don't know. A teacher's acts of teaching can be thought of as claims to knowledge. By asserting these claims in public they are opened up to judgement and critical evaluation. By making a claim of certainty of knowledge, of what to do, a teacher makes a complementary claim of not knowing, of uncertainty.[52] This becomes a vehicle for learning and a vehicle for recognizing and examining the moral underpinnings of particular choices, representations, beliefs.[53]

Shulman describes pedagogical content knowledge as knowledge of how to teach which entails an intersection of subject matter knowledge, knowledge of children and of milieu. A teacher can say what they know about a particular student at any one time but this knowledge is continuously altered as the teacher and student interact and the student interacts with others in the teacher's presence. That knowledge of that student is also contingent upon the teacher's knowledge of the other domains --this knowledge specifies the form that the teacher-student interaction will take. The teacher's knowledge of the student does not exist out of the context constructed to contain the other domains of teacher knowledge or out of the interdependent

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[50] Schon (1983) *The Reflective Practitioner: How Professionals Think in Action.*

[51] Kerr, D.H. (1991) The structure of quality in teaching..

[52] Ludwig Wittgenstein (1969) *On Certainty.*

[53] Habermas (1991) *Moral Consciousness and Communicative Action.* Kathleen Weiler (1988) *Women Teaching for Change: Gender, Class and Power.* Schwab (1976) "Education and the state: Learning community."

evolution of that knowledge. Shulman emphasizes that pedagogical content knowledge draws upon a teacher's knowledge of multiple domains which intersect in enabling the act of teaching but this intersection is one of mutually dependent variables. The different domains of teacher knowledge are located within a web a inter-supporting beliefs, facts, theories, ethical choices. An articulation of this knowledge takes on particular meaning and substance in the context of the act of teaching. This context is different from the ones in which the knowledge was originally constructed. This articulation can also make obvious the things a teacher doesn't know and give the teacher pathways to learn.

In teaching the unit on dinosaurs, I *knew* what I wanted to teach, how I wanted to teach it, and why. Because of the particulars of the children and the context of this teaching, I found myself questioning this knowledge. I was making a claim about knowledge and ways of doing things which I became increasingly uncertain of through those actions. The past contexts in which my knowledge of the subject matter and how to teach that subject matter were formed--that of being a woman scientist in a male dominated field--were different from those in which I tried to apply that knowledge. In this particular instance, I abandoned one set of values and goals--about using a writing workshop model to teach scientific theorizing--and I am still questioning others--about the morality of teaching science in the way that I do. Kathy, in teaching the way that she does, learned new facets and interpretations of subject matter. She learned things about her students and their beliefs which broadened and extended her own ideas or caused her to re-rationalize and re-think those ideas in this new context. In both cases, Kathy's teaching and my own, we came to learn about subject matter, teaching, our student's, ourselves through our teaching. Our teaching was predicated upon an articulation of things we knew and this articulation became a vehicle for questioning this knowledge and learning.

CHAPTER 6

CONCLUSION

In this thesis I have tried to show how relationships are constructed and developed. Teaching, learning and science are all fundamentally about relationships--between people and between people and things. These relationships are developed, they change and evolve over time, as an interplay between those involved (both animate and inanimate), as each side of the relationship is affected by the other. Relationships begin with statements (implicit or explicit) of assumptions and of purposes. As the relationships alter, assumptions are challenged and changed, purposes grow and shift direction.

I began this work claiming that the thesis was to be about method, how and why we do the things that we do. I have built up an argument that the things that we do, in science, in the classroom, as we interact with each other, are done for a purpose. A purpose guides and shapes our actions and also develops and evolves as we act. As this purpose shapes our actions, the actions become "method." A difference between traditional, "scientific" definitions and uses of the word "method" and the one that I have constructed is that I have tried to show that method develops (it isn't preexistent, it isn't a "standard" of behavior) as relationships between people and phenomena, people and people, evolve. People develop norms for these ways of acting because of the demands of both the relationship and of the purpose itself. Methods and their norms underlie scientific ideas, discoveries, procedures and the construction and need for community. Because it reflects an evolving relationship and changing purposes, method itself changes through time--it is a tool not an end-point. Another word for this "method" might be

"knowledge". Knowledge of facts and ideas and of ways to do things is both an end-point of what we are doing in class but it also exists before we do things and guides our actions. This first knowledge changes and grows. Knowledge is a vehicle for learning because it is acted upon and shared with others. In this thesis, this knowledge is of science, of each other, of teaching--all evolve.

