CHAPTER 1
GETTING THE BALL ROLLING, AN INTRODUCTION TO THE STUDY

This dissertation is a case study of an elementary school class and their teacher who embarked upon a journey through scientific terrain. It is terrain, like all educational lands, that can be (and should be) given close and critical scrutiny. Among the most salient features of the class and its journey are the age of the children and the nature of the terrain. It was a second grade class and they were engaged in studying about physical science – specifically, the motion of balls down inclined planes.

What I have done in this dissertation is review the records of the class’ journey in various ways, juxtaposing events and ideas that occurred in order to try to understand what the journey was like. This is an interpretive and descriptive study, and I will not make claims about the generalizability of my findings. Yet, I think I have the evidence to say that the journey took the class to places with ideas they had not encountered before and, indeed, that they started to learn a new language, or, at the very least, were exposed to one.

In many regards, it was not an easy trip. The class struggled and grappled with many challenges as they traversed a landscape which was filled with counter-intuitive claims, new terminology, new forms of representations, and new expectations for justifying one’s thoughts. Yet, it was the kind of journey that I think Floden and Buchmann had in mind when they proposed that it is important for students to have opportunities to “break with
their everyday experience” in order to “see the extraordinary range of options for living and thinking” (p. 34). It is important for education to offer such opportunities, because, as they went on to remind us, “unless students can give up many commonsense beliefs, they may find it impossible to learn disciplinary concepts that describe the world in diverse, surprising ways” (Floden & Buchmann, p. 34).

Describing and trying to understand in scientific terms what variables affect the motion of balls down inclined planes was certainly a disciplinary-based realm, and one that was largely unfamiliar to the second graders in Mrs. MacLean’s class. I do not feel comfortable claiming that the children ever truly broke away from their everyday ways of understanding motion, but I do think they managed to bend a good deal. My idea of “bending” is similar to what D.C. Phillips, in his reaction to the essay quoted above by Floden and Buchmann, would describe as the “liberating of the student from the confines of the immediately available environment.” This does not occur, he goes on to say, “at the expense of the students’ firsthand experience; rather, it occurs via the directing of this experience into fruitful and liberating areas – such directing being possible because educators have at their disposal maps of the intellectual domain (in the form of the disciplines)” (p. 69).

One can contrast these ideas with those expressed by many early childhood educators, such as Eleanor Duckworth in “The Having of Wonderful Ideas” and Other Essays on Teaching and Learning. In this book Duckworth puts forth a compelling case that early childhood education should consist of “providing a setting that suggests wonderful ideas

1 All proper names in this dissertation, with the exception of Mrs. MacLean’s, are pseudonyms. Mrs. MacLean has consented to the use of her real name.
to children -- different ideas to different children -- as they are caught up in intellectual
problems that are real to them” (1996, p. 7). Although she draws many of her examples
from children engaged in science-related activities, disciplinary knowledge on the part of
teachers structuring these settings is only hinted at as she goes on to write about what one
hopes to have happen for children over the course of elementary school. "Certainly the
material world is too diverse and too complex for a child to become familiar with all of it
in the course of an elementary school career. The best one can do is to make such
knowledge, such familiarity, seem interesting and accessible to the child. That is, one
can familiarize children with a few phenomena in such a way as to catch their interest, to
let them raise and answer their own questions, to let them realize that their ideas are
significant -- so that they have the interest, the ability and the self-confidence to go on by
themselves” (1996, p. 8).

I believe all early childhood educators would agree that we should provide children in
their first years of formal schooling opportunities to have wonderful ideas. Yet, what
constitutes “wonderful” is subject to debate. For Duckworth, “wonderful ideas” spring
from children’s everyday experiences and foster deep engagement with topics for which
children have strong interests. This is highly individualized process, one in which
children “raise and answer their own questions.” For Floden and Buchmann, pondering
notions beyond the confines of experience is the epitome of “wonderful.” This might
well involve thinking about questions raised by others – questions that one might never
have thought to ask. One would need to depend a great deal on having multiple sources
of ideas about the world, many of which may differ substantially from one’s own. Often,
these ways of thinking about the world may be within long-established (though ever-
evolving) disciplinary fields such as philosophy, art, political science, or mathematics. Within such fields of study questions may be asked in particular ways – ways that one might never have thought to try.