Relationships are also tools not end-points. For this reason the traditional "scientific" idea of the dichotomization of subject from object becomes a fiction. In realty this relationship shifts and changes also, whether or not this is acknowledged. The relationships described in this thesis are between the children and the phenomenon we are examining, between myself and the phenomena, between children and children and between myself and the children. Each relationship results in two things, the construction of science and the construction of a community. Science and communities aren't "things" that exist separate from person and phenomena, they exist in the conceptual space between the phenomena and the actor, science *is* a relationship and communities *are* relationships. Each relationship is shaped through a dialogue between partners and also between those partners and ideals and needs formulated outside the relationship. These ideals and needs are not just the manifestation of an individual's thinking but are also constructed and shaped through the interactions among people in the class. Ideals (values, beliefs, goals, dreams) and needs are formed through conversation, within a community. It is these ideals and needs and their means of formation that keep the relationships dynamic, prevent them from reaching a climax, fulfilling themselves. That lack of closure, of coming to an end, drives the community within the class, causes people to need and appreciate each other.

In this thesis I have written of the words design, pattern, method, community. I have suggested but not defended the idea that these are legitimate goals of teaching in general and science teaching in particular. In each chapter I have worked to develop the meanings of the words, in science, in teaching, in relationships between people. I have worked to develop the interrelationships between these words--these words and their applicability in my stories is through an organic interdependence. It is because of this interdependence that they are

legitimate, and I would argue, unavoidable goals, of teaching and of science teaching. In this final chapter I would like to underline this interdependence. I will do this by recapitulating the meanings I have given to each word.

The first word that I talked about at length is the word design. The word design has two meanings as I use it in this thesis. Design is a noun and a verb--the end result of designing is a design, a pattern. A design is constructed through framing--given meaning differentially, comparatively; meaning is dependent on context. The act of framing creates a background and a foreground from the whole of the phenomenon. By doing this we, in turn, create lenses, develop selective vision. The net result of this process can be that the background, the ignored parts of the phenomenon, become forgotten, are lost. Rather, in this thesis, I argue that this process of differentiation and use can remain an interplay of the background and the foreground. This can lead to the development of a critical consciousness, an awareness or questioning of context and the process of differentiation.

Design, the verb, is an interactive process between person, materials, purpose, context, reflecting assumptions about all of these. In the act or process of designing, these assumptions also compose the background. When the design is completed, reflecting upon that design or putting the design to some use can cause us to think back on those assumptions and reconsider. The act of design is purposeful, it expresses a need, is directed toward a need. It is this need that underlies our assumptions and conversely our assumptions underlie our perceptions of need. Recognizing this in combination with an understanding of the interplay of background/foreground which makes up the design can also generate a critical consciousness concerning that need.

Design serves cyclical conceptions of time as a verb, as patterned action. It serves progressive conceptions of time as a noun because it addresses needs. For example--what the children are doing with soap bubbles, what I am doing in teaching, what we are constructing as science--all of these embody patterned action but they also address needs. What we are doing

and the needs we are addressing also shift and change through the foreground/background interplay which I generate and encourage. The design--of science, of interaction, of teaching--is a tool as we (myself, the teacher, and the children) construct a community in the classroom. Because of our designs we become people with a shared purpose, language, methods of acting and these are vital--they can grow and change. Curriculum is a design and is formulated through the design process. Science and community are also.

The concept of design that I outline is critical for understanding science--how science explains and acts as a vehicle to create new things and knowledge--the role of people in science, how science changes and evolves. The concept is also critical for understanding the idea of community. The scientific community is a sub-set of the larger community. The scientific community has its own ways of communicating and acting; its own special questions. All of these, though, are derived from those of the larger community, constructed and maintained in a relation to the larger community. The word design captures the qualities of human agency fundamental to an understanding of both science and community.

The second and third words that I talk about are pattern and method. Designs are the cumulative effect of patterns: they contain patterns. Patterns are characterized by variables situated in a relationship. Defining these variables defines the foreground. Pattern as design (the noun) is composed of a background and a foreground. It exists as an interplay between the two. Therefore pattern has the same potential to foster critical thinking as design. The ability to construct a pattern, to design a pattern is dependent upon our ability to selectively create a foreground--move some elements of a phenomenon to the fore and others to the back. The decisions that we go through to make this differentiation are often buried by the things that we are able to do in and with the foreground. If we can remember to critically confront ourselves with things we *can't* do with the foreground we can remind ourselves of those decisions, remind ourselves of the things we have excluded and reconstruct the foreground/background relationship and the assumptions buried within the relationship.

Patterns are created through repetition and relationships. Patterns in science, in class--both reflect relationships and construct relationships. There are patterns in relationships between people and between people and things. Both result from a purpose. This defines method. Patterns in relationships between people define community. Because patterns reflect relationships, they can alter as relationships alter. The ideas of pattern and method follow from design. They are components of design, make up design, the noun and verb. As such they are components of both science and community. They are the means of interpreting (through description, making sense of, doing things with) phenomena. Patterns don't always appear to be created by people (although they are, if only passively, by selective vision)--sometimes they appear to be "found." This is why the concept of design in science is so important. Through the idea of design, human agency is recognized.

The fourth word is community. Communities are constructed through a medium: In this thesis and these classrooms, this medium is the pursuit of the science. A community is composed of people who are different and the same simultaneously. Similarities are constructed (not necessarily present beforehand) by developing a common language and ways of doing things framed by the medium, the science. This process is driven by a shared purpose. Differences between people drive the need for community--a shared need for each other. The essence of community is people interacting with each other because each can contribute something different and unique towards a purpose, towards fulfilling a mutual need. Unlike a discourse community, in the community in my classroom, hierarchical power relationships don't develop because of my actions to keep the need, the questions, which drive the community, a vanishing point, unfulfilled. The idea of community focuses the word relationship. When I say that science, teaching, learning are fundamentally about relationships, relationships that can not be adequately described by the subject-object dichotomy, I am arguing that the relationships are reciprocal--all sides contribute and the contributions of all sides are formative and *important*. That is a expression of the foundational ideals of community.

This leads to the teacher's role, my role, in enacting the above four words. As the teacher I act as a designer of experiences and activities. By choice my actions are proactive around instantiating values about how children should interact but reactive about the science--the science follows from the conversation which results from the interactions of the children. The teacher's choices, my choices, reflect standpoints which, in turn, reflect personal history and ways of knowing. Acting on this knowing introduces opportunities to learn, because whenever I act it basically doesn't work out in some dimension(s). Assertions of knowing (the basis of praxis) are also statements of not-knowing, of uncertainty. They are also questions.

As I teach, I act on my values, I impose those values on others. Often times these values, formed from different experiences, reflecting different parts of my history, are actually in conflict with each other or come into conflict with each other when enacted in a social situation with others who come from different backgrounds and histories. Since vital communities contain people who are both fundamentally different and the same, conflict is an integral, essential part of community.

For example the most obvious place of conflict between my values (and this is illustrated throughout this thesis) is between my desire to impose ways of acting and interacting on the children but to take a reactive role in the science. The two value choices are linked--much of my discussion about community hinges on the idea that social interactions and the interactions which compose "science" are co-constructed, interlinked. In separating them from each other as I plan my classes, as well as when I am actively teaching, I am setting myself up to continually be at the focus of this conflict.