My own view is that we need to create opportunities for both types of wonderful ideas to occur and be regular parts of every child’s intellectual diet. I recognize that children’s everyday experiences and firsthand knowledge about the world are critical building blocks for ideas. However, I think contemporary early childhood educators actually limit the range thoughts to which children have access by over-relying on children’s capacities to generate their own “wonderful ideas.” Like Floden and Buchmann and Phillips, I believe it is critically important that children become able to imagine worlds beyond any that they have experienced first-hand. To achieve this end, I believe the field must pay more attention to creating opportunities for children to learn to use, or at least to recognize and appreciate, multiple discipline-specific ways of understanding their worlds.

For the purposes of this dissertation, my focus is on what it can look like for young children to be engaged in particular disciplinary-based activity: scientific inquiry. Within this particular domain there are pressures from multiple directions that result in limiting opportunities for young children to participate in scientific inquiry, one of which is, I think, an over-reliance on children generating their own questions and (often) their own resources for addressing those questions.

An over-reliance on children to direct their own exploration of phenomena may stem in part from an over-literal interpretation of the beguiling image of young children as “natural” or “intuitive” scientists (Carey, 1985; Trumbull, 1990). For example, in an
article entitled, “If we call it science, then can we let the children play?” an early
colorific childhood education professor described various ways kindergarten children as “thought
like scientists” as they explored water and balance scales during what someone might
have initially thought to be “just playing.” Using these observations as the basis of an
argument for the value of play-based curricula that are ripe with rich open-ended
activities, she suggested that early childhood educators should use the language of
scientific inquiry when describing children’s play, writing: “the resurgence of interest in
science education provides a new vocabulary and compelling perspective that
kindergarten teachers can use to explain the open-ended, cognitively challenging learning
experiences that characterize their play-based programs” (Goldhaber, 1994, p. 27). Now,
I’m all for young children having many opportunities to play and to explore phenomena
and generate ways of understanding phenomena through their play. However, this should
not be the sum total of how young children experience science in their primary grade
years, and, I fear, as Rebecca New has written, that, “although the concepts of play and
teacher planning of educational experiences are not necessarily in opposition, the notion
that conceptual understandings are best pursued by children through play and other child-
initiated activities has frequently served to eliminate the need for purposeful teacher
planning in domains such as mathematics and science.” [New, 2000 #174, p. 6]

It is interesting that notion of children as “intuitive” scientists, stemmed, I think, from
needing a metaphor for describing the range of competencies, especially with regard to
tory building, that young children exhibit (e.g. [Gelman, 2000 #80; Karmiloff-Smith,
1992 #106; Ruffman, 1993 #11; Sodian, 1991 #92; Samarapungavan, 1992 #97]. I
suspect that the coiners of this expression never intended it to be interpreted as meaning
that young children are already like scientists and therefore have little to gain by experiencing more formal practice with science inquiry processes. Although children’s ways of approaching tasks, particularly those that involve trying to understand physical phenomena, have some similarities with how practicing scientists approach tasks, there are critical differences (Gelman & Brown, 1986, Zimmerman, Kuhn, 1997). The most fundamental of these has, at its root, the difference in knowledge and experience between a practicing scientist and a young child. Practicing scientists simply know more about their domain than a young child is going to have the possibility of knowing, and this expertise engenders highly nuanced understanding of their fields, as well as highly refined capacities for expressing those understandings. Another dimension that distinguishes children and scientists is a meta-level awareness of one’s actions and reasoning. I am not suggesting that young children are incapable of exhibiting meta-awareness of their questions and actions and thinking processes, but it does seem to be the case that young children (and it should be said, adults too) do not always process activities at this level (Kuhn, Klahr, ). In addition, people engaged in scientific inquiry often need to deal with abstract concepts and abstract relationships among concepts. Although much research has shown that even very young children, much younger than 2nd graders, make categorizations of ideas on the basis of abstract properties (Gelman),