A second and equally fundamental conflict is between myself and the children. My value choices arise from my history but the children are not blank slates, lacking values or scientific knowledge and understanding. There is a conflict between how I think people should act and how the children assume they should act. This is conditioned by the fact that we are both in the

setting of school. We inherit roles and relationship expectations that we didn't create, a conflict not of our making. This is heightened, I would argue, because I am rarely explicit about how I think the children should act. Therefore they never state their assumptions about how they should act and so the conflict rarely becomes articulated, talked about. It remains a struggle beneath the surface. This is how learning and change occur on both sides (myself and the children). If the struggle was explicit, on the surface, sooner or later a resolution would be reached and the problem would appear to disappear but the point is that if the community is to remain alive, vital, it can't and shouldn't.

There is an obvious conflict in roles here--as I have outlined the conflicts between values and portrayed them as opportunities to learn and change, I am portraying myself as a learner as well as the children. When the children explain a phenomenon or state a theory in class conversations, when they create a design for the bubble solution, when I set up a class, we are all saying "I know" in one way or another. This statement is fundamentally in opposition to the actuality of it which is to say "I really don't know and actually I know I don't know." There is a conflict between the role of the knower and the role of the learner.

To be a learner requires more than just a statement of not-knowing, it also requires an internal recognition of not-knowing. It is hard to combine within yourself this recognition with the social and other demands of a situation which ask you to claim that you do know. I would argue that this tension between knowing and learning is fundamental to science and to teaching (and, because both are social, is why community is also fundamental to both). It is the driving force behind the curiosity which is central to both. The difference between the two (science and teaching) is I believe that in science ever having to articulate this fundamental form of not-knowing can be avoided but this articulation (recognition) is central to teaching. It can be buried in science because of science's progressive nature: the present buries the past, future desires and goals bury the past and the present. There can be an accumulation of knowledge without an accumulation of wisdom.

In teaching, knowing more means knowing less (as in science) and also recognizing this (which isn't necessarily true in science). For example, I know a lot in science but as I teach and use this knowledge, I am again and again confronted by things I don't know, by new subtleties of understanding, by new questions that generate new connections. As I teach I come to know a lot about the children I am working with--about each individual's qualities, history, beliefs and desires. As I consider this knowledge and act on this knowledge in my interactions with the child I find that this knowledge is partial. The more I know the more I realize I don't know. This is the basis of my claim that I take a reactive role in my teaching, that I set up potential experiences for the children in science and with each other and then I react to shape those experiences based upon what the children show me. I can only do this because I recognize that I know a lot and also know almost nothing.

So much has been written on what teachers need to know and the knowledge base of teachers but I am aware of little that addresses this "knowing that isn't knowing" which I am arguing is central to both teaching and the discipline. In the introduction to this thesis I claim that I will address three conversations:

- The learning science conversation, particularly the misconceptions interpretation of learning. A sub-conversation here is the knowledge children bring with them and what teachers ought to do with that knowledge.
- The teacher knowledge/learning conversation and the idea of pedagogical content knowledge. This has implications for teacher education--what prospective teachers should be taught in their pre-service programs.
- The socio-cultural learning conversation, particularly the idea that, for cognitive and emotional reasons, learners' cultures must be incorporated, somehow, in both the curriculum and the teachers' pedagogy.

Central to all of these are claims about teacher's knowledge--the knowledge that they should have and how they should use that knowledge. In this thesis I am not making an argument for a particular kind of knowledge that teacher's should have. I am arguing for an attitude towards knowledge, that knowledge is not an end-point. It is a starting point for learning. Acting upon this knowledge doesn't reify that knowledge. Rather the assertions of knowing and the knowledge itself become increasingly questionable. As a teacher, the more I know, the more aware I am that to explicitly state this knowing would act to fix it in one place, solidify something

that should never be made solid. Knowing for me doesn't lead to direct action. It leads to the creation of possibilities.

Embedded in this are value assumptions about purposes of education that have nothing to do with imposing a canon of knowledge and societal beliefs on a child. Rather I am suggesting as an end-point to education the same attitude toward knowledge I am claiming to manifest in my teaching--that knowledge has little value except as a starting place for asking questions. The societal beliefs, the standards for acting, which I am imposing on the children are both vehicles in imparting this attitude towards knowledge and goals in themselves. It would be dishonest for me to claim otherwise. The knowledge and attitude towards the discipline, the ways the children interact with each other and myself, the development of a community are linked. None are possible without the others.

The question is how defensible are any of these as educational goals? Looked at in isolation, each ideal entails questionable outcomes. For example, respecting children, their ideas, values, history, necessitates redefining what science is. Valuing the community and its evolution means not staying with topics long enough sometimes to reach a closure satisfactory to me as a trained scientist. When I don't act as an authority in the one domain, science, does it make questionable my right to act as an authority over the children's actions?

These seem to be inherent paradoxes. Embedded in this education is a reverence for knowledge as well as a questioning of that knowledge. There is a similar paradox in the values that underlie the class. I would argue that it is this paradox which feeds the need for community. A vital community embodies both a love of things as they stand and a love of change. A vital community must both know and learn. If that is so, that these paradoxes form the foundations for the community (the community of science, of the class), then the paradoxes must be maintained. The goals of this education become defensible through the cyclicity of this argument. To question the goals would necessitate stepping outside the argument something that a person within the community, involved in the teaching, is not able to do.

APPENDICES

APPENDIX A

SCHOOL AND CLASSROOM DESCRIPTIONS

The school in which I teach the science units described in this thesis is a public elementary school which serves primarily the children of married students at Michigan State University. The population of this school is diverse; it is not characterized by a particular class or ethnic background. The children represent approximately 50 cultures from around the world. In this paper, I have given all the children pseudonyms which preserve as much as possible an indication of their culture. There is a list of children with their country of origin in Appendix II of this thesis. The classes in which I worked were a first grade, a first and second grade combination and a third grade. These classes each had approximately 20 children. I say approximately because the number of children changed over the course of the year as children left and children came as their parents enrolled or graduated from the university. The children listed in Appendix II are children who stayed for a length of time but did not necessarily complete the year. Children who only came at the very end of the year or who only stayed for a short amount of time are not included.

The times that I taught first grade and the first and second grade combination, I worked with Kathy Valentine, the classroom teacher for all other academic subjects. The classroom teacher in the third grade class was Sylvia Rundquist. In the thesis I refer to these teachers by the correct (real) names by their choice. During the time that I was working in third grade I was also collaborating with the art teacher of the school, Phyllis Victoria. This collaboration does not feature in this thesis but it did frame the projects that I was doing in this room. I have not explicitly discussed this in the chapter which revolves around the third grade class.

My involvement at this school was through an internship with the Michigan Partnership for a New Education. The projects that I was involved in were collaborative with the classroom teachers and, in the case of the third grade, with the school's art teacher. In each case, the teaching collaboration was around integrating science and literacy teaching and, in third grade, science, literacy and art.

I collected the data used in this thesis from transcripts of audiotapes--I audiotaped each class and transcribed the tapes myself. I also kept copies of the majority of the children's written work. The children were always aware of the audiotaping going on and quite interested in what I was doing. The children periodically requested that they could listen to the tapes and would comment upon them. The children also knew that I was writing about my teaching in the classes and using the classroom discussions in these writings. I asked the children to help me pick their pseudonyms.

In transforming transcripts to stories I have reduced and edited what was said by the children and myself and also descriptions of what we did. In doing this and in choosing to focus on science content (rather than control issues, say) I have, deleted much of the everyday activity of the class. I would like to describe some of that here.

I tried, in my teaching in these classrooms which were not my own, to conform to and respect the classroom teacher's rules and methods of procedure for classroom control. I adopted Kathy's and Sylvia's methods of classroom control. The methods of classroom control that I found myself using were first: to clap my hands in a rhythmic pattern to get the children to stop whatever they were doing and listen to me. In doing this first I would clap and then they were expected to clap the same pattern back. I also used a timer to constrain activities. The timer had a bell and when the bell went off children were expected to follow some prearranged pattern of activity. I turned the lights off to get the children to immediately stop their activities--they were expected to freeze when the lights were off and wait for instructions.