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2 Indeed, it is often further implied that “formal” or “academic” experiences will stunt young children’s interests in science. (e.g. DAP, 2000, Elkind, 2000, Katz & Chard)

3 Of course, sometimes these are so refined as to be unintelligible to those outside a particular field.

4 For reviews of scientific reasoning research, see (Zimmerman, Markman & Gentner, DeLoache, Miller & Pierroutsakos). Try, Harris, 1994, for an interesting discussion of how scientists’ and children’s resemble and differ.
one finds much skepticism about children’s abilities to reason with ideas which require symbolic, or “second-order” representation (Elkind, 2000).

The observation that young children have limited knowledge about scientific domains, generally do not articulate a meta-level awareness of their actions and reasoning, and tend to focus on concrete things rather than abstract concepts, has contributed to the idea that they are not “ready” for scientific thinking. This belief and the associated action of postponing any scientific inquiry activity that would involve needing to think about abstract concepts until later grades is yet another notion that constrains the opportunities primary-grade children have. As Metz has expressed it, “most problematic, the targeting of purportedly elementary science processes for the first years of schools with a postponement of the integrated practice of goal-focused investigations until the higher grades results in decomposition and decontextualization in the teaching and learning of scientific inquiry.” (1997, p. 152)

This decontextualization has lead to a tendency to engage young children in a piecemeal hodgepodge of discrete activities that focus on “process skills.” Exacerbating this tendency is the view of some science educators and others that in an effort to make science concepts accessible to young children, the children may be subjected to watered-down science that so distorts and oversimplifies various concepts and relationships as to be worse than ineffectual, as such instruction may actually promote misconceptions that will prove to be intractable. With this perspective, one would argue that one should wait until are “ready” for the fully elaborated accepted scientific view rather than oversimplify
the science for younger children (Elkind, 2000, [Wenham, 1995 #170]). Teachers are often admonished to be extremely careful about the language they choose as some everyday ways of talking about certain things can conflict with the scientific meaning [Palmer, 1997 #166; Twigger, 1994 #137]. Take, for example, this excerpt urging precision and caution when using certain words related to the study of motion, which is from a book written for primary grade teachers that explains the “formal” or “accepted” scientific view of various phenomena:

“The words force and energy are used very precisely in science to denote concepts which are quite distinct, though connected to each other, and which are related to different aspects of change. In everyday speed these words are used much more loosely, and even interchangeably at times, but this is a language habit science education should seek to overcome rather than reinforce, at least in the context of scientific investigations. For similar reasons, concepts which show the relationship between force and energy, but which cannot be developed with understanding, should never be introduced at primary level. The main one to avoid is momentum, and the scientific concept of work should be used only if children’s investigation and questioning make it necessary. The introduction of these concepts before they are needed, like any premature use of specialized scientific language, leads away from productive experience, not towards it [Wenham, 1995 #175, pp. 188-189].

Given this array of pressures and beliefs, what is an early childhood educator to do? With objections from so many directions, the safest tactic may be to simply ignore
science all together, the route all too many seem to take [Bowman, 2000 #174; Dickinson, 1997 #171; Shymansky, 1991 #173].

**Capitalizing on curiosity to get to inquiry**

Engaging in inquiry is more than just asking questions. Questions are of course asked, and are fundamental, but also essential is having a reason for asking specific questions and taking actions and asking additional questions on the basis of what one observes and how one interprets these observations. Curiosity, often the impetus for engaging in inquiry, is not, in itself, the same as inquiry. Distinguishing characteristics of inquiry include systematicity and recursiveness of action and questioning. The goals of scientific inquiry include description of, explanation of, prediction about, and control of phenomena. Yet, when children are taught science, they are all too often only taught about the end products of various lines of inquiry. Indeed, even when young children are taught the “processes” of science, such as observation and classification, it is often via isolated activities during lessons unrelated to any line of inquiry about phenomena in the world. With school science that focuses on decontextualized skills and memorization of science facts, children are in danger of developing only inert knowledge of science without any understanding of the scientific enterprise of inquiry.