Classroom discussions were usually teacher centered--I determined who would talk and usually what about. To do this I required the children to raise their hands and be recognized by me before they could speak. Often a child gave a semi-formal presentation of an idea or of some item and then the procedure was that they controlled the conversation, again semi-formally--children who wanted to make questions or comments raised their hands and were recognized by the speaker. Classroom discussions in the first and first-second grade combination usually occurred in a "learning circle"--children and I would sit in a circle at the front of the room, Discussions in third grade occurred with the children at their desks while I tended to walk about the room. As I say, these discussions were controlled by me in a semi-formal manner. They almost always, though, became conversations in which the children directly addressed each other rather than waiting for my recognition to talk. These free conversations were punctuated by me taking the control back and choosing who would talk. So discussions would usually start with me posing a question or asking for a description, calling on a number of children until this pattern broke down into a freer discussion. I would allow this discussion to go on for a few minutes and then I would stop conversation and return to my initial pattern of calling on people.

In all classes the children were seated in groups of desks, usually three or four facing each other rather then a particular orientation in the room. In the first and first and second grade combination I did the seating arrangements by agreement with Kathy Valentine. In third grade the children's seating was primarily done by Sylvia Rundquist with some suggestions by myself and Deborah Ball, the mathematics teacher. In all classes these seating arrangements played an important role in the social and academic qualities of the classes. In particular in my teaching, experiments and informal discussions were carried on within groups.

APPENDIX B

CHILDREN'S COUNTRY OF ORIGIN AND PSEUDONYMS

First Grade:	
Bangladesh	Bulli (f)
Ghana-Malawi	Kojo (m)
Iran	Farzoneh (f)
Korea	Kyong Min (f) Chun So (f) Ho Sook* (f) Ok Ran (f)
Malaysia	Titon (m) Yasin (m) Mira (f)
Pakistan	Ahmed (m) Amina (f)
Palestine	Hanan (f)
People's Republic of China	Yu* (m)
Russia-Bangaladesh	Tatyana (f)
Sri Lanka	Vijay* (m)
Taiwan	Chen (m)
United States	Claire (f) Cory (m) Mike (m) Sondra (f) Paula (f)
Venezuela	Maria Theresa (f)

* English as Second Language Student. These children did not speak English and were in a pull-out program for approximately 30 minutes per day during which they received English language instruction. The form of this instruction was what I would call "immersion"--the children were involved in reading and writing books in English in which the meanings of words became apparent through context and use. The children also participated in activities such as cooking, gardening, field trips, in which they learned English through use. Typically a child spent one to two years in these classes.

First and Second Grade Combination:

Egypt	Ahmed (m)
India	Sakti (f)
Korea	Kwanhyo (f) Ho Sook (f)
Malaysia	Tity (f) Teton (m)
Nepal-India	Suni (m)
Nigeria	Abeni (f)
Pakistan	Shumshad (m)
People's Republic of China	Meiying* (f) Sueh-yen (m) Danping (f)
United States	An'gele (f) Emily (f) Paula (f) Andy (m) Timmy (m) Thomas (m) Cory (m) Benjamin (m) Dan (m)
Yugoslavia	Alyosha (m)

* English as Second Language Students

Third Grade:

Birundi	Diane--Dembe (f)
Brazil	Estevao* (m)
Costa Rico	Ricardo (m)
Egypt	Amina (f) Hamal* (m)
Ethiopia	Selamawit* (f)
Japan	Sen* (f)
Japanese-American	Evelyn* (f)
Kenya	Mwajuma (f)
Korea	Yong Sun (m) Sook Chin* (m)
Korean-American	John (m)
Malaysia	Jihad (m)
People's Republic of China	Jin (m)
Russia	Antoninya* (f)
United States	Alice (f) Daniel (m) Joey (m) Karen (f) Kristin (f) Timothy (m)

* English as Second Language Students

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