Recent national science education reform documents emphasize the importance of teaching science through inquiry, i.e., via instruction that allows students to be introduced to and to practice engaging in scientific inquiry for the purpose of addressing a question about the world in order to try to explain something. As described in the National Research Council’s (NRC) Science Education Standards (1996), “From the earliest grades, students should experience science in a form that engages them in the active
construction of ideas and explanations and enhances their opportunities to develop the abilities of doing science,” as long as these ways “are within their (K-4 children’s) developmental capabilities” (p. 121). The authors of the NRC standards go on to suggest that children in grades K-4 are capable of designing investigations on the basis of simple questions which incorporate the idea of a “fair” test, but that they “have difficulty with experimentation as a process of testing ideas and the logic of using evidence to formulate explanations” (p. 122). As an example of this, young children (and it must be said, even many adults), when left to their own devices, have been found to rarely consider alternative hypotheses or consider evidence contrary to ideas they hold (Klahr, 2000; Kuhn, Black, Keselman, & Kaplan, 2000; Schauble, 1990). Yet, even studies that have shown young children’s deficits in this regard have also demonstrated that K-4 children have many capacities integral to the scientific enterprise, such as (a) recognizing the utility of a schematic model of a system (Penner, Giles, Lehrer, & Schauble, 1997) (b) considering evidence when proposing causal mechanisms (Amsel & Brock, 1996) (c) exhibiting preference for theories that are logically consistent (Samarapungavan, 1992) (d) attacking conceptual problems in multiple ways (Metz, 1993), and (e) distinguishing between conclusive and inconclusive tests (Sodian, Zaitchik, & Carey, 1991). Thus, we know young children have intellectual strengths upon which to build. We also know that we value scientific inquiry and desire for all our citizens to become “scientifically literate.” As described in the NRC Content Standards, as a result of activities in grades K-4, all students should develop abilities necessary to do scientific inquiry as well as understandings about the purposes for and characteristics of scientific inquiry. How to
attain these capabilities and understandings is less clear even though, as Metz (1995) speculates,

"Science instruction can redress some of the disadvantages children are working under in attaining second-order thought. Capitalizing on social interaction within the science classroom can help children make their ideas explicit and subject them to criticism. Exploration of such ideas as theory, evidence, and hypothesis can support children's formulation and identification of their instantiations in their own and others' thinking." (Metz, 1995, p. 108)

Yet, there exist very few studies of young children engaged in scientific inquiry, and even fewer still that have examined classroom-based data, that might lead to models of what inquiry science instruction could be like at the primary grade levels.

**Purpose and Research Questions**

This dissertation is a case study examining primary grade children’s scientific thinking in a classroom context. It is a descriptive study in which I seek to characterize the shifts and changes in children’s thinking regarding physical science phenomena, as well as regarding the processes of doing empirical investigations. The study follows one second grade class over the course of a unit of school science instruction. The way that this unit was taught, and the things the students were able to do, provide an example of how young children can engage in a kind of scientific inquiry that has seldom been described. Given the focus age of the children as well as the classroom context, this study addresses several gaps in prior research which has paid scant attention to primary grade children, and even less attention on primary grade children’s school science experiences. Although this study does not provide a general sense of science instruction for young
children, it does provide evidence that students and teachers in the context of classrooms are able to experience the scientific enterprise, and become participants in that enterprise. The results of this study have ramifications for the preparation of early elementary school teachers as well as for the design of early elementary school level curriculum materials. In addition, this study provides grist for future, more formal, inquiry into young children’s science learning and the development of ways of thinking about the world that are characteristic of scientific inquiry.

The research question central to this dissertation is:

**What aspects of the enterprise of science do children experience and what understandings do they come to about motion?**

To address this question I examine children engaged in scientific inquiry about motion. These activities include scientific inquiry processes such as representing and analyzing data, making predictions, interpreting patterns, generating and testing explanations. I also trace and examine the ideas children have about the subject matter itself, specifically several relationships fundamental to thinking about the motion of objects down inclined planes. Throughout my examination of this question I also consider how the teacher, curriculum materials, and context served to mediate children’s learning.